Statistical Key to Predict the Performance of Cocoa Accessions (Theobroma cacao L.)

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Abstract

Cocoa is an important beverage crop grown all around the world for the delicious chocolates. Fifity clonal accessions of cocoa belonging to various countries of origin maintained at the Cocoa Research Centre, Thrissur were observed for key qualitative and quantitative characters. Pod shape, pod apex, pod basal constriction and pod rugosity which were highly variable and easily identifiable were selected as key qualitative characters. The commercially important characters viz., pod weight, total wet bean weight (TWBW), number of beans/pod, percentage of flat beans/pod and dry weight of peeled bean ranged from 318.67g to 1268.33g, 42.21g to 206.08g, 22.93 to 49.27, 0.00% to 12.60% and 0.58g to 1.72g respectively were identified as key quantitative characters. Statistical keys were developed for different combinations of key qualitative characters which can serve as a preliminary tool for predicting the performance of an accession of cocoa.

KEY WORDS: Cocoa, statistical key

Introduction

Cocoa (Theobroma cacao L.) belonging to the family Malvaceae (Alverson et al., 1999), is an important beverage crop grown all around the world for the delicious chocolates. It is indigenous to the tropical humid forests on the lower eastern equatorial slopes of the Andes in South America (Amma, 2010). The term 'cocoa' is believed to have been derived from the word 'cacahoatl' used by the Aztec Indians of the high Mexican plateau to represent the seeds of this plant. According to their belief cocoa was brought to earth by the God 'Quetzacoatl' (the plumed serpent) whom they called as 'xocolatl'. Hence, cocoa is considered to have a divine origin and is popularly known as the 'Food of Gods'. It was from 'xocolatl' the word 'chocolate' was derived. It may probably be with this legend in mind that Linnaeus gave the name Theobroma cacao to the cultivated cocoa plant using the Greek words theos meaning Gods and broma meaning food (Mossu, 1992).

Cocoa, the only source of chocolate, is cultivated in 58 tropical countries of the world for its nibs (Amma et al., 2011). The nibs form the source of energy rich and nutritious chocolates as well as an array of products. The large-scale cultivation of cocoa started in India in 1970's (Nair et al., 2002) and now it is widely grown as an intercrop in Kerala, Tamil Nadu, Andhra Pradesh

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and Karnataka (Apshara, et al., 2011). The spreading cultivation of cocoa has necessitated the production of large number of high yielding hybrids with pest and disease resistance suited to different agro-climatic conditions.

The periodic evaluation and assessment of the diversity status of a germplasm will update the breeders on the genetic resources of the germplasm and form a base for further breeding programmes. Diversity analysis based on phenotypic traits with high heritability is more reliable in the characterization of cocoa (Sounigo et al., 1997). The morphological and structural characteristics of pods and beans often exhibit large and high discriminatory variation within the species (Adewale et al., 2010).

Usually different cocoa genotypes are identified using descriptors based on qualitative characters of pod as they are decipherable. However, such a descriptor will be of limited use as the quantitative characters of pod and bean are also equally important. Hence, an attempt was made to develop statistical keys considering both qualitative and quantitative characters. To achieve the aforesaid objective the key qualitative and quantitative characters observed in 50 clonal accessions of cocoa maintained at Cocoa Research Centre (CRC), Thrissur was used. The study serves as a preliminary tool for predicting the performance of various accessions. It also informs the cocoa breeders of the inherent genetic potential in the fifty genotypes for subsequent selection and further improvement.

Materials and Methods

Fifty clonal accessions of cocoa selected from the germplasm maintained by Cocoa Research Centre, Vellanikkara served as the material for the study. The selected accessions included 40 exotic ones belonging to various countries of origin as well as 10 accessions from local areas. The details of these accessions are presented in Table 1. All these accessions, already laid out in Randomized Complete Block Design (RCBD) with three replications, have reached the steady bearing stage.

Table 1. The accessions of cocoa used for the study

Sl. No	Accession	Derivation	Source of collection
1	SC 10	Santa Cruz	Brazil
2	BE 3	Belen	
3	RB 33/3	Rio Branco	
4	COCA 3370-3	COCA river	Ecuador
5	AMAZ 10-1	AMAZonas	
6	AMAZ 15	AMAZonas	
7	AMAZ 6-3	AMAZonas	
8	AMAZ 3-2	AMAZonas	
9	EET 400	Estacion Experimental Tropical	
10	EET 397	Estacion Experimental Tropical	
11	IMC 16	Iquitos Mixed Calabicillo	

Sl. No	Accession	Derivation	Source of collection
12	B5-7	Balao	Ecuador
13	LV 28	Large Vuelta	
14	CLM 90	CLementina farm Mixed	
15	EQX 3348-44	EQuator crosses	
16	PINA	-	French Guiana
17	B7 B2	Borne	
18	KER 9	River KERinionton	
19	B7 A6	Borne	
20	GU 310	Guyana	
21	KER 2 E	River KERinionton	
22	B7 B4	Borne	
23	B7 B5	Borne	
24	DOM 4	DOMinica	Trinidad & Tobago
25	GDL 3	GuaDeLoupe	
26	MAR 9	MARtinique	
27	DOM 25	DOMinica	
28	ICS 95	Imperial College Selections	
29	R (10) (MEX)	Rosario Izapa Mexico	Mexico
30	R (39) (MEX)	Rosario Izapa Mexico	
31	PA 56	PArinari	Peru
32	IMC 67	Iquitos Mixed Calabacillo	
33	SCA 6	SCAvina	
34	PA 137	PArinari	
35	PUCALA 1	-	
36	IMC 54	Iquitos Mixed Calabicillo	
37	IMC 14	Iquitos Mixed Calabicillo	
38	Criollo	-	Costa Rica
39	UF 677	United Fruit Selections	
40	SPEC 160-9	SPECimen	Columbia
41	Calicut local 1	-	Calicut
42	Calicut local 2	-	
43	Konni local 1	-	Konni
44	Konni local 2	-	
45	Konni local 3	-	
46	Konni local 4	-	
47	Konni local 5	-	
48	Thodupuzha local 1	-	Thodupuzha
49	Thodupuzha local 2	-	
50	Thodupuzha local 3	-	

Fifteen uniformly mature cocoa pods (5 from each replication) were selected and harvested from each accession. Observations on various qualitative and quantitative characters of pods were then taken from all the accessions. Among the pod qualitative characters, the characters which were highly variable and easily identifiable viz., pod shape, pod apex, pod basal constriction and pod rugosity were taken as key qualitative characters. These qualitative characters in each accession were assessed following the descriptor for cocoa (Bekele and Butler, 2000).

Among the various pod quantitative characters, the commercially important yield contributing characters viz., pod weight, total wet bean weight (TWBW), number of beans/pods, percentage of flat beans/pod and dry weight of peeled bean were identified as key quantitative characters. For assessing these characters, the harvested pods were weighed at first. Then, the pods were opened and wet seed mass was removed from the central placenta and weighed and recorded as total wet bean weight (TWBW). Wet bean content was calculated in per cent as the ratio of total wet bean weight to the pod weight (TWBW/pod weight). The number of seeds per pod (including flat beans) and the number of flat beans were counted. Pods with an inordinately large number of flat beans were discarded. Fifteen beans were then selected at random from each accession. The outer slimy layer of the seeds was removed by hand. The dry weight of peeled beans was taken after oven drying the beans to moisture content below 8 per cent. The means per replication for each of the five economically important quantitative traits were then generated accessions wise and subjected to Analysis of Variance.

Using these key qualitative and quantitative characters, statistical keys were developed for the selected accessions of cocoa. At first, the accessions were classified into different groups based on the combinations of different key qualitative characters. Then statistical keys were developed for each group using the range of key quantitative characters of the corresponding accessions included in the particular group.

Results and Discussion

The appearance of pod or its morphology plays an important role in the definition of types and populations in cocoa (Wood & Lass, 1955). The variation expressed by the accessions under study in terms of pod qualitative traits was very high. The key qualitative characters of 50 accessions of cocoa are presented in Table 2.

Table 2. Variability in pod qualitative characters of 50 accessions of cocoa

Variability in pod qualitative characters				Name of accessions
Pod shape	Basal constriction	Apex form	Rugosity	
Cundeamor	Slight	Acute	Absent	CLM 90
			Slight	IMC 16, konni local 1, thodupuzha local 3
			Intermediate	BE 3, IMC 67, SCA 6, KER 2E, Thodupuzha local 2
			Intense	SC 10, EET 400
	Intermediate	Acute	Absent	AMAZ 10-1, PA 56, DOM 25
			Slight	AMAZ 15, AMAZ 6-3, IMC 14, RB 33/3, MAR 9, DOM 4, Konni local 3& 4
			Intermediate	AMAZ 3-2, IMC 54, R (10) (MEX), PINA, B7 B2, EET 397, GDL 3, Konni local 5, Thodupuzha local 1
			Intense	COCA 3370-3, B7 A6, B5-7, LV 28R (39) (MEX), KER 9, GU 310, ICS 95, B7 B4, Konni local 2
	Strong	Acute	Intermediate	B7 B5
Angoleta	Absent	Acute	Absent	EQX-3348-44
			Intermediate	UF 677, SPEC 160-9
Amelonado	Slight	Acute	Absent	Calicut local 2
			Slight	PUCALA 1, PA 137, Calicut local 1
Criollo	Intermediate	Attenuate	Intense	Criollo

Depending upon the ratio between pod length and width as well as the shape of the two ends of the pod, pod shape can be cundeamor, angoleta, amelonado, calabacill and criollo. Cundeamor types are characterized by the presence of pods which are deeply ridged and warty as well as having bottle neck. Pods are square shaped at the stalk end and devoid of bottleneck in angoleta type. Smooth, melon shaped pods with blunt end, shallow furrows and

slight bottle neck are the features of amelonado types. Calabacillo types are small, nearly spherical in shape with a point at its apex. Criollo types show resemblance to cundeamor types. Pods though warty like cundeamor are characterized with attenuate apex in criollo types. Among the five descriptor states for pod shape only four types were observed in the present study. Forty four accessions were having cundeamor shaped pods. The pod shape was angoleta in UF 677, SPEC 160-9, EQX-3348-44 and amelonado in PA 137, PUCALA 1, Calicut local 1 and Calicut local 2. The pod apex was acute in all the accessions except criollo where it was attenuate.

The pod apex was acute in all the accessions except criollo where it was attenuate. Pod basal constriction may or may not be present in the accessions. In the accessions UF 677, SPEC 160-9 and EQX-3348-44 the pod basal constriction was absent. Sixty six percent of the accessions exhibited intermediate basal constriction. Thirteen accessions were having slight basal constriction. The accession B7 B5 alone had strong basal constriction. Pod rugosity was absent in the accessions DOM 25, AMAZ 10-1, PA 56, CLM 90, EQX-3348-44 and Calicut local 2 and intermediate to intense in most types.

Accessions COCA 3370-3, AMAZ 3-2, B7 B 2, R (39) (MEX), MAR 9, KER 9, Konni local 3 and Thodupuzha local 1 were having cundeamor type pods with intermediate basal constriction and acute apex. Similarly different combinations of pod shape, basal constriction, apex and rugosity were observed in different accessions (Table 2). The typical criollo type pods with intermediate constriction at the base and attenuate apex were observed only in the exotic accession criollo.

The mean values of key quantitative characters for 50 accessions of cocoa are presented in Table 3. The flat bean content of the pods is expressed as a per cent of the total number of beans per pod, for easiness of comparison among the accessions. The selected accessions of cocoa differed significantly with respect to the five key quantitative characters. This reflects the heterogeneity expected within these accessions.

Among the accessions, COCA 3370-3 was having the highest pod weight. However, its wet bean weight accounted for only 14.79 per cent of the pod weight. This shows that the pod weight is not the indicator of the total wet bean weight. The total wet bean weight per pod was the highest for the accession EET 400 (206.08 g) and the lowest for the accession KER 2E (42.21g). The highest wet bean content was recorded by the accession R (39) (MEX) (33.82%) followed by R (10) (MEX) (33.26%) (Table 3). Among the indigenous types, Konni local 2 was the best performer for these traits (Table 3).

The characters of economic interest viz., pod weight, number of beans/pod, dry weight of peeled bean, per cent of flat beans/pod and pod index ranged from 318.67g to 1268.33g, 22.93 to 49.27, 0.58g to 1.72g, 0.00 to 12.60 per cent and

12 to 49 respectively among the accessions. Pound (1932) and Enriquez and Soria (1966) revealed that yield expressed as dry or wet weight of bean is a highly variable character.

According to the international standards the dry weight of peeled bean must be 0.8g or more. Among the evaluated accessions, Criollo, KER 9 and CLM 90 failed to satisfy this international standard. The unfertilized ovules are considered as developing into flat beans in cocoa. Presence of flat beans is an undesirable character in cocoa and the crop improvement programmes in cocoa aims to reduce the number of flat beans/pod. The flat bean content was the highest in accession LV 28 (12.20%) followed by AMAZ 6-3 (10.42%) (Table 3). Flat beans were absent in the pods of accession EQX 3348-44 (Table 3). Among the indigenous types flat bean content was the highest in Thodupuzha local 1 (7.86%) and the lowest in Calicut local 2 (0.75%) (Table 3).

Using these key qualitative and quantitative characters statistical keys were developed for the identification of different accessions of cocoa. Based on the different combinations of key qualitative characters, the accessions were classified into different groups (Table 2), then, using the range of key quantitative characters of the corresponding accessions coming under each group, statistical key for that particular group was developed (Fig. 1).

If the combinations of key qualitative characters are known, it is possible to predict the range for the different key quantitative characters. For example, if the combination of key qualitative characters are cundeamor shaped pods with slight basal constriction, acute apex and intense rugosity, we can predict the approximate range for pod weight, total wet bean weight (TWBW), number of beans/pod, per cent of flat beans/pod and dry weight of peeled bean as shown in Plate 1a. Statistical keys thus developed for different combinations of key qualitative characters in cundeamor types are presented in Plate 1a to 1c. Similarly the keys developed for angoleta type is presented in Plate 2. Plate 3 shows the key developed for Amelonado type. The key for criollo type is presented in Plate 4. Thus, a statistical key can serve as a preliminary tool for predicting the performance of an accession of cocoa.

Table 3. Mean quantitative economic trait values for 50 accessions of cocoa

Accessions	Pod wt.(g)	Total wet bean wt. (g)	Wet bean content (%)	No. of beans/pod	Flat beans/ pod(%)	Dry wt. of peeled bean (PB)(g)
SC 10	552.67	150.19	27.18	33.66	3.25	1.53
COCA 3370-3	1268.33	187.57	14.79	30.66	4.16	1.37
AMAZ 10-1	503.33	125.67	24.97	39.00	2.18	0.83
BE 3	531.33	132.20	24.88	35.73	3.43	0.94
AMAZ 15	576.67	150.22	26.05	36.13	1.45	1.25
AMAZ 6-3	520.00	110.90	21.33	33.27	10.42	1.39
AMAZ 3-2	483.33	124.46	'25.75	35.13	2.96	1.01
PIN A	541.67	146.59	27.06	42.33	1.56	1.07
B7B2	392.67	135.47	34.50	36.47	3.70	1.49
PA 56	402.67	116.74	28.99	38.13	4.68	0.89
DOM4	403.00	136.25	33.81	24.07	0.82	0.92
KER 2 E	318.67	42.21	13.25	41.67	0.64	0.75
R(10)(MEX)	396.00	131.70	33.26	49.20	0.81	1.68
B7B4	496.00	114.57	23.10	37.87	0.53	1.26
UF677	527.33	158.73	30.10	42.80	1.09	1.35.
GDL3	645.00	148.44	23.01	29.60	0.67	1.18
B5-7	788.67	98.99	12.55	34.87	1.89	1.16
MAR 9	621.33	129.99	20.92	38.27	1.03	1.28
CLM90	580.33	115.09	19.83	42.73	1.54	0.71
R (39) (MEX)	400.00	135.26	33.82	32.27	2.03	1.21
B7B5	389.33	87.32	22.43	40.27	0.81	0.97
DOM25	504.33	124.48	24.68	33.07	0.39	0.93
KER 9	417.33	102.77	24.63	38.53	1.71	0.71
LV28	532.33	128.97	24.23	35.60	12.60	1.16
B7 A6	322.00	95.98	29.81	39.20	1.01	0.87
GU 310	594.00	152.83	25.73	37.93	1.74	1.18

Accessions	Pod wt.(g)	Total wet bean wt. (g)	Wet bean content (%)	No. of beans/pod	Flat beans/ pod(%)	Dry wt. of peeled bean (PB)(g)
PEGT400	797.67	206.08	25.84	47.07	0.15	1.37
MMC 16	795.33	149.22	18.76	41.20	1.13	1.01
EET397	563.67	144.84	25.70	36.93	0.73	1.03
ICS95	552.67	129.20	23.38	40.80	0.49	1.35
IMC 67	734:67	186.80	25.43	36.80	1.42	1.10
SCA6	423.00	95.24	22.52	37.20	1.92	0.81
PA 137	436.33	99.77	22.87	31.07	1.49	1.07
RB 33/3	375.33	64.59	17.21	39.80	0.50	1.07
SPEC 160-9	534.67	152.01	28.43	22.93	0.82	1.72
EQX-3348-44	408.67	75.25	18.41	44.80	0.00	0.88
PUCALA 1	395.33	107.52	27.20	48.27	0.14	1.03
IMC54	451.33	118.07	26.16	49.27	0.14	0.73
IMC 14	395.33	96.10	24.31	49.07	0.41	1.13
Criollo	474.67	119.21	25.11	35.53	2.92	0.58
Calicut local 1	503.67	128.07	25.43	35.87	1.46	1.19
Calicut local 2	530.00	192.06	36.24	43.80	0.75	1.12
Konni local 1	531.33	113.66	21.39	40.27	3.20	1.07
Konni local 2	719.33	149.21	20.74	37.67	4.87	1.42
Konni local 3	476.00	108.53	22.80	36.80	1.08	1.03
Konni local 4	448.67	107.33	23.92	39.33	1.01	1.52
Konni local 5	562.00	146.84	26.13	40.07	3.84	1.34
Thodupuzha local 1	466.67	122.18	26.18	32.00	7.86	1.17
Thodupuzha local 2	495.00	109.68	22.16	46.27	3.04	0.93
Thodupuzha local 3	416.67	89.17	21.40	31.60	4.13	0.93
CV (%)	30.38	26.46	-	16.45	120.78	23.64

Steps in the development of a Statistical Key

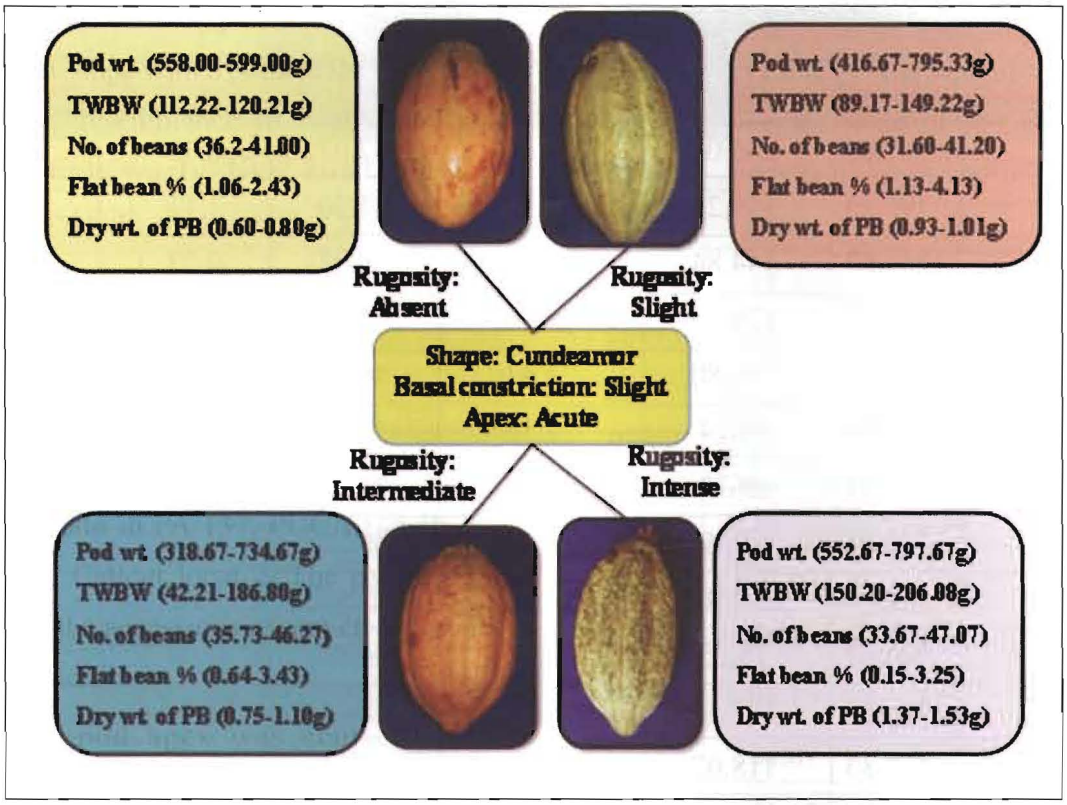

Plate 1a: Statistical key for cundeamor types

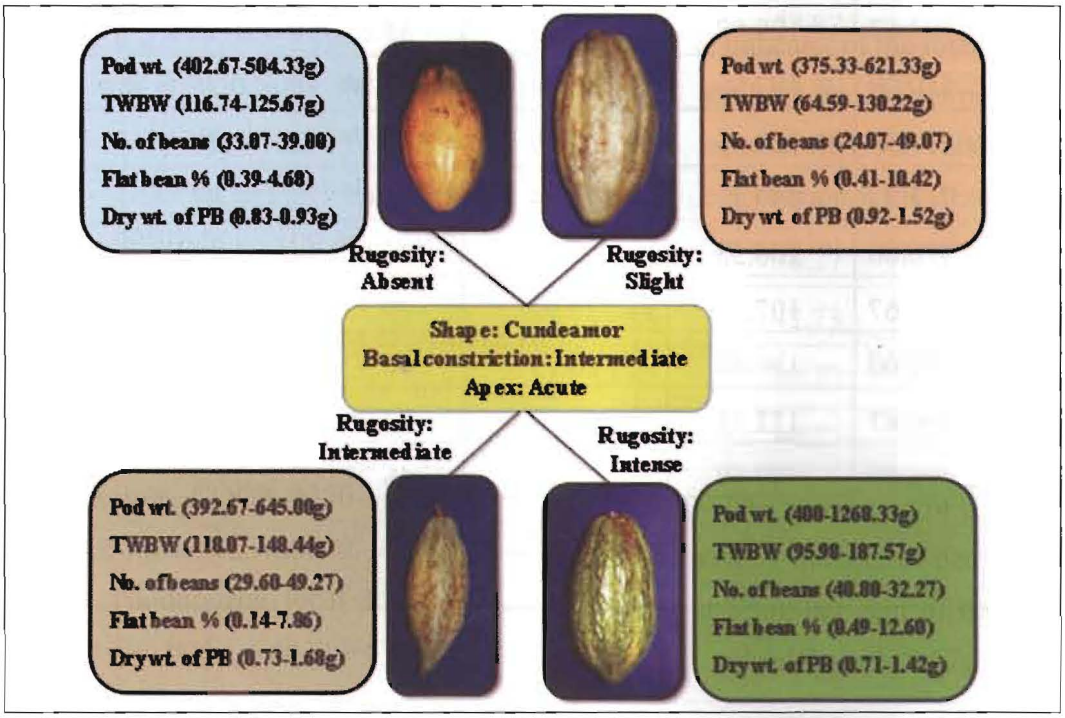

Plate 1b: Statistical key for cundeamor types

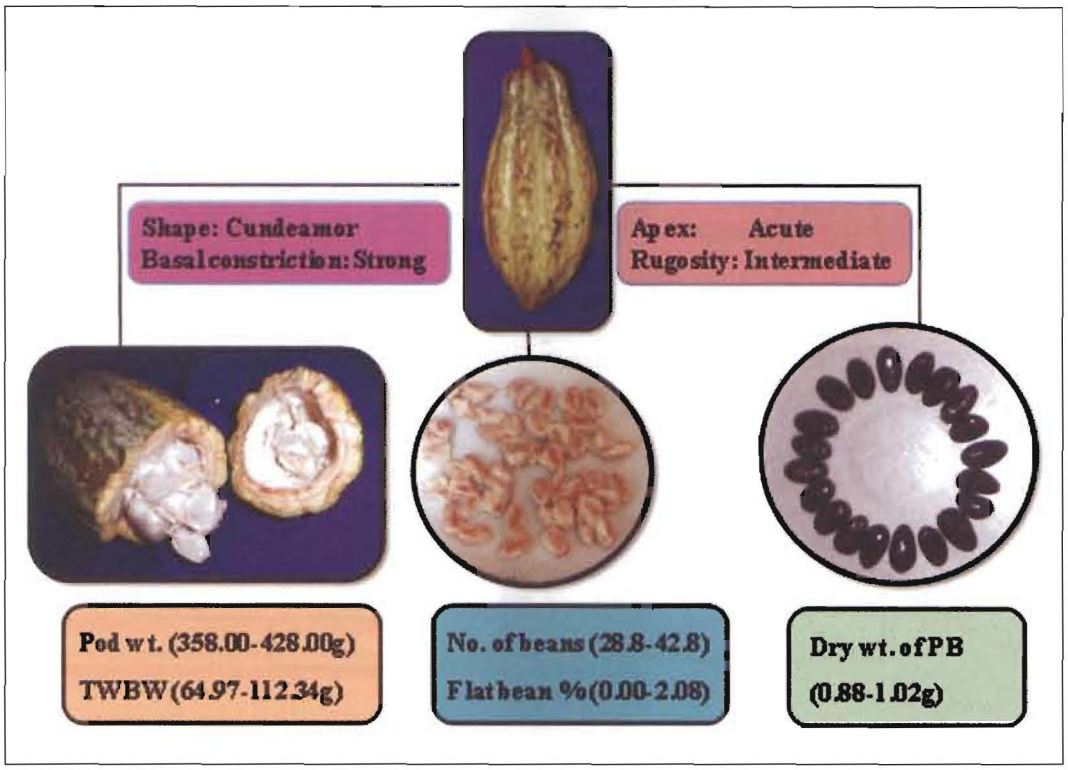

Plate 1c: Statistical key for cundeamor types

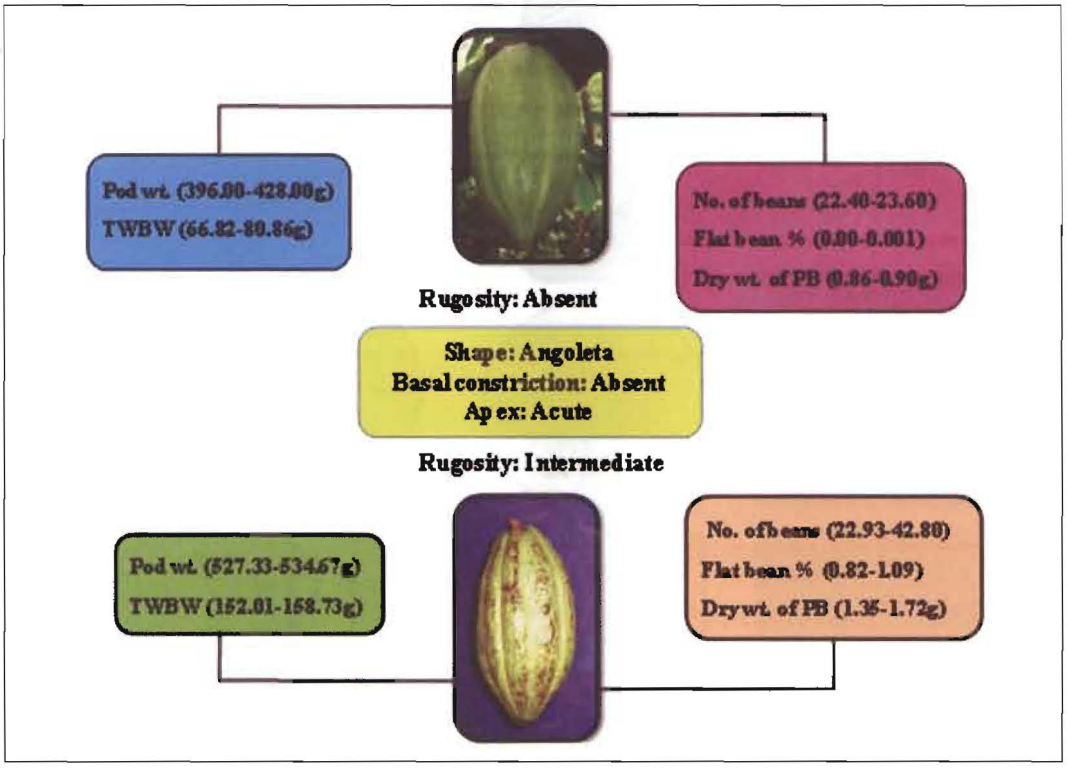

Plate 2: Statistical key for angoleta types

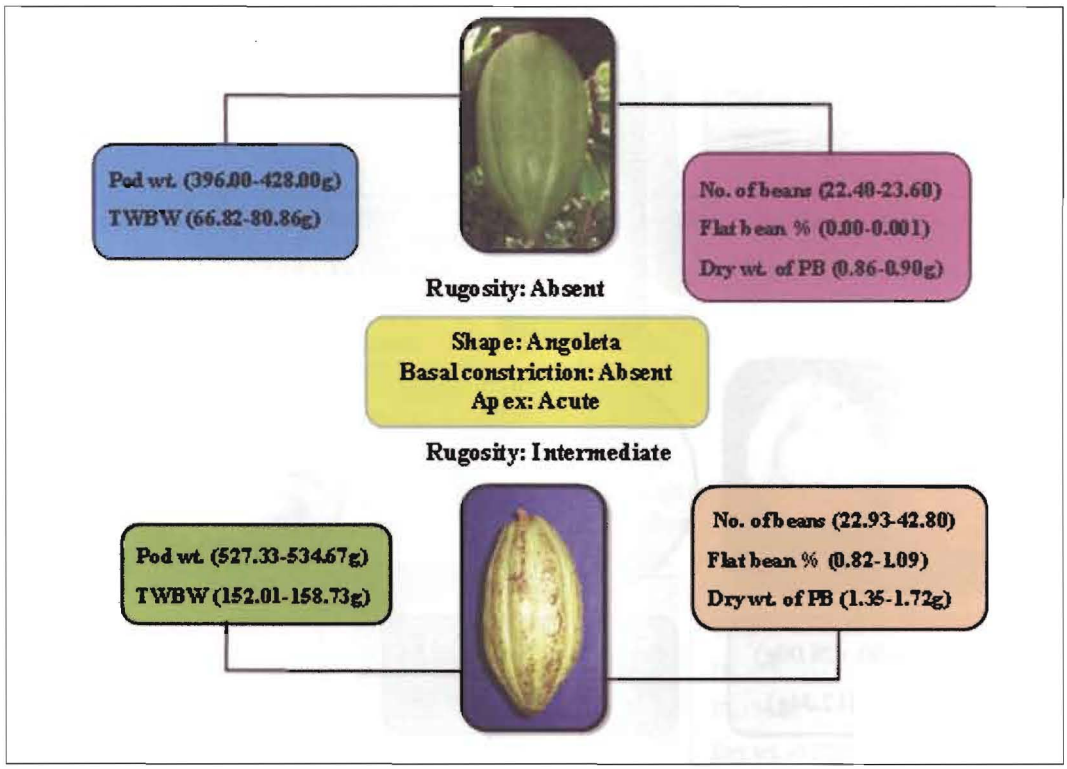

Plate 3: Statistical key for amelonado types

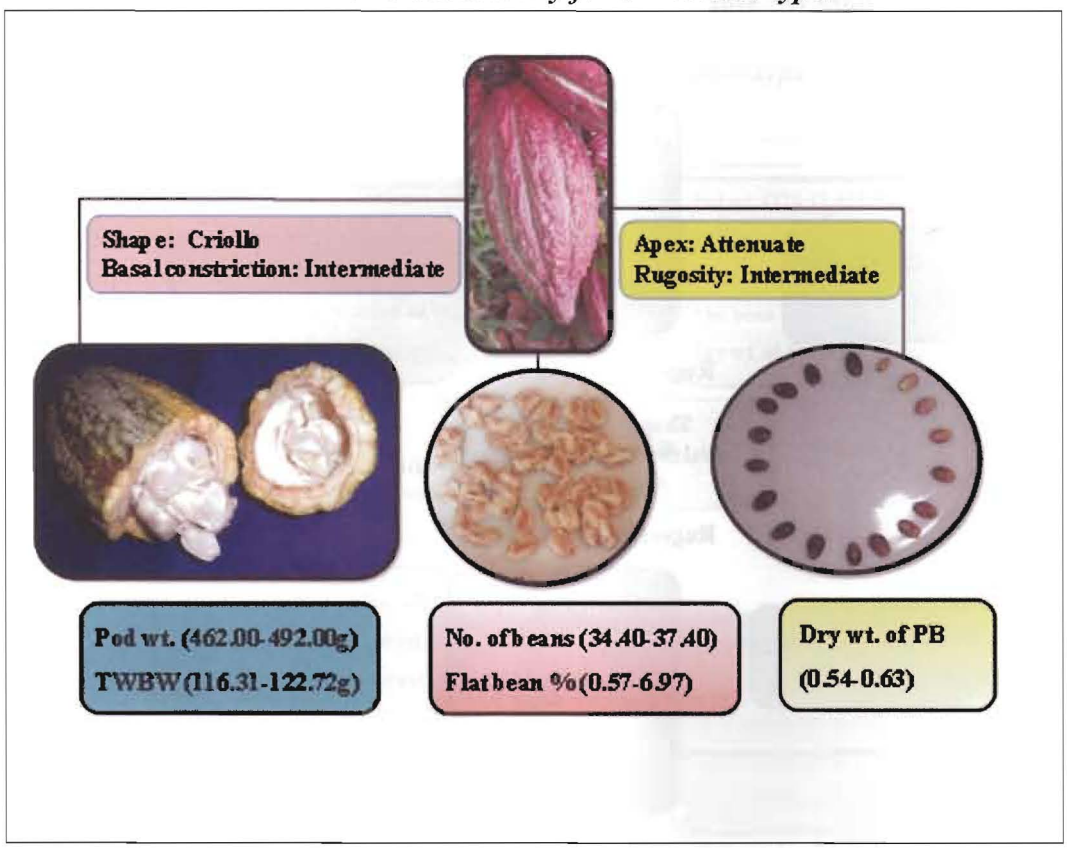

Plate 4: Statistical Key for criollo types

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