*Research Article*

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# A method for non-destructive estimation of dry weight of coconut stem

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## Abstract

In order to obtain the information on density gradation along vertical axis in coconut stem and for developing a non-destructive method of estimation of stem dry matter in a standing coconut palm, five palms were sampled destructively and data were recorded on stem segments on parameters such as fresh weight, diameter and girth at both the ends and dry weight. From all above data density gradation in stem on vertical axis was calculated and also a statistical model was developed for estimation of stem dry matter in a standing coconut palm. Results indicate that the stem dry weight was about 87 to 103 kg in COD palms of approximately 32 years age. Density of stem varied from 0.32 $g.cm^{-3}$ just below canopy to about 0.8 $g.cm^{-3}$ at the base with a mean density of 0.517 $g.cm^{-3}$ with a gradual decrease from base to top. Density gradation varied from 0.04 to 0.08 $g.cm^{-3}$ along the vertical axis of stem. Using the parameters such as girth, length of stem and density of stem, the equation developed is: Stem dry weight (kg) = Length (in meters) *girth$^2$ (in meters, at 1.5 m above ground level)*41.14142. The validation results indicated a significant $R^2$ value of 0.8982. Thus, it can be concluded that the coconut stem has a vertical density gradation with bottom being denser than the top. The equation presented in this paper is quite useful for non-destructive estimation of stem dry matter in a standing coconut palm.

*Keywords:* Coconut stem, density, dry matter estimation, non-destructive method, wood

## Introduction

Coconut palms are monopodial with cylindrical stem. Structure of stem is typical of woody monocotyledons plants, with vascular bundles scattered in the ground tissue and lack of secondary growth. The stem starts visible from about three years of field planting as it is masked by the leaf petioles earlier. Considerable amount of dry matter partitions into stem, for its growth, before flowering. Even after flowering, the amount of dry matter partitioned into stem is significant. Generally in yielding adult palms accumulation of dry matter in stem is taking place at a rate of about 3.8 $kg.palm^{-1}.year^{-1}$ in LCT x GBGD to 7.3 $kg.palm^{-1}.year^{-1}$ in LCT (Kasturi Bai and John George, 2002). Earlier studies have indicated that coconut stem accumulates considerable amounts of nonstructural carbohydrate reserves (Mialet-Serra *et al.*, 2005) and the specific gravity in the center of stem was roughly one-third that at the periphery (Huang *et al.*, 2002), on horizontal axis. However, there is the lack of information on density gradation in stem on vertical axis. Even though, there exists a method for non-destructive estimation of annual dry matter accumulation into stem (Ramadasan and Jacob Mathew, 1987), there is no method as yet to estimate the dry weight of stem of standing coconut palm.

The removal of old palms leave a large number of coconut stems, which can be used for making several value added products. Information on density gradation in coconut stem will be useful for exploiting coconut stems for development of value added products. Further, estimation of total dry matter accumulated into stem of a standing coconut palm is gaining importance in view of the possibility of exploiting coconut plantations as carbon sequesters under the umbrella of Clean Development

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Mechanism of UNFCCC (Naresh Kumar, 2007). This sort of information will be important for estimation of carbon stocks in stem. Apart from this, estimation of dry matter accumulation into stem on long term basis is important for investigations probing physiological efficiency of palms for dry matter partitioning. There is no method that exists for non-destructive estimation of total stem dry matter in a standing coconut palm. Therefore, in this paper, we describe the method for non-destructive estimation of stem dry matter in a standing coconut palm and also the density gradation along vertical axis in stem.

## Materials and Methods

For developing a non-destructive method of estimation of stem dry matter in a standing coconut palm, five coconut palms of COD, grown at CPCRI research farm were sampled destructively. Palms were of about 32 years of age. They were up-rooted and stem was cut into one meter logs. Thus, from six palms a total of 39 stem segments were made and data were recorded on parameters such as fresh weight, diameter and girth at both the ends. From each stem segment, one circular disc of about 15 cm length was cut from each end, thus 68 discs were obtained. On these discs also data on above mentioned parameters were recorded. All the segments were numbered indicating their position in the stem. Thereafter, these small segments were put for oven drying at about 110 °C for 3 hrs and at 80 °C for 48 hrs. Drying was done till consistent dry weights could be recorded. Large segments were put for sun drying. Using the data obtained from small stem segments dry weights were calculated for large segments and thus for whole stem. Subsequently, weights of dried large segments also were recorded. Using all the above data, dry weights of whole stem was obtained. Apart from these, density of each segment was calculated by dividing the dry weight of segment with the volume of segment. Variation in density along the vertical axis was obtained by calculating the difference in density of successive stem segments. Sum of variations in density along the vertical axis indicates the difference in density from base to top. From all above data statistical model was developed for estimation of stem dry matter.

### Validation of method

The statistical model was validated using data on 40 dried coconut stem logs from different sources. These logs were from tall cultivars, hybrids and dwarf cultivars. Logs were fully dried and their dry weights were recorded apart from parameters such as length and girth of log. Dry weights of these logs were estimated using the equation. Recorded and estimated dry weights were scatter plotted for obtaining the $R^2$ value. Chi square test was also performed to test the goodness of fit of the model at 5% level of significance.

## Results and Discussion

The biometric data on stems of five palms, which were destructively sampled, indicate that palms varied in height from 585 cm to 675 cm (Table 1). Mean girth of palms also varied from 58 cm to 65 cm. Dry weight of stem varied from 87.7 kg to 103.9 kg in about 32 years of growth. This gives about an average annual accumulation of 3 kg dry matter per stem in each palm.

**Table 1. Biometrical parameters of stems sampled from five COD palms**

| Parameter | Palm 1 | Palm2 | Palm 3 | Palm 4 | Palm 5 |
|---|---|---|---|---|---|
| Length (cm) | 585 | 660 | 678 | 638 | 621 |
| Mean girth (cm) | 60 | 61.13 | 60.13 | 58.25 | 65 |
| Stem dry weight | | | | | |
| *Observed* | 93.13 | 103.2 | 103.9 | 87.7 | 92.07 |
| *Estimated** | 86.64 | 101.47 | 100.85 | 89.06 | 91.02 |
| Chi test | 0.96 | | | | |

**Estimated dry weight is derived using the formula developed, which is presented in this paper.*

Results indicate that the density of stem varied from 0.32 g.cm$^{-3}$ just below the canopy to about 0.8 g.cm$^{-3}$ at the base (Fig. 1) with a mean density of 0.517 g.cm$^{-3}$. This indicates that the density of stem is higher at

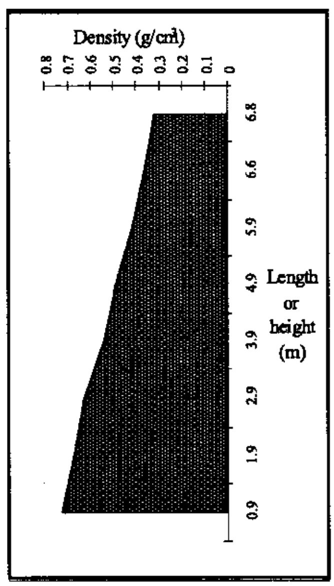


**Fig. 1. Density gradation along vertical axis in coconut stem (Y axis-height of stem)**

the base and gradually declines towards top. Variation in density from base to top was to the tune of around 0. 42 g.cm$^{-3}$ (Fig. 2). It can be inferred from the results that dry matter is translocated into stem not only to the growing

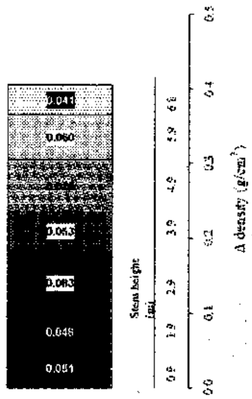

**Fig. 2. Difference in density along the vertical axis of coconut stem at one meter interval (Ä density on Y1 axis is a cumulative value; values on bars indicate difference in density from just below segment).**

segment but also to the lower parts of stem, thus increasing stem density at the base as well. This inference opens a possibility that the annual dry matter production can be higher than estimated. Carbohydrate reserves of coconut tree are mainly stored in the stem in soluble form, largely in sucrose form, whereas, the root system seems to have no storage function (Mialet-Serra *et al.*, 2005). It is possible that the carbohydrate reserves which are not used for production of nuts are translocated and stored in stem for future use, particularly in stress conditions. However, in pruning experiment it was concluded that coconut showed little phenotypic plasticity and the stem reserves are not influenced by the pruning (Mialet-Serra *et al.*, 2008). This indicates a possibility of translocation of photosynthates to stem base in irreversible manner. Apart from this, increased lignification of cell walls of fiber and ground tissue as the tree ages may also influence the strength of the trunk (Rich, 1987; Fisher *et al.*, 1996). Specific gravity in the center of stem is about one-third that of periphery (Huang *et al.*, 2002). Present study indicates that there exists a variation in density along vertical axis of stem as well. Density gradation varied from 0.04 to 0.08 g.cm$^{-3}$ along the vertical axis of stem. Higher density of stem in the lower portion indicates a higher strength of wood as strength of wood increases with increasing specific gravity (Kollmann and Cote, 1968).

Using the parameters such as girth, length of stem and density of stem, the equation developed is

Stem dry weight (Kg) = Length (in meters) *girth$^2$ (in meters at 1.5 m above ground level)*41.14142

Where length is the height of stem from ground level to base of the canopy and girth is the mean girth of stem at 1.5 m height from base.

Once dry matter is estimated, the density of stem can be estimated using the formula

Density (g/ cm$^3$) = Dry weight of stem (g) / volume of stem (cm$^3$)

Where, volume can be estimated by measuring the height/length of the stem upto the base of the canopy and girth of the stem at 1.5 m$^2$ above the ground level using the formula

Stem volume (cm$^3$)= Length (in cm) * girth$^2$ (in cm at 1.5 m above ground level) *0.08.

The validation results indicated a good $R^2$ of 0.8982 (Fig. 3).

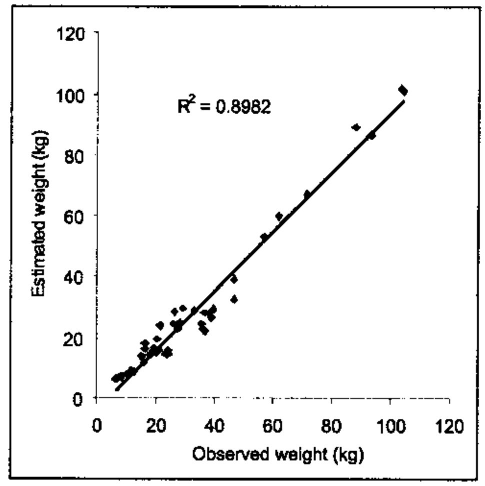


**Fig. 3. Validation of model for non-destructive estimation of stem dry matter in a standing coconut palm.**

This could have been more had the logs were of full length. Majority of the stem logs used for validation were from lower portion of the stem and the density of these logs was higher (Table 2) thus making higher observed values compared to the estimated values, thus bringing down the $R^2$. However, the above method is developed for estimating the stem dry matter in a standing coconut palm for the purposes mentioned earlier.

**Table 2. The frequency distribution of coconut stem logs, used for model validation, at different densities**

| Density (g.cm$^{-3}$) | Frequency distribution of stem logs |
|---|---|
| <0.5 | 3 |
| 0.5-0.6 | 16 |
| 0.61-0.7 | 8 |
| 0.71-0.8 | 5 |
| >0.81 | 8 |

From the above, it can be concluded that the coconut stem has a vertical density gradation with bottom being denser than the top. The equation presented in this paper is quite useful for non-destructive estimation of stem dry matter in a standing coconut palm.

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