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Non-structural carbohydrate pools in vegetative organs of two tropical palms: the coconut and the oil palms

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Carbon reserves or non-structural carbohydrates (NSC) are resources accumulated under mobilizable forms to sustain plant growth and development. Perennial plants accumulate NSC during periods of excess production of photo assimilates and use then when demand exceeds production. This characteristic is well documented for temperate forest and fruit-bearing species, although little information is available for tropical perennial species (Mialet-Serra et al, 2008) like palms.

Coconut and oil palms are arborescent, monocotyledonous species with indeterminate growth, producing fruits with high caloric contents (from 70% to 80% of lipids in a mature kernel or mesocarp), continuously over several decades. Source-sink imbalances occur in coconut and oil palms as environment factors affecting reproductive sinks and carbon assimilation rate are not the same and act with different time lags, requiring transitory compensation through carbon storage and mobilization (Mialet-Serra et al., 2008; Legros et al., 2009). Harvest index (fruit dry matter : total dry matter yield ratio), equal to 0.32 and 0.37 (Mialet-Serra, unpublished data), respectively for coconut and oil palms, indicates that oil palm is a more efficient crop than coconut.

The objectives of this study were (i) to characterize the chemical nature, location and amount of carbohydrate reserves in adult coconut and oil palms and (ii) to determine the role of the carbon pool in different situations affecting source-sink relationships.

Materials and Methods

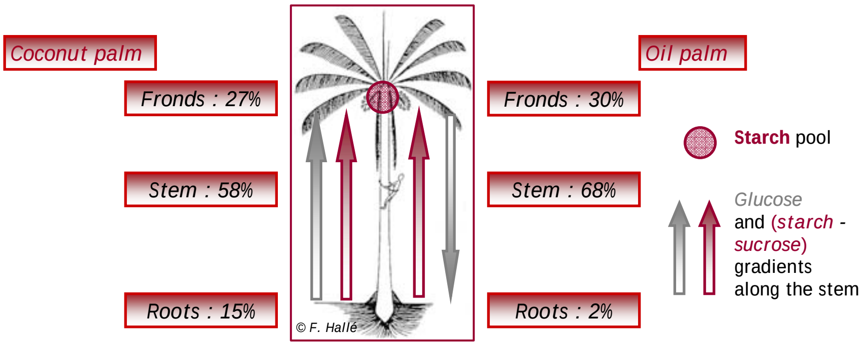
The study was implemented in two experimental plantations, for coconut palm, from the Agriculture Research and Training Centre located in Espiritu Santo island (Vanuatu, South Pacific) and, for oil palm, from the SMART Research Institute (SMARTRI, SMART Tbk.) located in Kandista Estate (Sumatra Island, Indonesia), both climatically favorable sites. the plant materials originated from two high-yielding genotypes obtained, for coconut palm, from the Vanuatu Red Dwarf (VRD) × the improved Vanuatu Tall (VTT) cross; for oil palm, from a *dura* Deli × AVROS *pisifera* cross. Coconut palms were 19 years old on the onset of the study, oil palms, 12 years old.

Firstly, without any initial hypothesis on the localization of reserves, a wide and systematic sampling strategy was applied. Samples were taken in the morning (i) from the stem: at the top (sub-apical area), at mid-height, at the base (20 cm from the ground) and in the stump (ii) from leaves of different ranks from petiole, rachis and leaflets, (iii) from large, medium and thin roots and (iv) from the remaining leaf bases for oil palm.

Secondly, the time course of carbon reserves based on sampling of the principal storage compartments (e.g. stem and petiole) were compared to the time courses of structural aboveground vegetative growth, reproductive growth and yield variations over several consecutive seasons.

Results

① Composition and Location – Soluble sugars were the dominant sugars in all tissues of both palms, mainly **sucrose** for coconut palm (81%) and mainly **glucose** for oil palm (53%). However, in oil palm, sucrose and starch (20% each) may be found locally at non negligible concentrations. Stem was the major storage organ.



③ Amounts – In coconut, NSC represents *ca* 8% of total vegetative dry matter (± 32 kg $plant^{-1}$; Mialet-Serra et al., 2005), in oil palm *ca* 20% of total vegetative dry matter (± 141 kg $plant^{-1}$; Legros et al., 2006). These large carbon pools were theoretically sufficient to sustain full growth for 1 month and for 5 months in the absence of newly synthesized assimilates, for coconut and oil palms respectively or to sustain copra or fruit production for the equivalent of 8 months in both cases.

④ Time courses

- Vegetative growth rate – Dry matter growth rates, equal to 90 and 145 kg $plant^{-1}$ $year^{-1}$ for coconut and oil palms respectively, did not differ among seasons in our study conditions.

- Reproductive growth rate – For coconut palm, fruit dry biomass per harvested bunch, mainly due to fruit number per bunch, were higher (about twice as high) during the wet season; the reverse was observed for oil palm.

- Reserves – In favourable conditions, total NSC pool, in particular in the stem of both species did not differ significantly among seasons. However, for oil palm, soluble:total sugars ratio in stem increased significantly from 0.68 to 0.74 during high yield season (e.g. dry season). For coconut palm, our results were close, with higher sucrose pools in leaves during high yield period (e.g. wet season). Even if reserve variation was weak in both species among seasons, mobilization was more frequent and widest in stem for oil palm, in particular at the stem top, topologically closed to major sinks (fruits and expanding leaves) and the single apical meristem and instead in leaf petioles closed to the main sinks (fruits) and source (leaves) for coconut palm.

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Discussion - Conclusions

① About biochemical composition and location

Storage in the form of soluble sugars as labile forms may be well adapted to the overall functioning of both palms e.g. continuous growth, many sinks and extended development with strong energy needs. It is common to find plants that store mainly sucrose in vegetative tissues. However it is quite rare for glucose, a very labile molecule, generally located near sites of high metabolic activity (Mialet-Serra et al., 2005). Oil palm seems to be an exception.

In contrast to the majority of higher plants, both palms do not use starch as a major form of carbohydrate storage at whole plant scale but likely for local use.

Unlike dicotyledonous trees, the roots of both palms store only very little NSC; vegetative aboveground organs in particular the massive stem with high concentration throughout have to assume this function.

Reserve distribution in both palms showed identical topological gradients except for glucose probably due to its own function in each system.

② About physiological function

Under our favorable conditions, total NSC pools may thus simply reflect the over-abundance of assimilates but, in the case of severe situations, have a vital function, proved in particular for oil palm in situations of water constraints in a drought-prone site (data not shown).

Starch variations were largely explained by source-sink relationship in terms of vegetative growth and demand for fruit filling, indicating a role for starch as a buffer, in particular for oil palm. In this case, its function is vital because seasonal peaks of fruiting are not associated with periods favorable for high photosynthesis (drought).

The physiological function and adaptive value of the large sucrose pool in coconut palm remain unknown. The role of the substantial glucose pool in oil palm stem might be driven by environmental conditions (drought) and might not act primarily as a carbohydrate reserve. These points require more research work.

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Non-structural carbohydrate pools in vegetative organs of two cultivated tropical palm species: the oil palm and the coconut palm

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Abstract

Coconut and oil palms are perennial tropical monocotyledonous species that continuously produce fruits with high caloric demand and were marked by long development cycles of individual phytomers. Little is known about the physiological function of non-structural carbohydrate (NSC) reserves in these types of plants. The underlying hypothesis was that reserve storage and mobilisation enable the crops to adjust variable sink-source relationships at the scale of the whole plant. This study describes *firstly*, the chemical composition, amounts and distribution of NSC in both palms, *secondly*, storage adjustments to resulting source-sink imbalances in response to seasonal climatic variability or to fruit or leaf pruning. Our experiments were carried out on a 19-year-old coconut plantation on Vanuatu Island in the South Pacific and on a nine-year-old oil palm plantation in central Sumatra in Indonesia. Twelve palms for each species were felled and stem, leaf and root tissues were sampled to characterize dry matter and concentrations of soluble sugars and starch. The aggregate NSC pool size was compared with estimates of demands for assimilates for growth and fruit production. Coconut palms contained a large amount of sucrose and little starch; oil palms a large amount of glucose, followed by starch and sucrose. In both cases, reserves were mainly located in the stem and then in the leaf crown. No clear seasonal variations were observed during our experiments, except in coconut leaves and roots. Whereas the pruning treatments had little effect on carbohydrate reserves in coconut, affecting only petioles, not the main reserve pool in the stem, in oil palm, source-sink imbalances caused by treatments were buffered by significant fluctuations in NSC reserves in the stem. In conclusion, non-structural carbohydrate storage in oil palm was a major adjustment process, not for coconut in our study conditions.

Key Words: *Cocos nucifera* L.; *Elaeis guineensis* Jacq.; dry matter partitioning; carbon storage; source-sink relationships; yield.