Variations of carbon content among oil palm organs in North Sumatra conditions. Implication for carbon stock estimation at plantation scale

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INTRODUCTION

Nowadays many estimations of the carbon stock are done for oil palm plantations mainly due to the controversial position of this crop towards international environmental concern. The estimation of the carbon stock at the tree scale (or plantation scale) is very related to an important parameter : the exact carbon content of the biomass. Most of the time values between 40 to 45 % are used for oil palm (Lamade et al, 1996; Lamade et Bouillet 2005). Concerning the direct measurement of the carbon content of oil palm biomass, few data seems to be available. It is the reason why we decide to publish the second part of our results obtained in North Sumatra during ^{13}C content exploration in oil palm biomass (Lamade et al., 2009). There is also carbon content variation within organs. This carbon content is depending of the development stage (age) and upon metabolic components. Lignin and cellulose content makes this rate contrasted within species.

MATERIALS AND METHODS

Genetic material and environment

Biomass samples was done between 2003 and 2004 in North Sumatra (Aek Pancur Research Station from the Indonesian Oil Palm Research Institute – 3°30'N, 98°48' E; 25 m above sea level) on ten oil palm trees selected in a genetic trial planted in 1995 belonging to the clonal material : *Dura x Pisifera - Deli x La Mé* type - MK60 : LM007T x DA 128 D. Leaves, trunks, roots, bunches components, buds were sampled as well. The leaves were sampled from rank -6 to rank 57. For the trunks, sampling were done at 3 different levels (i) at the base (ii) at the middle part considering the height (iii) at the upper part. Additional samplings were done in the meristem zone and in the terminal bud. For the bunches: sampling were done on fruits every month since the pollination. Spikelets and stalls were sampled too (at least one bunch per tree). Roots were also investigated by category (I,II,III+IV). All samples were all disinfected by ozone, put into liquid nitrogen then dried directly during at minimum 2 days just below 80°C.

Carbon analysis

The carbon composition of bulk organic matter of the leaves (rachis, petioles, leaflets), the trunk (up, middle, base, meristem and terminal bud), the bunches (fruits, spikelets, stalls) and the roots (I,II,III+IV) was determined with an NA-1500 elemental analyser (Carlo-Erba, Milan, Italy) coupled to an isotope ratio mass spectrometer (VG Optima, Micromass, Villeurbanne, France). The carbon content is given in % of MS as the same time with the $\delta^{13}C$*. A total of 920 analyses were done in IBP Plateforme Métabolisme-Métabolome www.pmm.u-psud.fr (France).

The "source" organs : the leaves

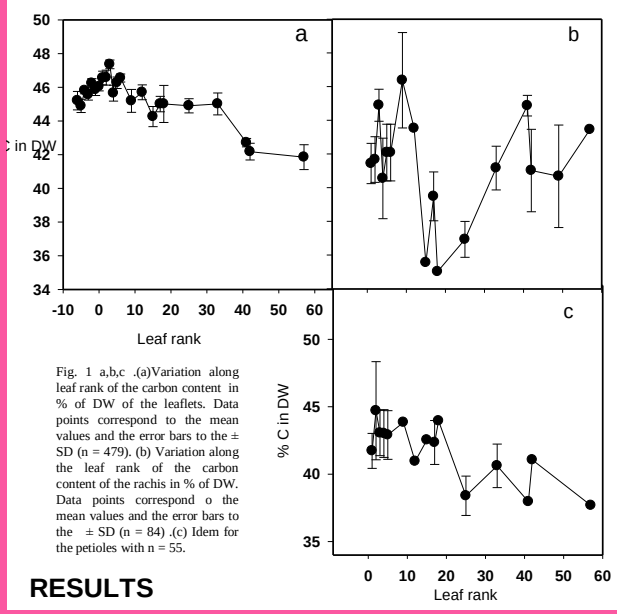

Fig. 1 a,b,c .(a)Variation along leaf rank of the carbon content in % of DW of the leaflets. Data points correspond to the mean values and the error bars to the ± SD (n = 479). (b) Variation along the leaf rank of the carbon content of the rachis in % of DW. Data points correspond o the mean values and the error bars to the ± SD (n = 84) .(c) Idem for the petioles with n = 55.

RESULTS

For the leaflets, an increase is observed from the very young leaves, still at the heterotrophic stage as spear leaf, to the leaflets belonging to the rank 3 (Fig. 1a) which showed a maximum value (47% DW ± 0.2, n = 20). After rank 3, the carbon content is around 45 % DW until the leaf rank 33. After the rank 33, there is a very clear decrease of the carbon content until the leaf rank 57 (41.8 % ± 0.7, n = 7). The total average over all ranks is 45.2 % ± 0.03 (n = 479).

For the rachis, very variable trends are observed (Fig. 1b). Then it is difficult to give an interpretation of what was found. The carbon content of the rachis is in average (41.2 % ± 0.22, n = 84) lower than for the leaflets with a minimum around rank 15 (35% DW) and a maximum at rank 9 (46% DW). For the petioles (Fig.1c), a decrease was observed from the youngest leaves (rank 5) with a value around 43 % DW and the oldest one (rank 57) with a value around 37% DW. The average values for the carbon content in petioles was measured at 41.8 %± 0.3 (n= 55).

The "sink" organs : the trunks, the roots, the bunches

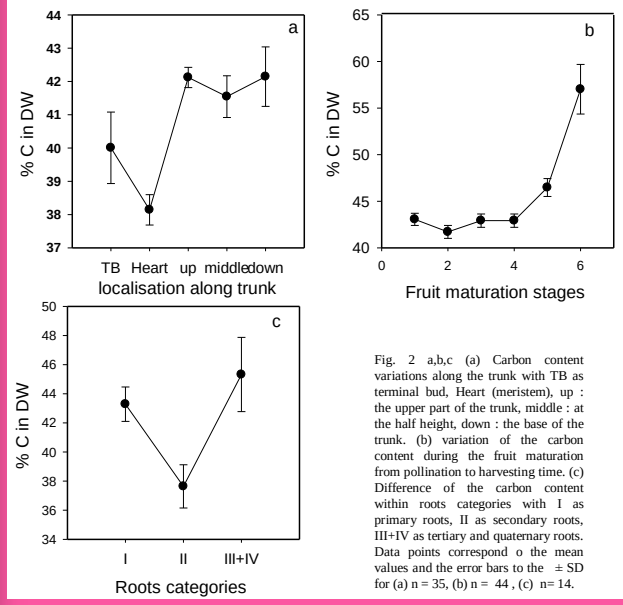

Fig. 2 a,b,c (a) Carbon content variations along the trunk with TB as terminal bud, Heart (meristem), up : the upper part of the trunk, middle : at the half height, down : the base of the trunk. (b) variation of the carbon content during the fruit maturation from pollination to harvesting time. (c) Difference of the carbon content within roots categories with I as primary roots, II as secondary roots, III+IV as tertiary and quaternary roots. Data points correspond o the mean values and the error bars to the ± SD for (a) n = 35, (b) n = 44 , (c) n= 14.

For the carbon content, no difference was observed along the trunks (Fig. 2a) from the upper part (42.12% DW± 0.3, n=11), the middle (41.54% DW ± 0.6 n = 10) and the base (42.14 DW ± 0.8 n = 6). It is interesting to notice that heterotrophic tissues present always a lower carbon content that the full active photosynthetically one (see leaflets at 45 %) : the meristem zone showed lowest carbon content with a mean value of 38.14% DW ± 0.8 (n = 3). Concerning the roots, the variations observed were related to their category and functions. The secondary roots (Fig. 2c), which are responsible for the expansion of the root system, with a short turn-over, showed a lowest content than both others categories (I, and III+IV) with a mean value of 37.6 % DW ± 1.5 (n = 5). Primary and absorbent roots did not presented any significant difference with a mean value equal to 43.28 ± 1.2 (n = 4) for the roots I and 45.32 ± 2.5 (n = 5) for the roots III+IV (Fig. 2c). An interesting feature was found for the fruits during their maturation (Fig. 2b). During the 4 first stages (4 months) the carbon content of young fruits (at this stage full of soluble sugars and starch) presented an average of 42.6 % DW, then during the last month, corresponding to the oleosynthesis process, a significant increase was observed with a value equal to 46.47 % DW ± 0.9 until 57.02 % DW ± 2.7 (n = 9).

Estimation of carbon stock for two different genetic materials

organs	D x L (biomass)	D x Y (biomass)	D x L (carbon)	D x Y (carbon)
Leaflets (t.ha^{-1})	6.25	10.69	2.83	4.83
Rachis (t.ha^{-1})	10.93	20.14	4.50	8.30
Petioles (t.ha^{-1})	8.31	13.6	3.48	5.69
Trunks (t.ha^{-1})	21.23	39.3	8.66	16.03
Roots I (t.ha^{-1})	5.71	4.11	2.47	1.77
Roots II (t.ha^{-1})	3.88	3.73	1.46	1.4
Roots III+IV (t.ha^{-1})	4.53	1.84	2.05	0.83
(FFB)	(24.02)	(16.8)	(4.55)	(2.34)
Total t.ha^{-1}			**25.45**	**38.87**

To give a new estimation of the carbon stock from our previous one (Lamade and Bouillet 2005), the same measurements of the standing biomass (Lamade et al. 1998) is used again because there were very near of the material sampled for carbon analysis. These measurements were done on two genetic material (*La Mé* x *Deli* : DA18D self x LM7T self and *La Mé x Yangambi* : BJ 3 D self x BJ 21 P). Vegetative and reproductive characteristics are shown on Table 1. If we applied the new rate – 41.8 % DW – which is the result of a mean ponderation upon all the organs biomass to evaluate new carbon stock at the plantation scale (Table 1) we obtained 25.4 t C ha^{-1} for Deli x *La Mé* material (when bunches are removed) and 38.9 t C ha^{-1} for *Deli x Yangambi* . The difference with the former estimations (D x L : 27.1 t C ha^{-1}; D x Y : 41. 1 t C ha^{-1} in Lamade and Bouillet 2005) is around 2 t C ha^{-1}.

CONCLUSION

The exact evaluation of the carbon stock at plantation for oil palm is well done with firstly the measurement of the carbon content of the oil palm tissues composing all the standing biomass. For our estimations in 2005 we did not have such analyses. The difference is around 2 t C ha-1. It is not that much but if this new rate is apply upon 1000 ha, the implication is an error of 2000 t C already. Then our conclusion is that precise direct field studies with organs samplings and carbon analysis on different oil palm tissues are more than necessary also because genetic and ecology will change this rate as well as planting ages.