Exploiting the Cocoa genetic variation for flowering time and pod development period for climate adaptation: genetic variation and relationship to selected yield components

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Importance of *Theobroma cacao L.*

- Contributes to a 130 billion USD chocolate and confectionary industries, worldwide
- Other products such as cocoa based beverages, alcohol, cosmetic and nutraceuticals
- Cocoa pulp and husk are also used as animal feed or fertilizer

Origin of cocoa in the South American Tropics

Cocoa a neotropical tree species indigenous to the Upper Amazon region of South America.

Motomayor et al (2008) identified

- 10 genetic groups cocoa dispersed in tropical Central and South America.
- Two hybrid populations, Trinitario (from Trinidad) and Refractario (from Ecuador)

The geographical diversity allows local adaptation to different environments

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Identifying and exploiting the genetic diversity that exists in the collections in breeding is critical for the survival of the cocoa industry.

The International Cocoa Genebank, Trinidad (ICGT) is considered the **largest** and most diverse collection of cocoa in the public domain.

Strategies for drought tolerance/ resilience in cocoa

- **Anatomy**
  - Root architecture, fine roots
  - Canopy characteristics - Leaf morphology, size, stomatal density,
- **Physiology**
  - Osmotic adjustments (P & K accumulation in leaf)
  - Stomatal Conductance (stomatal sensitivity, leaf rolling, turgor)
  - Flushing behaviour
  - Interaction between drought & CO_2 enrichment; drought & temp
- **Biochemistry**
  - Polyamine synthesis (general stress avoidance mechanism)
- **Agronomy**
  - Agroforestry and shade management – species dependent
  - Mineral nutrition particularly potassium
  - Water retention within fields

AVOIDANCE OF CLIMATE CHANGE

There is an opportunity to select for avoidance mechanisms as a means of developing climate tolerant cocoa genotypes

In this study we investigated two such mechanisms

- **Time of flowering following the dry season**
- **Pod development period**

Objectives

1. To determine the genetic diversity that exist within a representative subset of the germplasm held at the International Cocoa Genebank (core collection) for flowering time and pod development period
2. To correlate the selected traits for three consecutive years
3. To identify the interrelationships among the selected traits like flowering time, pod development period on yield related traits such as pod size, number of beans per pod, bean size and bean weight

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97 accessions or genotypes were evaluated for

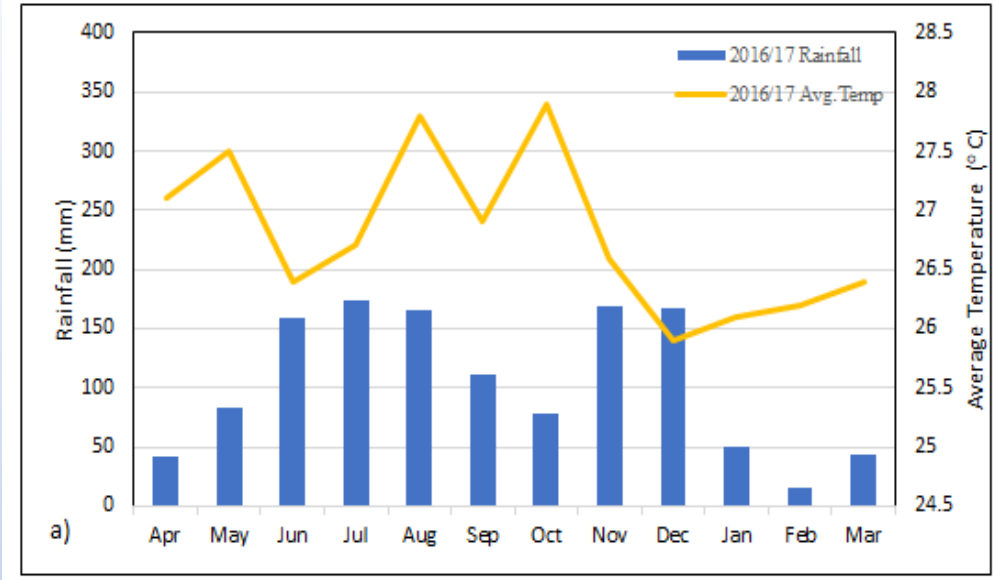
- Flowering time
- Pod development period
- Pod size
- Pod growth rate
- Bean number
- Bean weight (wet)
- Bean weight (dry)

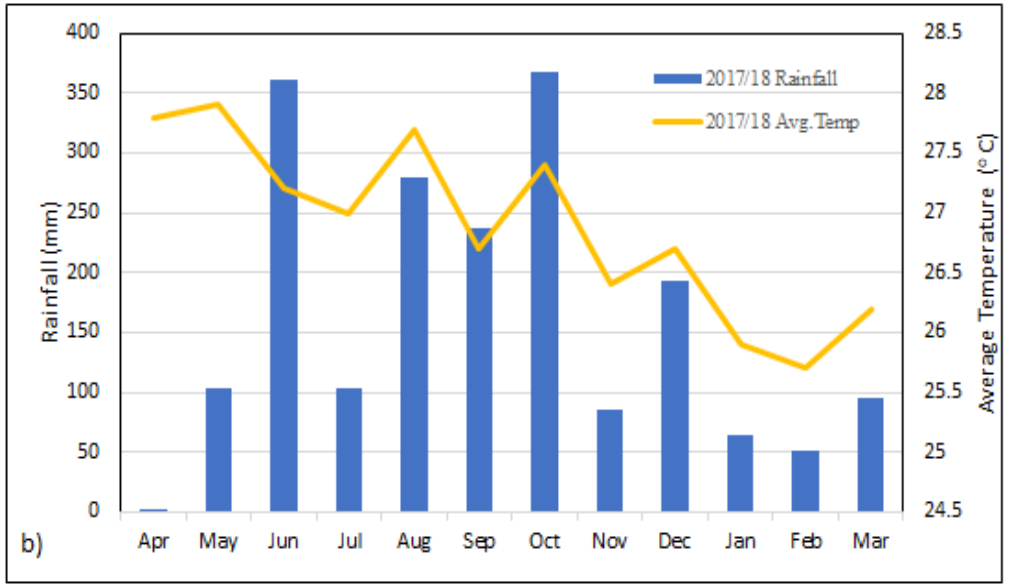
In the year spell of 2016/2017, 2017/2018 and 2018/2019. The period begins from April to March of the next year.

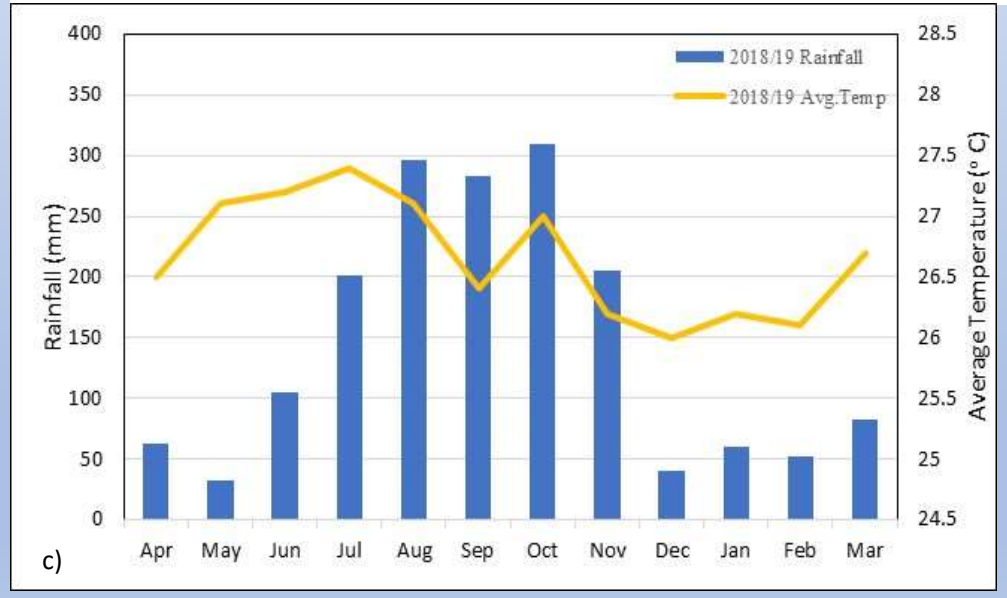
Materials and Method:

- The flowering time has been noted during the first flowering after first rain following the dry spell for each tree for each accession

- The pods were individually tagged after pod sets and measurements (length and width) were taken in every 15 days upto maturity for each accession



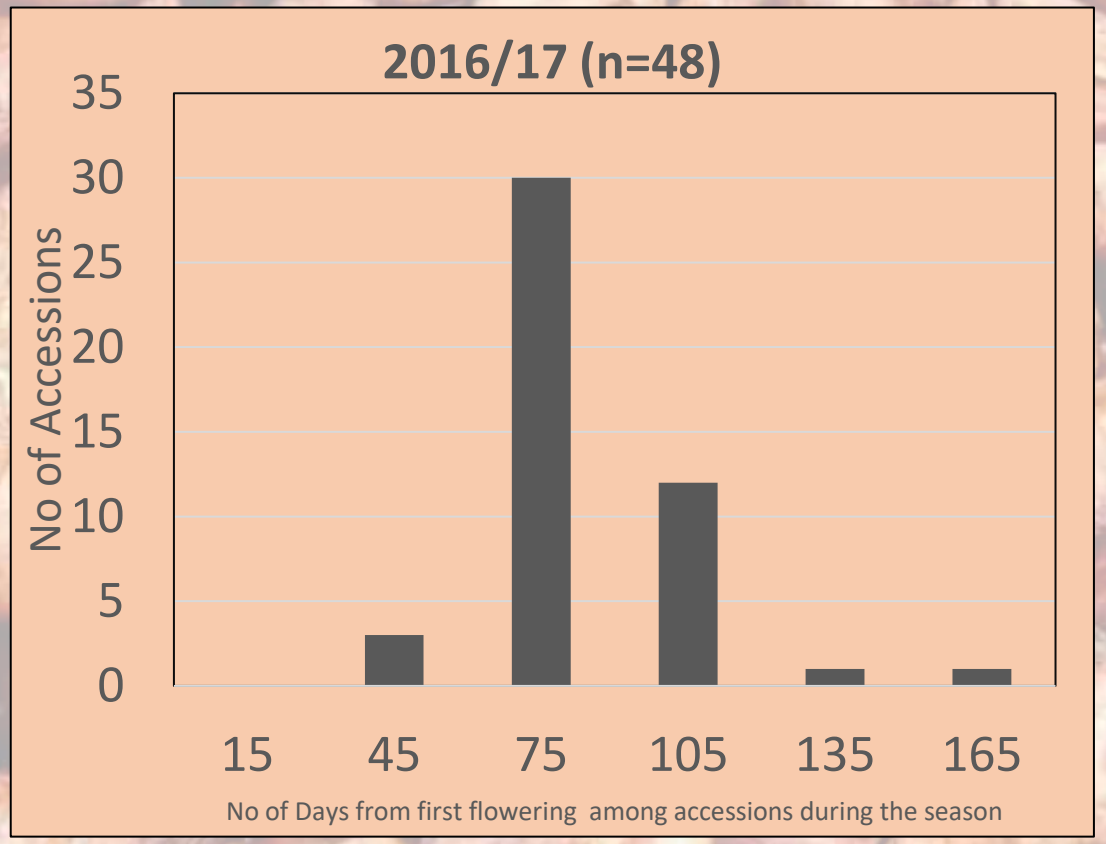


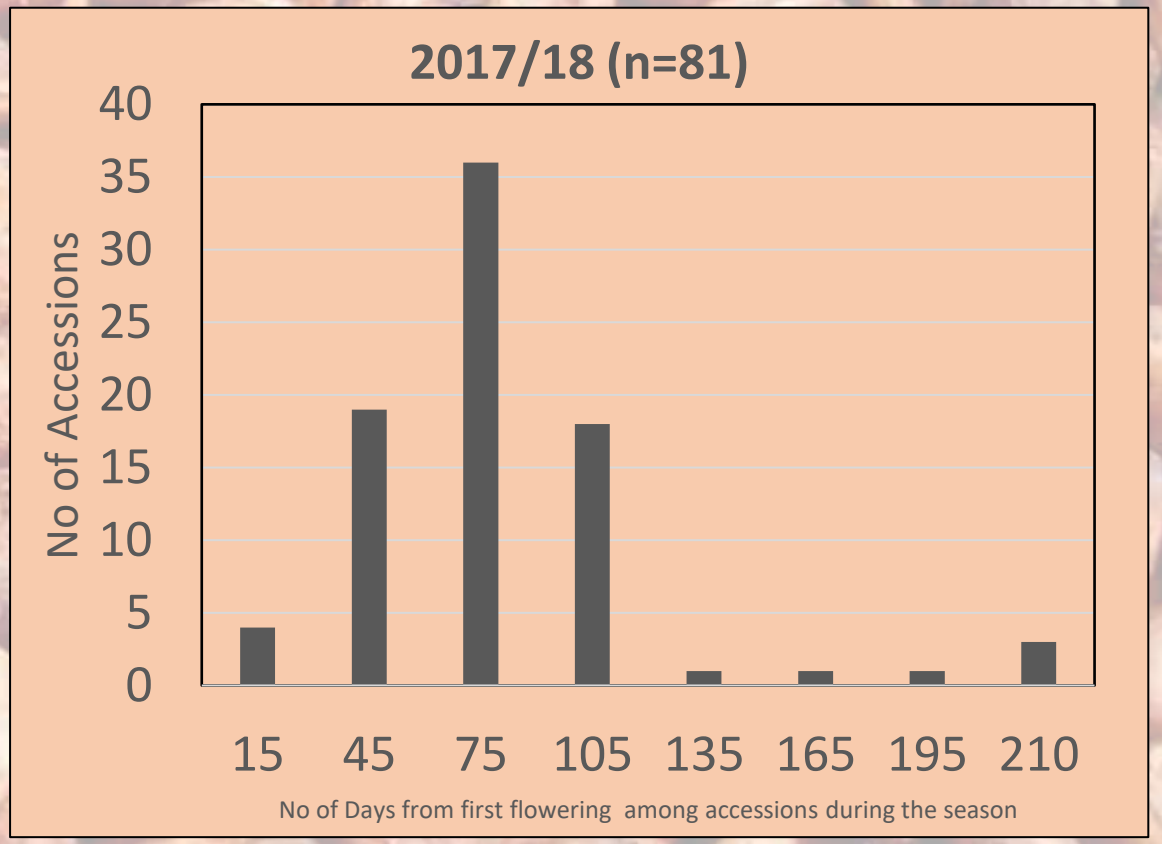


Monthly average rainfall (mm) and temperature (°C) for the seasons a) 2016/17, b) 2017/18 and c) 2018/19 in Trinidad and Tobago (Data obtained from University Field Station, Valsayn, Trinidad and Tobago)

Results – Flowering time

- **Significant differences among accessions were noted.**





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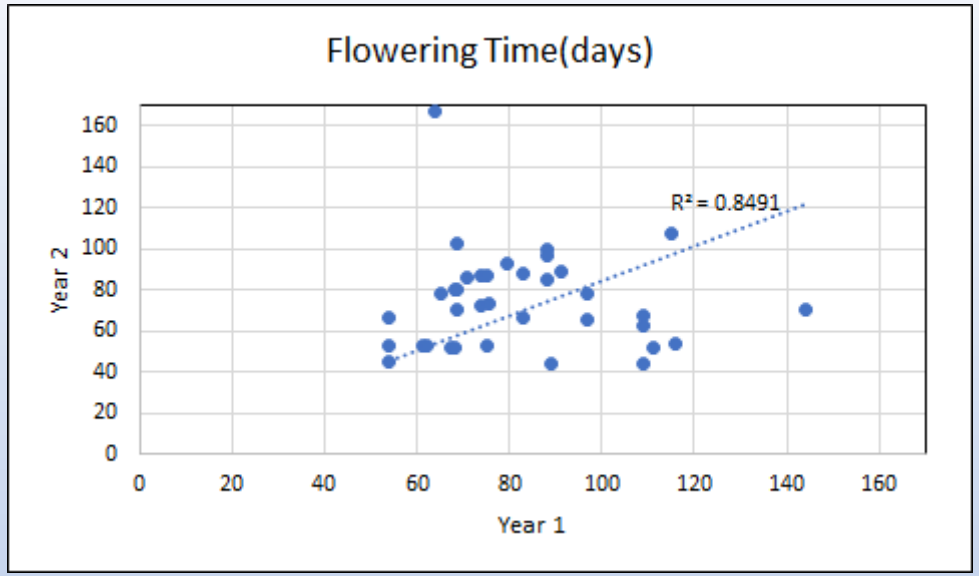
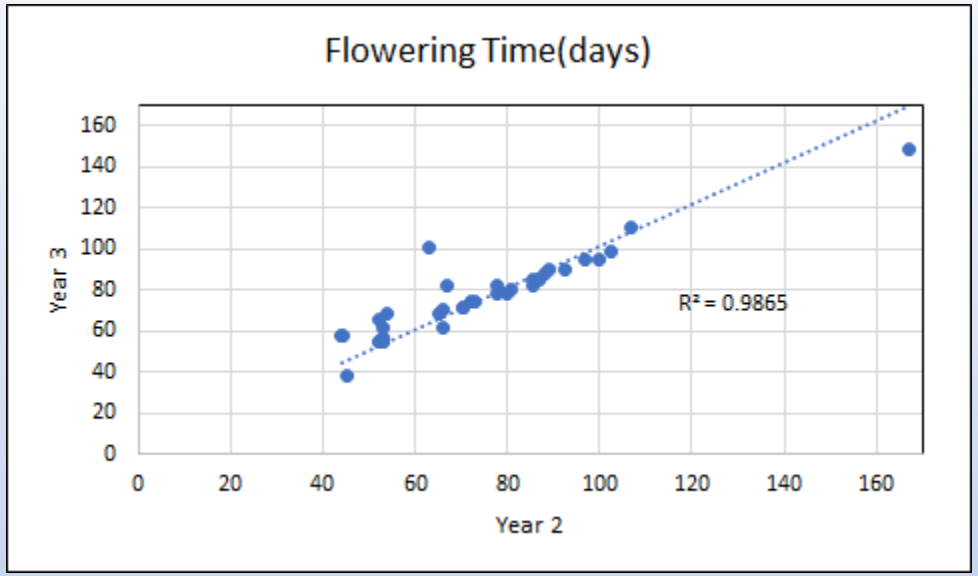
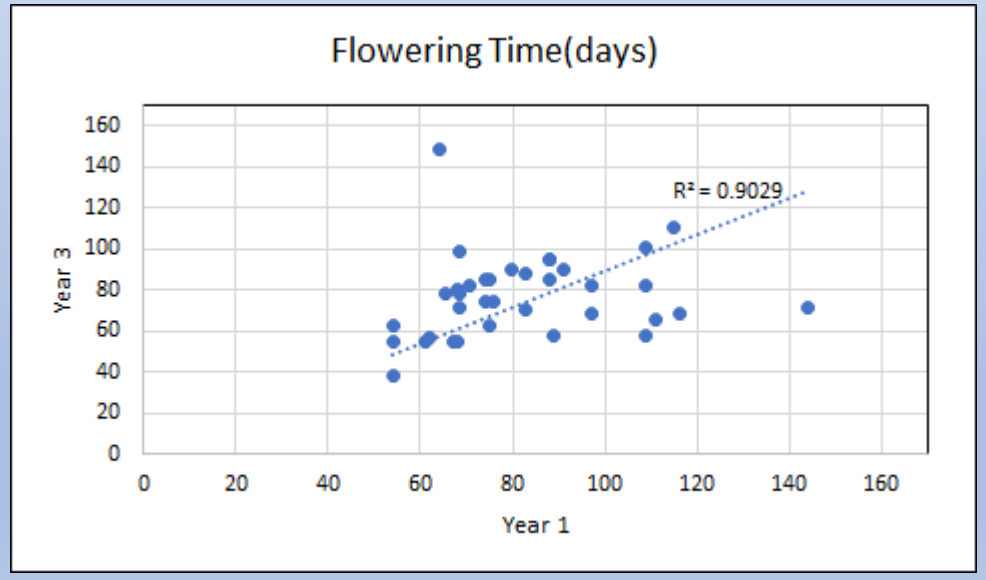
Flowering time

Early Flowering	**SIC,MO,CL,ICS**
Late Flowering	**ICA,AGU**
Intermediate flowering	**GU,AMELONADO,SIAL,NA,PA,JA,SIC, LV,LCTEEN,RED AMELONADO,EET**







Correlation between flowering time (days after commencement of wet season) of 32 cacao accessions evaluated over three years at Centeno, Trinidad.

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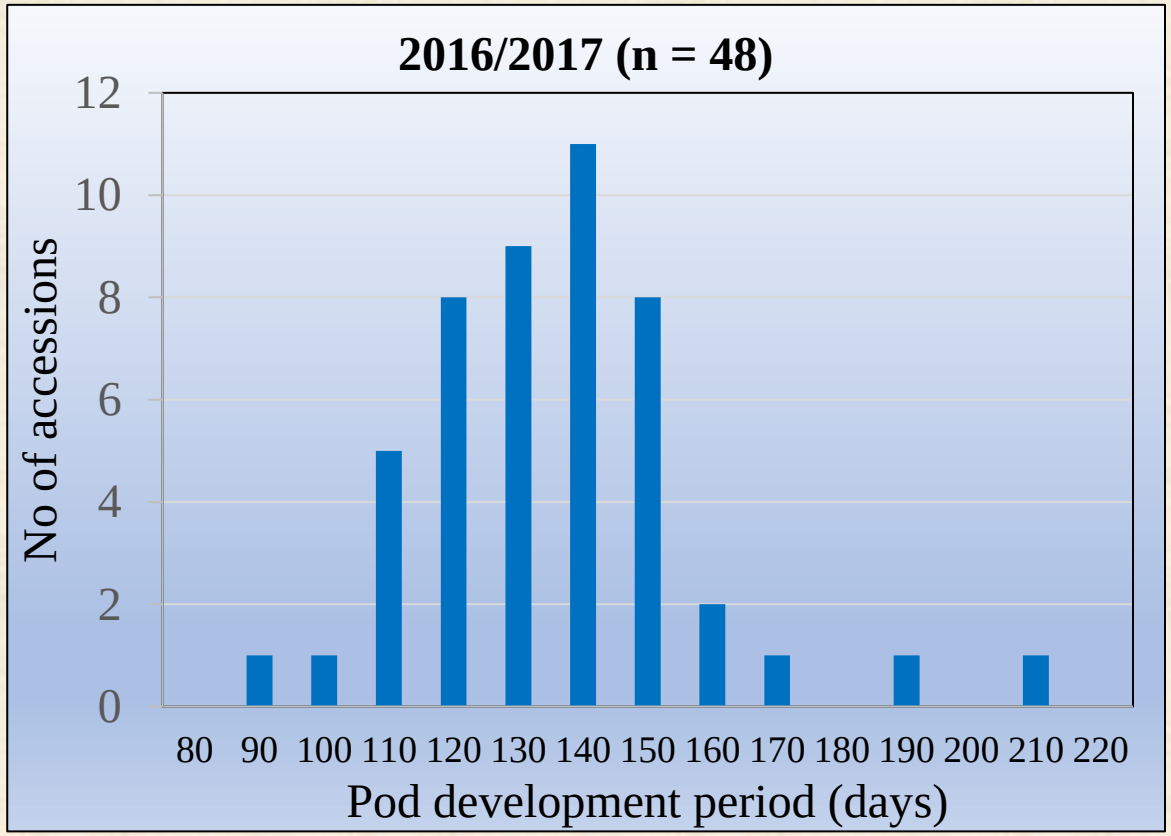
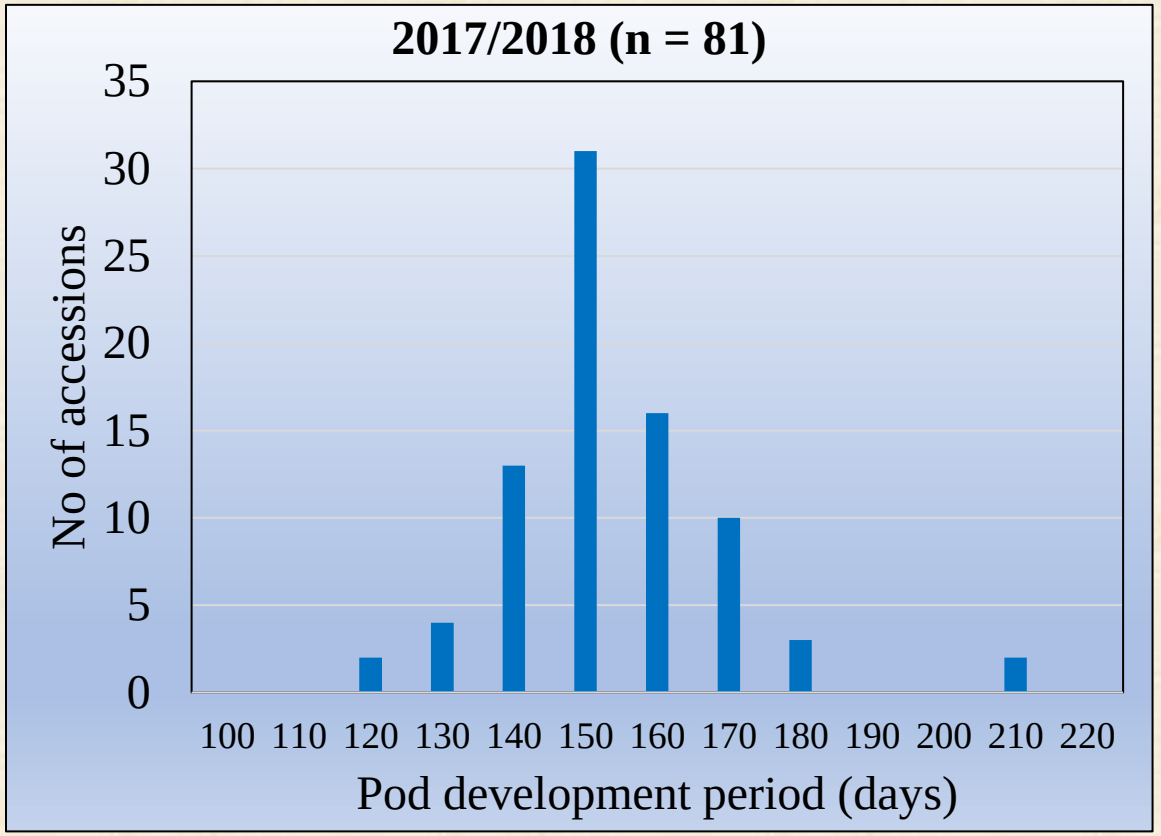
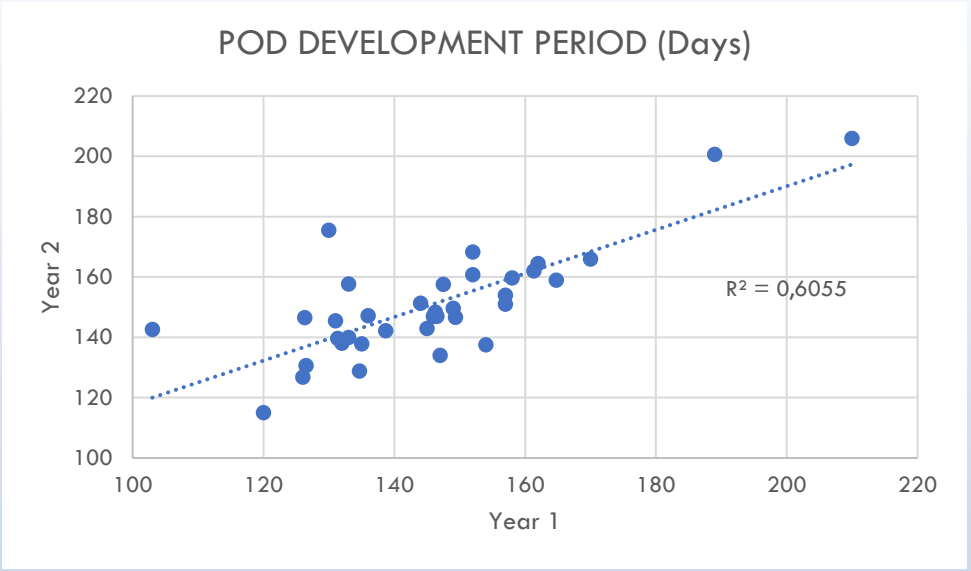
Results – Pod development period

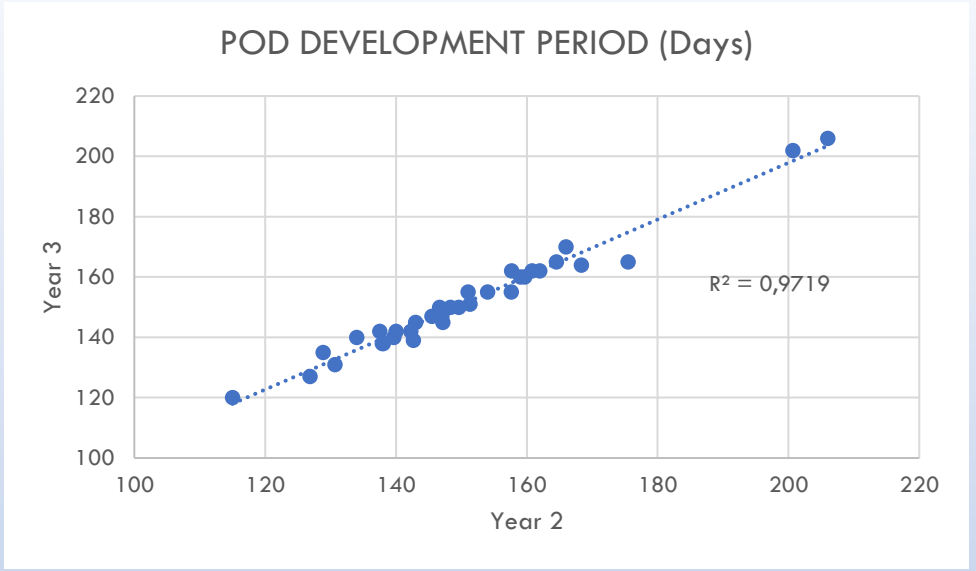


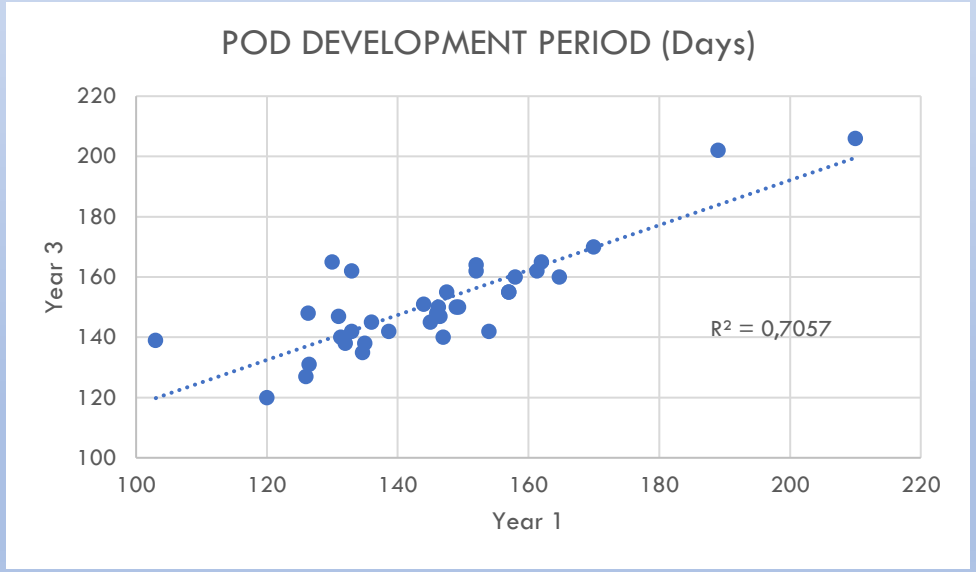


Mean 132
Range 90-210

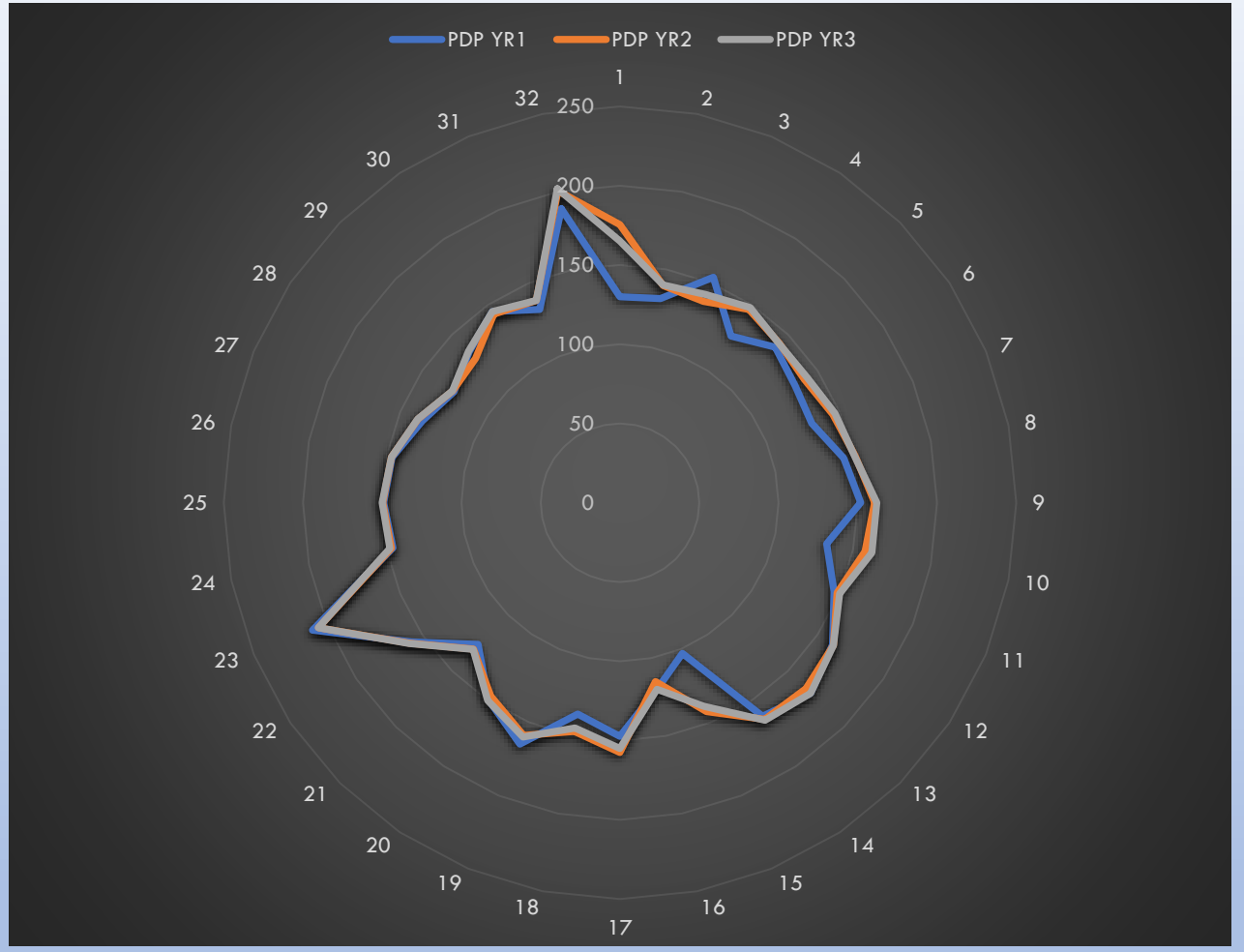
Mean 149
Range 100-210







Correlation among pod development period of 32 cacao accessions evaluated over three years (2016/2017 , 2017/2018 and 2018/2019) at Centeno, Trinidad.


PDP YR1
PDP YR2
PDP YR3
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2
3
4
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20
21
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25
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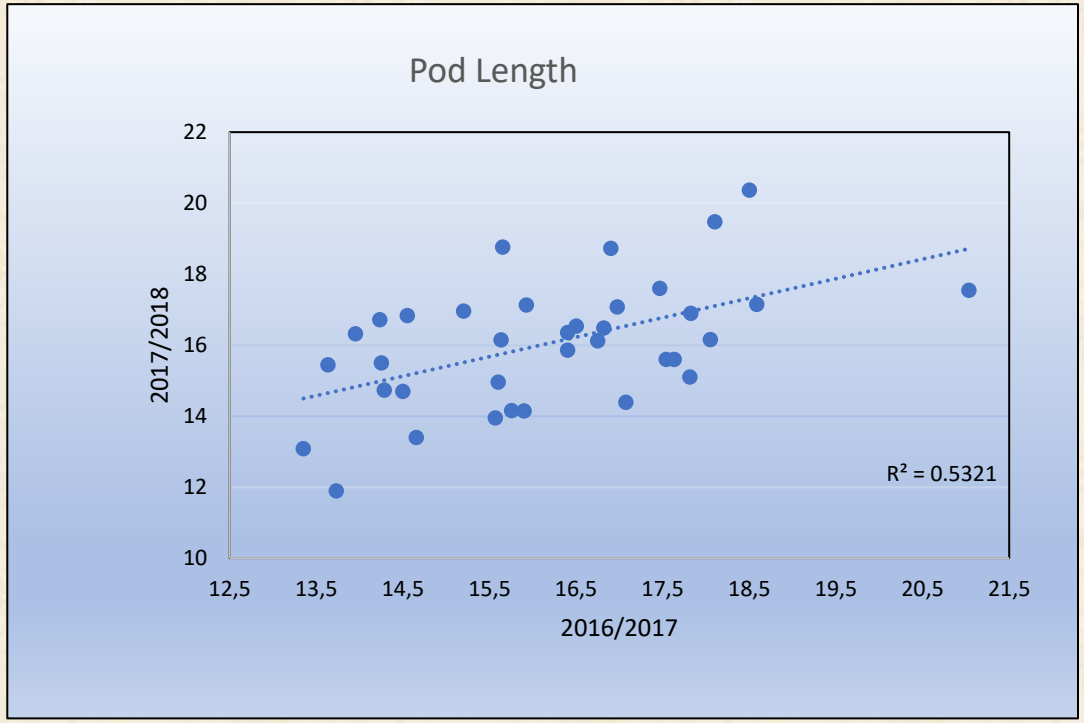
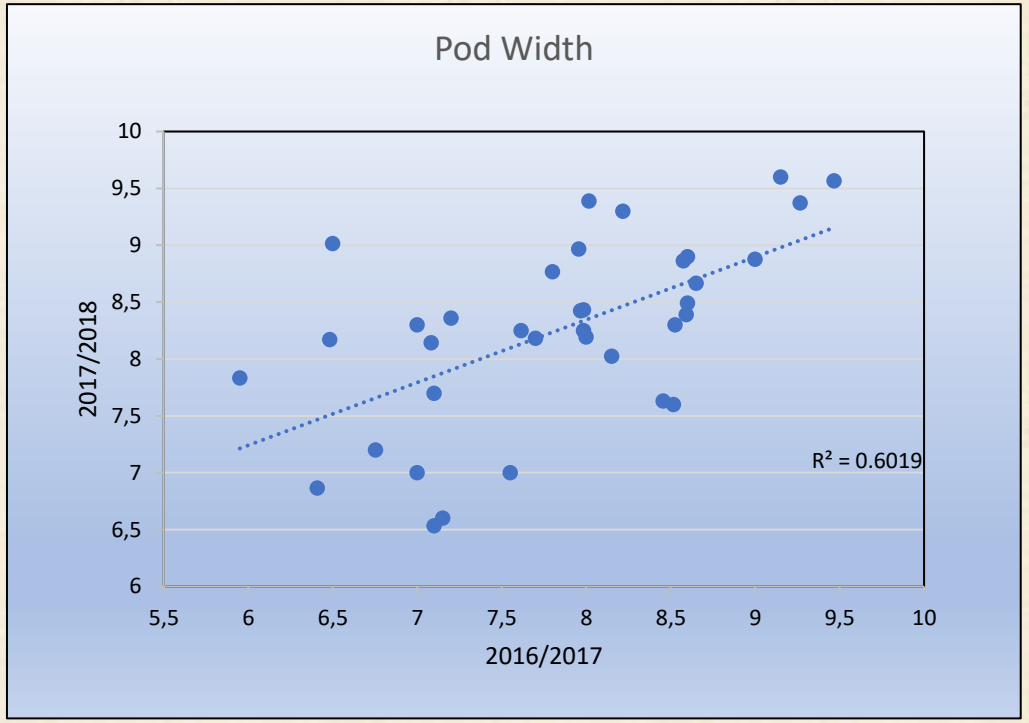
27
28
29
30
31
32
250
200
150
100
50
0

Results – Pod Length and Width





Correlation for pod length and pod width of mature pods of 32 cacao accessions evaluated over two years at Centeno, Trinidad.

Results - Correlation between phenotypic traits

	FT	PDP	Pod Len	Pod Wid	Pod Size	L/W	APGR	Bean #	Bean Siz	ABW
FT	1	0.15	0.22	0.11	0.17	0.16	0.11	0.01	0.32*	0.32*
PDP		1	-0.17	0.07	-0.06	-0.25*	-0.35*	-0.07	0.13	0.13
Pod Len			1	0.49*	0.83*	0.74*	0.82*	0.34*	0.39*	0.39*
Pod Wid				1	0.88*	-0.23*	0.81*	0.40*	0.50*	0.50*
Pod Size					1	0.24*	0.95*	0.42*	0.53*	0.53*
L/W						1	0.29*	0.08	0.05	0.05
APGR							1	0.42*	0.45*	0.45*
Bean#								1	-0.05	-0.05
BeanSiz									1	0.99*
ABW										1

Pearson Product Moment Correlations between 10 agronomic traits investigated in 81 cocoa accessions at the International Cocoa Genebank at Centeno, during the 2017/2018 period.

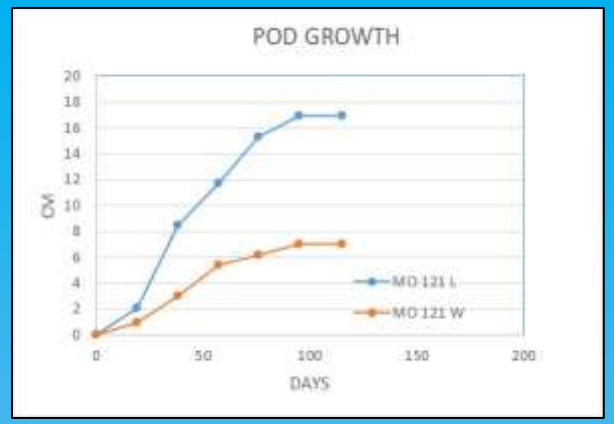
Results – Pod Growth

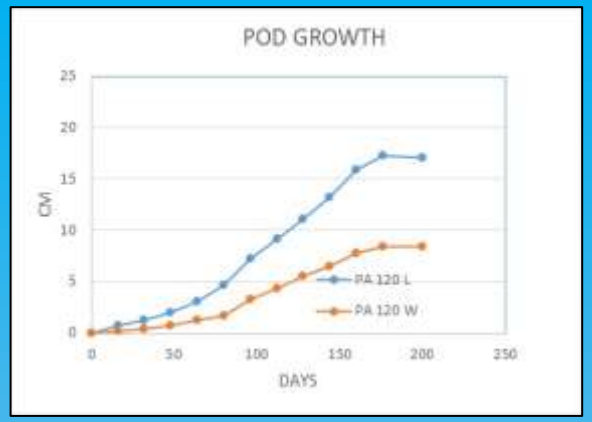
Pattern of pod growth measured as increase in pod length (cm) and pod width (cm) over time (days) in 4 accessions of *Theobroma cacao* L in 2017-2018

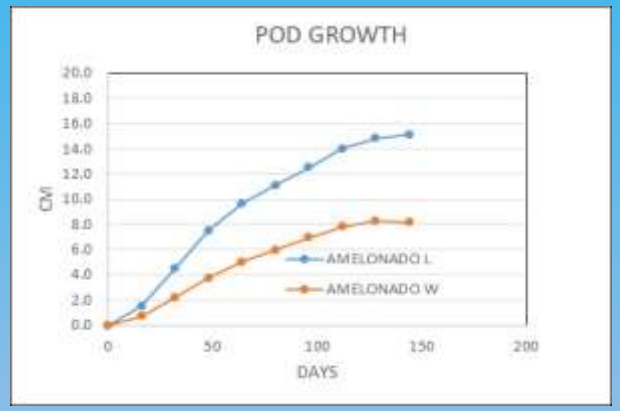
MO 121 - a genotype with shorter pod development period

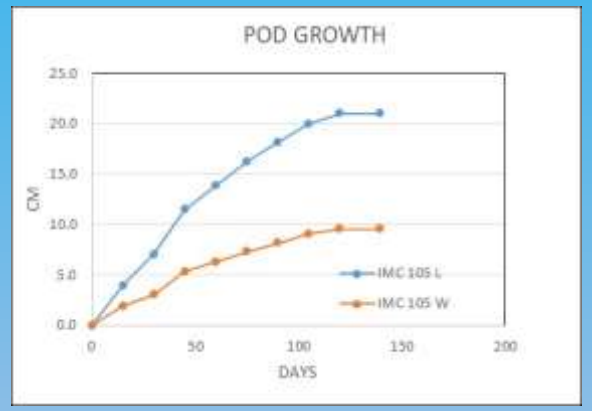
PA 120 – a genotype with longer pod development period than the others like

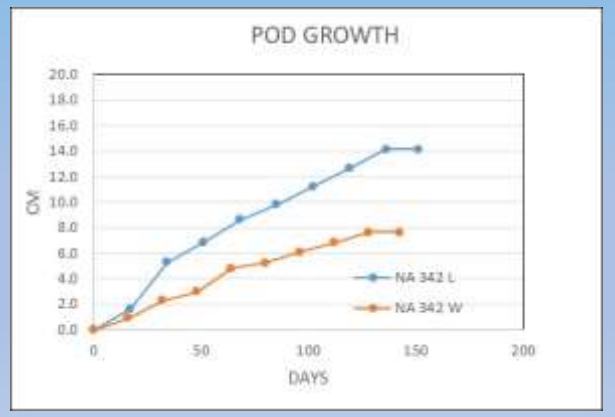
Amelonado, IMC 105 , NA 342 and SCA 6

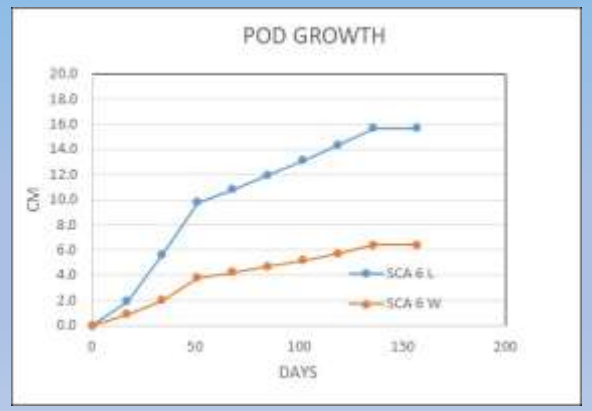












		2016/2017 (n =48)			2017/2018(n=81)	
Character	Mean	Range	cv	Mean	Range	cv
FT (days)	80	16 - 144	0.28	79	11 - 208	0.49
PDP (days)	143	97 - 210	0.15	149	115 - 206	0.10
PL (cm)	16.3	13.1 - 21.0	0.11	16.1	10.4 - 22.9	0.15
PW (cm)	7.7	5.7 - 9.8	0.13	8.5	6.3 - 11.1	0.10
PS (dm3)	4.17	2.00 -7.45	0.33	5.02	2.0 – 11.0	0.31
BN (No.)	-*	-	-	36	22.1 – 49.0	0.16
BS (cm3)	-	-	-	7.27	2.43-18.70	0.38
ABW (gm)	-	-	-	1.25	0.94 – 1.96	0.14

The genetic variation for 8 mopho-physiological characteristics of 48 accessions (2016/2017) and 81 accessions (2017/2018) of *Theobroma cacao* evaluated at the International Cocoa Genebank, Trinidad situated in Centeno, Trinidad.

FT = Flowering time; PDP = pod development period; PL = pod length; PW = pod width; PS = pod size; BN = bean number; BS = bean size and ABW = average bean weight

* data was not collected for BN, BS and ABW during 2016/2017

Conclusion

- **Significant differences with respect to flowering time and pod development period were observed**
- **Despite large year-to-year variation in climatic conditions PDP and FT showed remarkable consistency across accessions over the three years of study, suggesting a strong genetic influence**
- **There was evidence of genetic differences in PDP and FT across genetic groups from different geographical origins indicating that this variation could be an evolutionary adaptive response**

Conclusion

- **No correlation was seen between pod development period and yield components; bean number, bean size and bean weight whereas no/weak correlation was seen between FT and yield components, indicating that these traits can be selected , independent of yield**
- **Finally, the study shows tremendous opportunity to use flowering time and pod development period to select for local adaptability and drought avoidance**
- **We are pursuing Genome Wide Association study to further understand the genetic basis for flowering time and pod development period**

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Merci

Gracious

Thank you