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Estimation of Genetic Variability and Heritability for Yield and Its Related Components in Cassava (*Manihot esculenta* Crantz) Genotypes

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A B S T R A C T

Seventy seven cassava genotypes along with three check varieties were employed for assessment of genetic variability, heritability and genetic gain during the period from 2015 to 2016 at, Horticultural Research Station, Dr. Y.S.R. Horticultural University, Venkataramannagudem, Andhra Pradesh under All India Co-ordinated Research Project on Tuber crops. Analysis of variance revealed significant differences between genotypes for sixteen quantitative characters. Higher magnitude of PCV and GCV were observed for total leaf area, number of leaves per plant, HCN content, post-harvest physiological deterioration and tuber yield per hectare indicating the existence of wide range of genetic variability in the germplasm for these traits. High heritability estimates coupled with high estimates from genetic gain as per cent of means were observed for number of leaves per plant, plant height, HCN content and moderate heritability estimates coupled with high estimates from genetic gain as per cent of means were observed for petiole length, tuber dry matter content, tuber length, post-harvest physiological deterioration and tuber yield per hectare indicated that these characters were least influenced by the environmental effects and these characters were governed by additive genes and selection will be rewarding for improvement of such traits.

Introduction

Cassava (*Manihot esculenta* Crantz) is one of the most important staple foods in the tropics and sixth most important source of calories in the human diet worldwide (Alfredo *et al.*, 2000). It can be cultivated under marginal ecologies characterized by poor, erratic rainfall and extended periods of drought where most crops will fail (Hillocks, 2002). It is an important food crop for more than 900 million people in the tropics and sub tropics (Nassar, 2003). The crop has a comparative advantage over many other crops and can produce outstanding yields under harsh environmental conditions, where other crops would fail (Nweke *et al.*, 1994).

The critical assessment of nature and magnitude of variability in the germplasm

stock is one of the important pre-requisites for formulating effective breeding programme (Janaki *et al.,* 2015). Greater the variability in a population, there are the greater chances for effective selection for desirable types (Vavilov, 1951). Heritability is the portion of phenotypic variation which is transmitted from parent to progeny. Higher the heritable variation, greater will be the possibility of fixing the characters by selection. Hence, heritability studies are of foremost importance to judge whether the observed variation for a particular character is due to genotype or due to environment. Heritability estimates may not provide clear predictability of the breeding value.

Thus, estimation of heritability accompanied with genetic advance is generally more useful than heritability alone in prediction of the resultant effect for selecting the best individuals (Johnson *et al.,* 1955). Therefore, the present investigation was carried out with an objective to study the genetic variability, heritability and genetic advance for yield and its related components in 80 cassava genotypes.

Materials and Methods

The experiment was conducted with seventy seven cassava genotypes along with three check varieties (Table 1) during the period from 2015 to 2016 at Horticultural Research Station, Venkataramannagudem, Dr. Y.S.R. Horticultural University, Andhra Pradesh, India under All India Co-ordinated Research Project on Tuber crops. The location falls under the Agro-climatic zone number 10, East Coast Plain and Hills (Krishna-Godavari zone) at an altitude of 34 m (112 feet) above mean sea level with its geographical position 16.83° N latitude and 81.5° E longitude. The experiment was laid out in Augmented Block Design (ABD) consisting of seven augmented blocks in which three checks and eleven entries were planted. Observations were recorded on five randomly selected plants for following traits *i.e.* petiole length, total leaf area, plant dry matter content, tuber dry matter content, number of leaves per plant, plant height, stem diameter, number of storage roots per plant, number of commercial roots per plant, tuber length, tuber diameter, harvest index, starch content, HCN content, post-harvest physiological deterioration and tuber yield.

Statistical analysis

Phenotypic and genotypic coefficients of variation (PCV and GCV) were computed according to Burton and Devane (1953). Heritability in broad sense was estimated as per Allard (1960). Genetic advance was estimated as per the formula proposed by Lush (1940). The range of genetic advance as per cent of mean was classified as low (Less than 10%), moderate (10 - 20%) and high (more than 20%) suggested by Johnson *et al.,* (1955).

Results and Discussion

The analysis of variance (ANOVA) showed highly significant differences ($P < 0.01$) among the genotypes for the entire yield and yield related components studied (Table 2). In present investigation, magnitude of PCV was ranged from 6.74 to 55.18 per cent and GCV was ranged from 6.71 to 55.14 per cent. Higher magnitude of PCV (phenotypic coefficient of variation) and GCV (genotypic coefficient of variation) (> 20%) were observed for total leaf area (39.98% and 39.87%), number of leaves per plant (38.72% and 38.58%), HCN content (28.30% and 27.74%), post-harvest physiological deterioration (55.18 % and 55.14%) and tuber yield per hectare (31.09 % and 30.99%) indicating the existence of wide range of genetic variability in the germplasm for these traits (Table 3 and Fig. 1).

Table.1 Particulars of cassava genotypes under present study

S. No	Name of the genotype	Source
1.	Me Ap-1	AICRP on Tuber crops, Venkataramannagudem, Andhra Pradesh
2.	Me Ap-2	-do-
3.	Me Ap-3	-do-
4.	Me Ap-4	-do-
5.	Me Ap-5	-do-
6.	Me Ap-6	-do-
7.	Me Ap-7	-do-
8.	Me Ap-8	-do-
9.	Me Ap-9	-do-
10.	Me Ap-10	-do-
11.	Me Ap-11	-do-
12.	Me Ap-12	-do-
13.	Me Ap-13	-do-
14.	Me Ap-14	-do-
15.	Me Ap-15	-do-
16.	Me Ap-16	-do-
17.	Me Ap-17	-do-
18.	Me Ap-18	-do-
19.	Me Ap-19	-do-
20.	Me Ap-20	-do-
21.	Me Ap-21	-do-
22.	Me Ap-22	-do-
23.	Me Ap-23	-do-
24.	Me Ap-24	-do-
25.	Me Ap-25	-do-
26.	Me Ap-26	-do-
27.	Me Ap-34	-do-
28.	Me Ap-35	-do-
29.	Me Ap-36	-do-
30.	Me Ap-37	-do-
31.	Me Ap-38	-do-
32.	Me Ap-39	-do-
33.	Me Ap-40	-do-
34.	Me Ap-41	-do-
35.	Me Ap-42	-do-
36.	Me Ap-43	-do-
37.	Me Ap-44	-do-
38.	Me Ap-45	-do-
39.	Me Ap-46	-do-
40.	Me Ap-47	-do-

Cont...

S. No	Name of the genotype	Source
41.	Me Ap-48	AICRP on Tuber crops, Venkataramannagudem, Andhra Pradesh
42.	Me Ap-49	-do-
43.	Me Ap-50	-do-
44.	Me Ap-51	-do-
45.	Me Ap-52	-do-
46.	Me Ap-53	-do-
47.	Me Ap-54	-do-
48.	Me Ap-55	-do-
49.	Me Ap-56	-do-
50.	Me Ap-57	-do-
51.	Me Ap-58	-do-
52.	Me Ap-59	-do-
53.	Me Ap-60	-do-
54.	Me Ap-61	-do-
55.	Me Ap-62	-do-
56.	Me Ap-63	-do-
57.	Me Ap-64	-do-
58.	Me Ap-65	-do-
59.	Me Ap-66	-do-
60.	Me Ap-67	-do-
61.	Me Ap-68	-do-
62.	Me Ap-69	-do-
63.	Me Ap-70	-do-
64.	Me Ap-71	-do-
65.	Me Ap-72	-do-
66.	Me Ap-73	-do-
67.	Me Ap-74	-do-
68.	Me Ap-75	-do-
69.	Me Ap-76	-do-
70.	Me Ap-77	-do-
71.	Me Ap-78	-do-
72.	Me Ap-79	-do-
73.	Me Ap-29	-do-
74.	Me Ap-30	-do-
75.	Me Ap-31	-do-
76.	Me Ap-32	-do-
77.	Me Ap-33	-do-
78.	H-165 (Check 1)	-do-
79.	H-226 (Check 2)	-do-
80.	Sree Vijaya (Check 3)	-do-

Table.2 Analysis of variance for different quantitative characters in cassava genotypes

	df	PL (cm)	TLA (m2)	PDM (%)	TDM (%)	NLP	PH (cm)	STD (cm)	NSRT
Block (ignoring Treatments)	6.00	14.25 ***	152.52 ***	9.42 ***	13.54 ***	79855.66 ***	6861.84 ***	4.38 ***	9.33 ***
Treatment (eliminating Blocks)	79.00	12.89 ***	73.22 ***	6.58 ***	6.90 ***	22171.40 ***	1959.21 ***	2.05 ***	3.43 ***
Checks	2.00	41.92 ***	93.09 ***	26.78 ***	9.10 ***	23164.19 ***	3043.28 ***	3.94 ***	16.09 ***
Checks+Var vs. Var.	77.00	12.14 ***	72.70 ***	6.05 ***	6.85 ***	22145.61 ***	1931.06 ***	2.00 ***	3.10 ***
ERROR	12.00	0.00	0.25	0.12	0.05	139.89	37.88	0.17	0.05
Block (eliminating Check+Var.)	6.00	0.00	0.51	0.12	0.42 ***	81.04	66.56	0.04	0.09
Entries (ignoring Blocks)	79.00	13.98 ***	84.76 ***	7.28 ***	7.90 ***	28230.23 ***	2475.31 ***	2.38 ***	4.13 ***
Checks	2.00	41.92 ***	93.09 ***	26.78 ***	9.10 ***	23164.19 ***	3043.28 ***	3.94 ***	16.09 ***
Varieties	76.00	13.05 ***	57.01 ***	6.56 ***	6.79 ***	23433.62 ***	2492.07 ***	2.31 ***	3.69 ***
Checks vs. Varieties	1.00	28.69 ***	2177.37 ***	23.02 ***	90.29 ***	402904.59 ***	65.43 ***	4.24 ***	13.47 ***
ERROR	12.00	0.00	0.25	0.12	0.05	139.89	37.88	0.17	0.05
Ci – Cj	1.00	0.04	0.59	0.41	0.26	13.77	7.17	0.48	0.25
BiVi - BiVj	1.00	0.10	1.55	1.08	0.69	36.44	18.96	1.26	0.66
BiVi - BjVj	1.00	0.12	1.79	1.25	0.80	42.08	21.90	1.46	0.77
Ci – VI	1.00	0.09	1.36	0.94	0.60	31.81	16.55	1.10	0.58

Where: PL- Petiole length, TLA- Total leaf area (m^2), PDM-Plant dry matter content (%), TDM-Tuber dry matter content (%), NLP- Number of leaves per plant, PH- Plant height (cm), STD- Stem diameter, NSRT- Number of storage roots per plant

Cont…

		NCRT	TL (cm)	TD (cm)	HI (%)	STRCH (%)	HCN (ppm)	PPD (%)	TYHA (t ha^{-1})
Block (ignoring Treatments)	6.00	3.85 ***	19.07 ***	9.47 ***	0.01 ***	17.94 ***	525.73 ***	822.73 ***	53.54 ***
Treatment (eliminating Blocks)	79.00	2.46 ***	25.59 ***	4.89 ***	0.01 ***	5.39 ***	1198.86 ***	248.37 ***	88.82 ***
Checks	2.00	7.32 ***	222.30 ***	23.76 ***	0.04 ***	4.81 ***	5725.50 ***	2282.32 ***	118.10 ***
Checks+Var vs. Var.	77.00	2.33 ***	20.48 ***	4.40 ***	0.01 ***	5.40 ***	1081.29 ***	195.54 ***	88.06 ***
ERROR	12.00	0.04	0.25	0.16	0.00	0.35	15.15	0.33	0.43
Block (eliminating Check+Var.)	6.00	0.03	0.32	0.19	0.00	0.31	11.00	0.10	0.16
Entries (ignoring Blocks)	79.00	2.75 ***	27.02 ***	5.60 ***	0.01 ***	6.73 ***	1237.96 ***	310.85 ***	92.88 ***
Checks	2.00	7.32 ***	222.30 ***	23.76 ***	0.04 ***	4.81 ***	5725.50 ***	2282.32 ***	118.10 ***
Varieties	76.00	2.62 ***	22.11 ***	5.03 ***	0.01 ***	5.94 ***	458.01 ***	261.63 ***	79.28 ***
Checks vs. Varieties	1.00	3.30 ***	9.31 ***	12.42 ***	0.00 ***	70.19 ***	51538.93 ***	108.77 ***	1075.59 ***
ERROR	12.00	0.04	0.25	0.16	0.00	0.35	15.15	0.33	0.43
Ci – Cj	1.00	0.23	0.58	0.46	0.04	0.69	4.53	0.67	0.76
BiVi – BiVj	1.00	0.60	1.55	1.23	0.11	1.83	11.99	1.77	2.02
BiVi – BjVj	1.00	0.70	1.79	1.42	0.12	2.11	13.85	2.04	2.34
Ci – VI	1.00	0.53	1.35	1.07	0.09	1.60	10.47	1.54	1.77

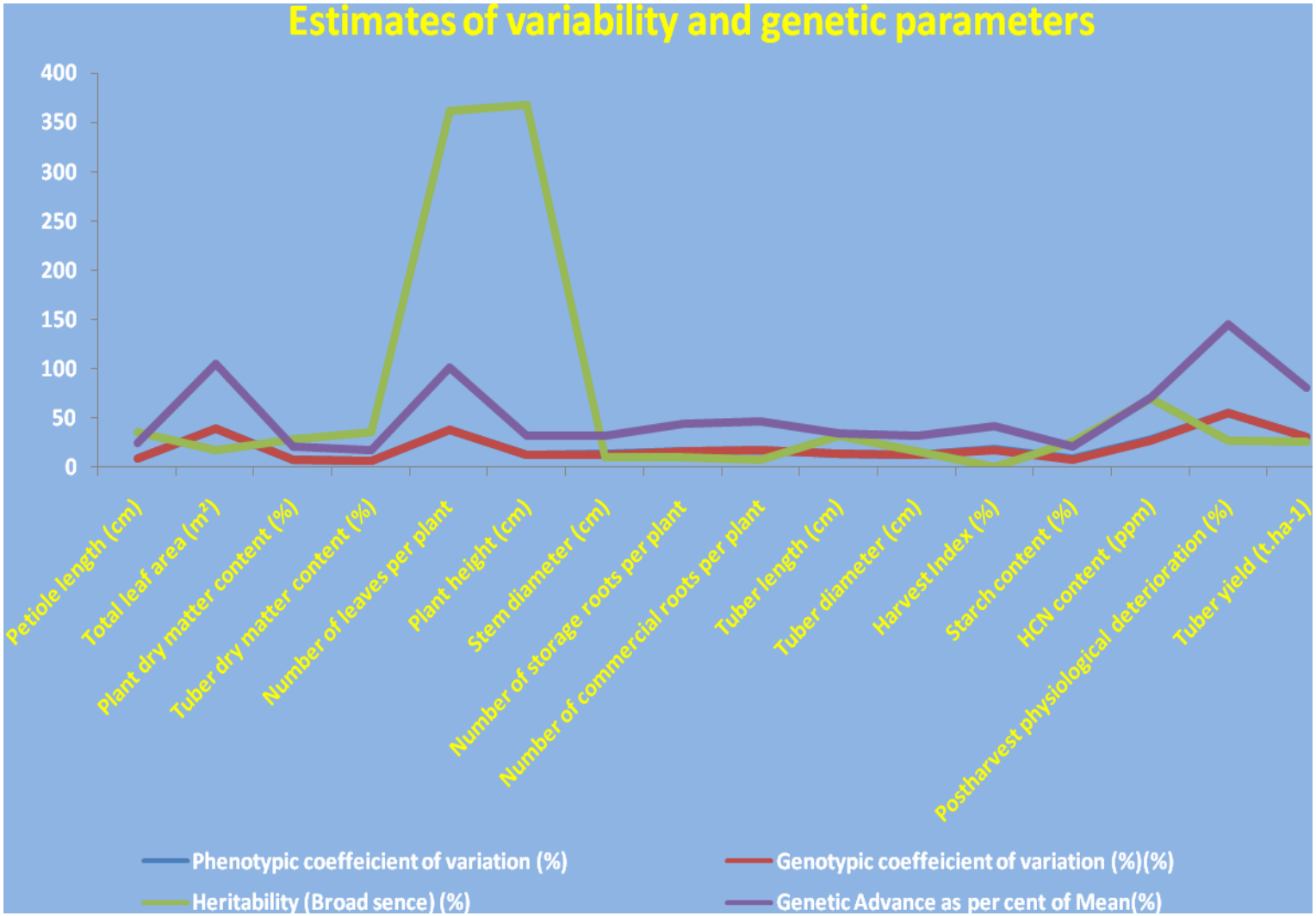
Where: NCRT- Number of commercial roots per plant, TL - Tuber length (cm), TD - Tuber diameter, HI-Harvest Index (%), STRCH-Starch content (%), HCN-HCN content (ppm), PPD-Postharvest physiological deterioration (%),TYHA- Tuber yield (t ha^{-1})

Table.3 Estimates of variability, heritability and genetic advance as per cent of mean for different characters in cassava genotypes

S. No.	Character	Range		Mean	Variance		PCV (%)	GCV (%)	h^2 (%)	Genetic advance	GA as % of mean
		Minimum	Maximum		δ^2ph	δ^2g					
1.	Petiole length (cm)	25.20	43.79	35.84	10.90	10.90	9.22	9.22	100.00	6.80	19.00
2.	Total leaf area (m^2)	3.09	36.69	17.70	47.65	47.40	39.98	39.87	99.47	14.14	81.91
3.	Plant dry matter content (%)	23.63	33.81	29.08	5.50	5.38	8.08	7.99	97.76	4.72	16.27
4.	Tuber dry matter content (%)	27.50	39.55	35.43	5.68	5.62	6.74	6.71	99.11	4.86	13.76
5.	Number of leaves per plant	102.14	842.48	367.41	19593.99	19454.11	38.72	38.58	99.29	286.30	79.19
6.	Plant height (cm)	251.48	512.30	368.18	2087.54	2049.66	12.41	12.30	98.19	92.41	25.10
7.	Stem diameter (cm)	6.51	15.11	10.37	1.96	1.79	13.52	12.92	91.43	2.64	25.46
8.	Number of storage roots per plant	6.88	13.95	10.45	3.09	3.05	16.88	16.76	98.50	3.57	34.26
9.	Number of commercial roots per plant	11.87	4.51	8.26	2.20	2.16	17.97	17.81	98.26	3.00	36.37
10.	Tuber length (cm)	21.92	46.05	31.81	18.51	18.25	13.51	13.42	98.64	8.74	27.45
11.	Tuber diameter (cm)	11.82	22.07	16.44	4.23	4.07	12.53	12.29	96.25	4.08	24.84
12.	Harvest Index (%)	0.18	0.70	0.47	0.01	0.01	18.82	17.30	84.52	0.15	32.76
13.	Starch content (%)	16.68	31.39	26.02	5.02	4.67	8.64	8.33	92.97	4.29	16.54
14.	HCN content (ppm)	30.40	150.73	71.43	385.01	369.86	28.30	27.74	96.06	38.83	56.00
15.	Postharvest physiological deterioration (%)	1.10	65.96	26.69	218.56	218.23	55.18	55.14	99.85	30.41	113.51
16.	Tuber yield ($t.ha^{-1}$)	13.65	44.39	26.49	66.28	65.85	31.09	30.99	99.35	16.66	63.63

Where: δ^2g = variance due genotypic, δ^2ph = variance due to phenotypic, GCV (%) = genotypic coefficient of variation, PCV (%) = phenotypic coefficient of variation, h^2b = broad heritability, EGA (%) = expected genetic advance

Fig.1 Estimates of variability and genetic parameters for yield and yield attributes in cassava



High GCV and PCV values indicating large amount of variation and consequently more scope for their improvement through selection. These results are in conformity with the findings of Ntawuruhunga and Dixon (2010) and Babu Rao *et al.,* (2016) for total leaf area and Ashok *et al.,* (2013) and Babu Rao *et al.,* (2016) for number of leaves per plant. Similarly Suryakumari and Anuradha (2000), Babu Rao *et al.,* (2016) and Danquah *et al.,* (2016) were also reported high GCV and PCV values for tuber yield.

The estimates of PCV and GCV were moderate for plant height (12.41% and GCV 12.30%), stem diameter (13.52% and 12.92%), number of storage roots per plant (16.88% and 16.76%), number of commercial roots per plant (17.97% and 17.81%), tuber length (13.51% and 13.42%), tuber diameter (12.53% and 12.29%) and harvest index (18.82% and 17.30%). The present results are in accordance with the findings of Ashok *et al.,* (2013) and Babu Rao *et al.,* (2016) for plant height and Suryakumari and Anuradha (2000) and Babu Rao *et al.,* (2016) for stem diameter and tuber length. Similarly moderate PCV and GCV was observed for number of storage roots per plant by Aina *et al.,* (2007) and for starch content (%) and harvest index by Nageswari and Palaniswamy (2011).

Magnitude of heritability (broad sense) was ranged from 84.52 to 100.00 per cent. High heritability coupled with high genetic advance as per cent of mean was observed for total leaf area (99.47% and 81.91%), number of leaves per plant (99.29% and 79.18%), plant height (98.19% and 25.10%), stem diameter (91.43% and 25.45%), number of storage roots per plant (98.50% and 34.25%), number of commercial roots per plant (98.26% and 36.37%), tuber length (98.64% and 27.45%), tuber diameter (96.25% and 24.84%), harvest index (84.52% and 32.76%), HCN content (96.06% and 56.00%), post-harvest physiological deterioration (99.85% and 113.50%) and tuber yield (99.35% and 63.62%) indicating the predominance of additive gene action and hence direct phenotypic selection is useful with respect to these traits. These results are in concurrence with the findings of Suryakumari and Anuradha, (2000), and Babu Rao *et al.,* (2016) for number of leaves, Ntawuruhunga and Dixon (2010), Ashok *et al.,* (2013) and Babu Rao *et al.,* (2016) for total leaf area, Aina *et al.,* (2007) and Suryakumari and Anuradha (2000) and Babu Rao *et al.,* (2016) for tuber dry matter content and stem diameter, Nageswari and Palaniswamy (2011), Ashok *et al.,* (2013) and Babu Rao *et al.,* (2016) for tuber diameter and starch content, Suryakumari and Anuradha (2000), Aina *et al.,* (2007), Babu Rao *et al.,* (2016) and Danquah *et al.,* (2016) for tuber yield.

High heritability coupled with moderate genetic advance as per cent of mean was observed for petiole length (100% and 19.00%), plant dry matter content (97.76% and 16.27%), tuber dry matter content (99.11% and 13.76%) and starch content (92.97% and 16.54%). Moderate heritability in conjunction with moderate GAM was observed for this trait which indicated the role of both additive and non-additive gene action governing the inheritance of this trait and offers the best possibility of improvement through progeny selection or any modified selection procedures aiming to exploit the additive gene effects. High heritability for petiole length was in line with the earlier findings of Babu Rao *et al.,* (2016). Similar results were also reported by Nageswari and Palaniswamy (2011) and Babu Rao *et al.,* (2016) for tuber dry matter content.

The findings indicate that there exists adequate genotypic variation in the genotypes for number of leaves per plant, total leaf area, height of first branching, number of tubers per

plant and HCN content showing high PCV, GCV and high heritability coupled with high estimates from genetic gain as percent of mean for total leaf area, number of leaves per plant, plant height, stem diameter, number of storage roots per plant, number of commercial roots per plant, tuber length, tuber diameter, harvest index, HCN content, post-harvest physiological deterioration and tuber yield suggesting predominance of additive gene action and lower influence of environmental factors in the expression of these traits with possibility for improvement through selection.

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