A new approach to reliably forecast Cacao Yield: Pod survivorship curves

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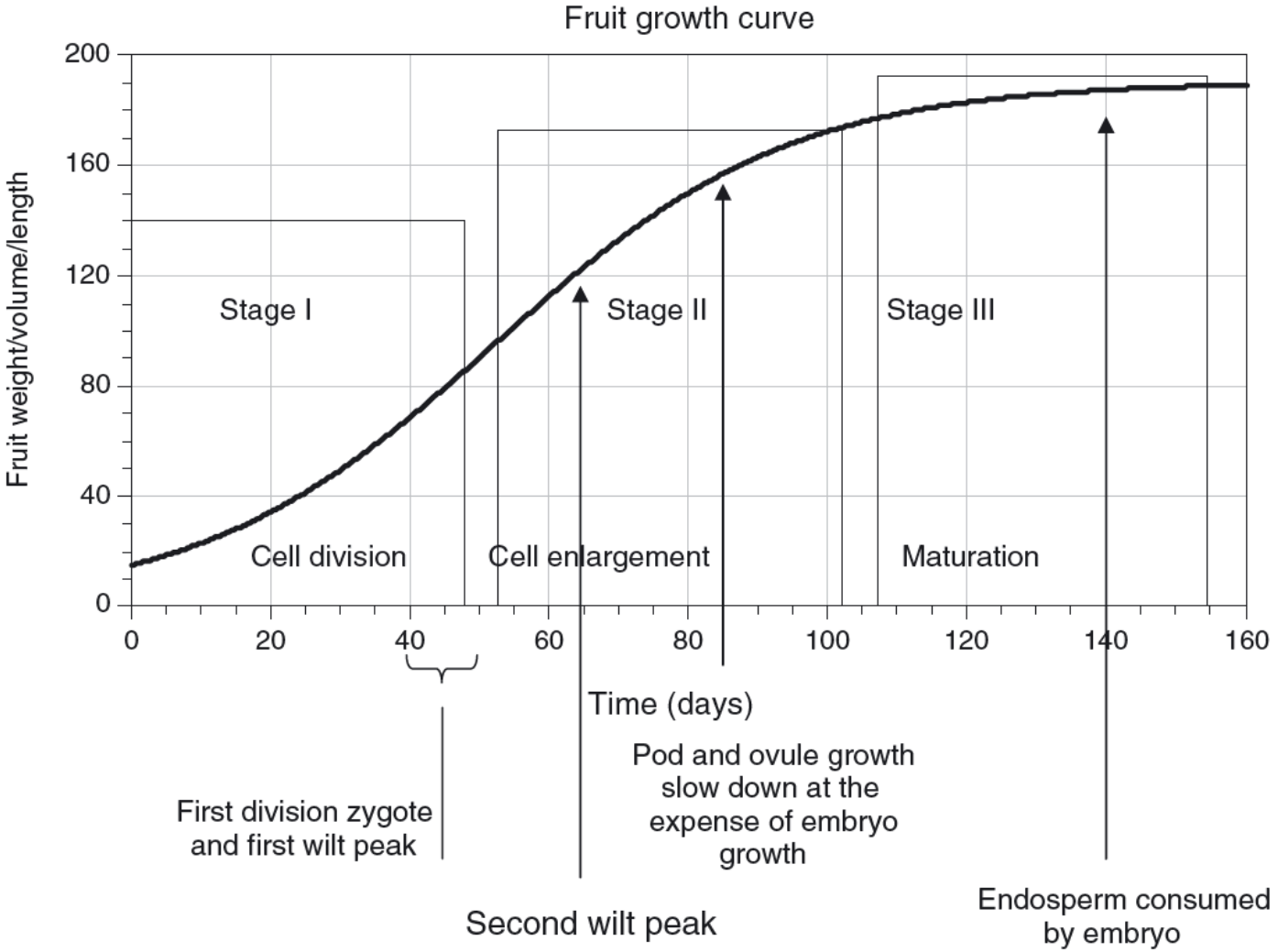
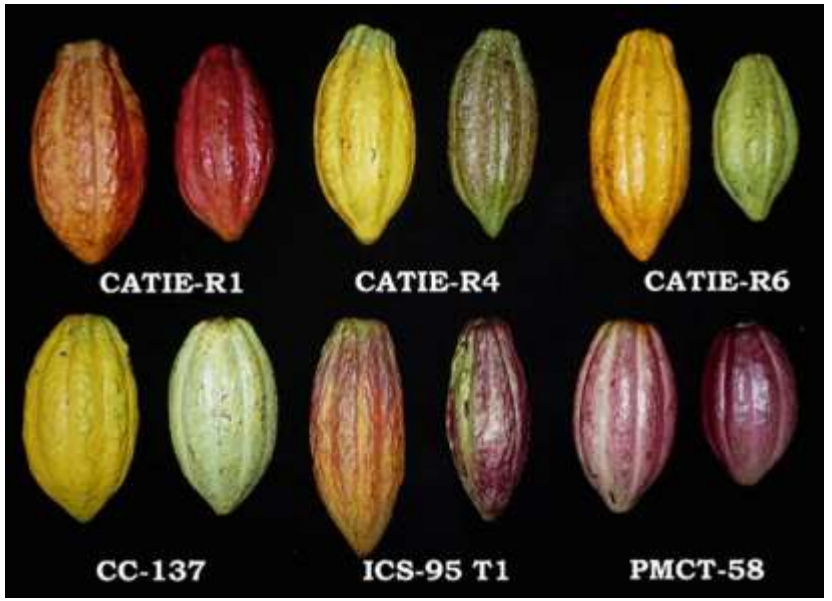
Background: Pod development and lifespan





Lifespan: Five to Six months. Several Risks/Hazards are faced overtime.

Figure 1 Sigmoid growth curve with specific cacao pod development periods as described by McKelvie (1956)

Background: Yield forecasting methods

- Bean Fresh Weight X 0.35-0.4 (Toxopeus 1969). (Based on harvesting round).
- Whole Pod Weight x 0.0875 (Lachenaud 1984). (season/genotype dependent).
- Total Pods/Pod Index (relies on the correct estimation of pod index).
- Tahi et al., (2007) proposed/tested five methods to aid researchers/breeding trials.
- At the farm level, UTZ (2016) offers a simple method for yield estimation:

Completado por el productor/personal técnico

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Árboles	Número de vainas por árbol/año	Número de árboles en el área de muestra[5]	Cantidad de cacao seco por árbol (kg)/año[6]	Cantidad de cacao seco (kg/año) para el área de muestra
Alto rendimiento	≥20	5	±1	5 x 1 = 5
Rendimiento medio	11-20	25	±0,6	25 x 0.6 = 15
Bajo rendimiento	≤10	9	±0,20	9 x 0.2 = 1.8
Total		***39 árboles***		***21.8 kg***

Without effective P&D management X 20% losses.

Methodology: site, climate, management…..

- La Montana, Turrialba, Costa Rica
- CAF-12 years, Altitude: 610 masl.
- Rain: 2065 mm/year, Temp: 25 °C
- RH: 80%, Soil: pH: 5,6, OM: 2,75%.
- Cacao at 2.5 x 2.5 m (1600 plants/ha).
- Fertilization: 4 events/year, 600 g/plant.
- Semi-intensive management.
- Tree cover 70% (135 individuals/ha).
- *Cordia alliodora + Swietenia macrophylla*.

Methodology: clones, data collection, timeframe….

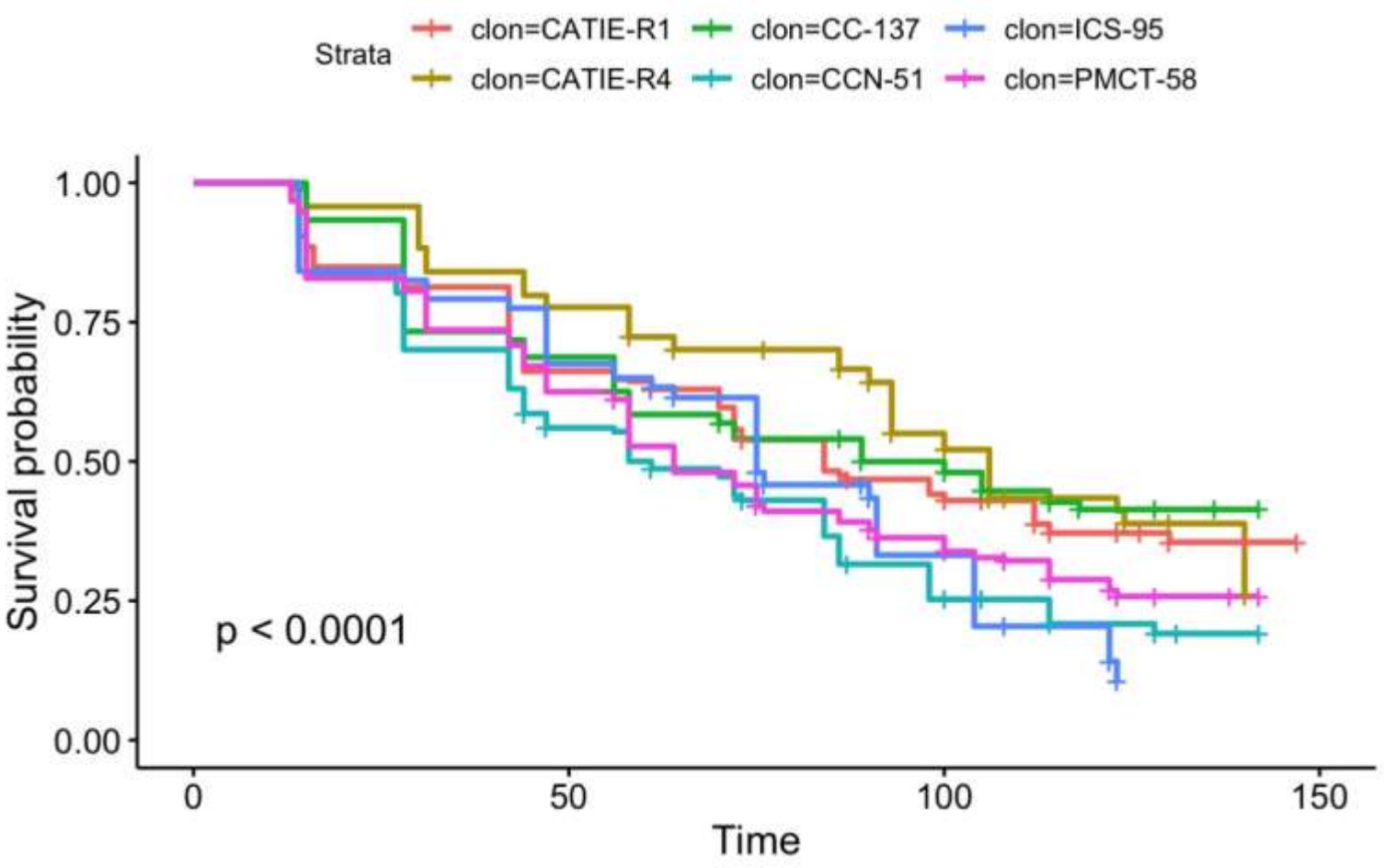
- Six clones were selected.
- 5-7 trees per clone, 15 months.
- **+1050 pods were monitored**.
- 120-150 pods/clone were measured at 15 days intervals.
- Pod Risk/Hazard overtime was assessed.
- Diameter (cm)/tree Height (m) and Length (m) of productive tissue were measured.
- Climate variables recorded…not shown.

	First cohort (28/08 to 17/12/2020)		Second cohort (07/12/2020 to 06/04/2021)		Third cohort (04/05 to 08/09/2021)	
Clones	# trees	# pods	# trees	# pods	# trees	# pods
ICS-95	5	49	6	33	4	38
CC-137	6	116	3	38	3	79
CCN-51	6	63	4	22	5	76
CATIE-R1	7	115	4	63	9	100
CATIE-R4	8	50	5	22	5	26
PMCT-58	5	45	10	71	12	93
Total	37	439	32	249	38	412

Methodology: data management and analysis

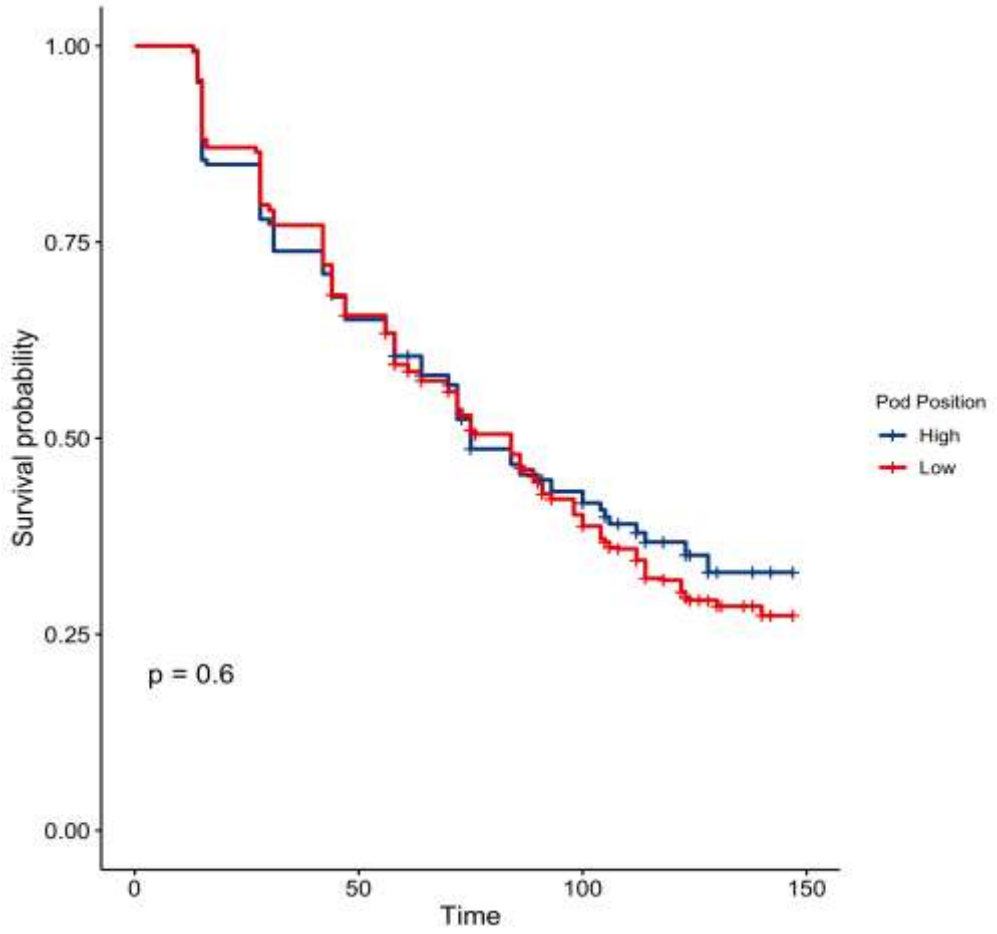
- We built the Kaplan–Meier survival curve per clone, is a non-parametric statistic used to estimate the survival function from lifetime data.
- A life table that summarizes survival data in terms of the number of events and the proportion surviving at each event time point.
- We run The Cox regression analysis to elucidate the hazard ratio and key site/tree explanatory variables
- **Paired tests were applied to understand the effects of clone, pod position, and pod size class on survival behavior.**
- **A set of discount factors based on pod size class is proposed/debated.**

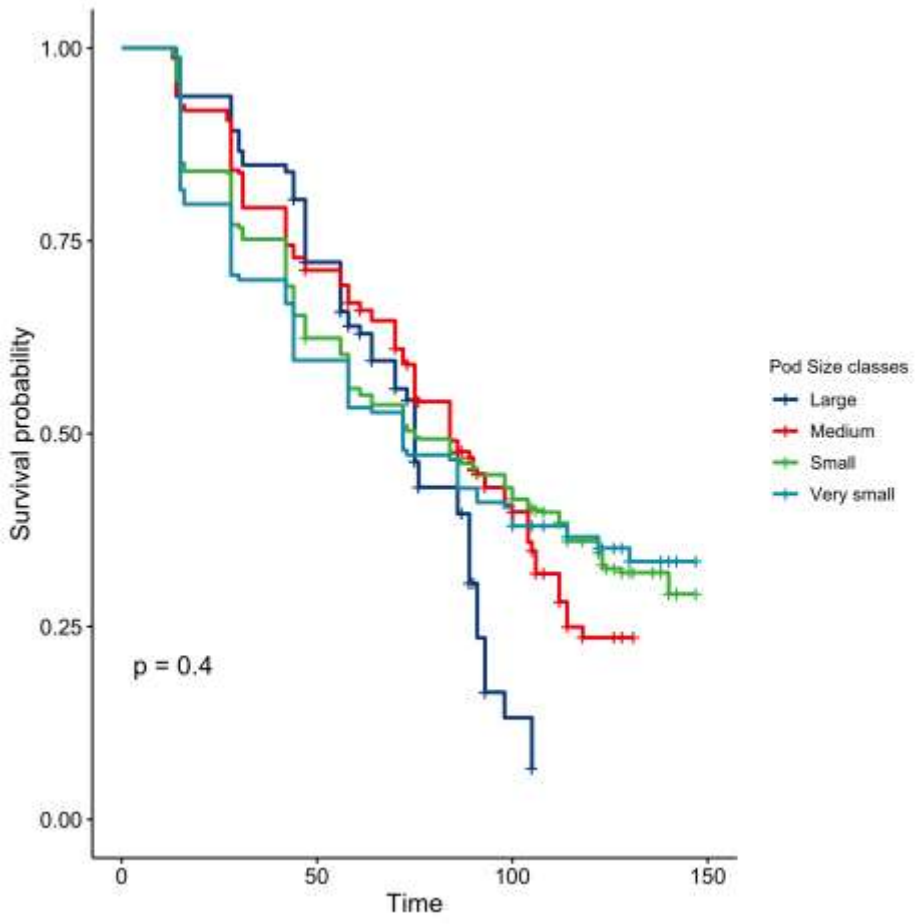
Results: Maturity and Survival behavior per clone



- Pods reached maturity at 150-165 days.
- Pod survival behavior was different among clones.
- About 50% of the pod load of CATIE R-1, CATIE R-4 and CC-137 were harvested.
- Only ≤ 30 % of the pod load of ICS-95, CCN-51 and PMCT-58 reached full maturity.
- 60/110 days were critical moments when most events/risks occurred.
- A combination of pests/diseases accounted for yield losses.

Results: Effects of pod position and size class

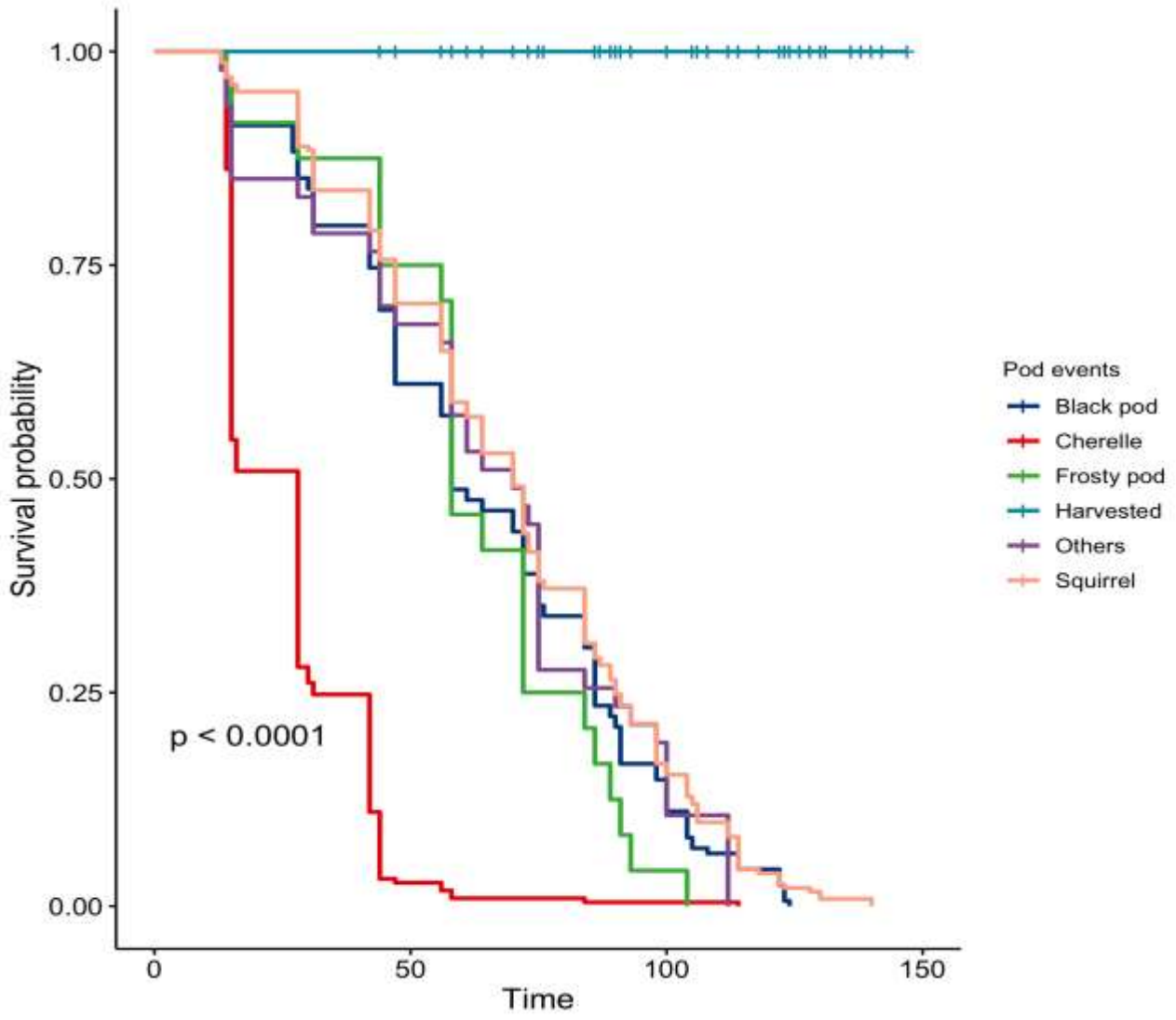




Position of pods on the trunk had no significant effect on survival behavior. Medium and large pods are more exposed to deadly hazards such as Squirrels and Birds in this agro-environment.

Implications for farmers/technical staff

- Multiple risks/events affected pod load and attainable yields. Key for the timing of agricultural practices.
- Pests, rather than diseases, were the greatest risk/hazard in this particular CAF.
  - 15-40 days: Cherelle
  - 65-80 days: frosty pod + black pod.
  - 110-130 days: rodents/birds
- For some clones, pod position along the trunk might be critical for hazard avoidance.
- Effects of climate variables (daily RH, Temp, Rain) on pod survival will be explored.



Take at home messages …

- The 2nd and Forth months of pod development are critical moments.
- A standard factor that accounts for “overall pests/diseases losses” is not a reliable means for yield estimates.
- Survival analysis allows the development of site-specific discount factors to improve yield forecasting methods.
- A set of discount factors could be combined with the Pod count/Pod Index method.
- The study is being replicated in other agro-environments: NIC, SAL, CR and Peru.
- **Thanks for your attention….**