American-Eurasian J. Agric. & Environ. Sci., 16 (2): 424-431, 2016
ISSN 1818-6769

DOI: 10.5829/idosi.aejaes.2016.16.2.12877

Modeling Vegetative and Reproductive Architecture of Date Palm (*Phoenix dactylifera* L.) The Case of Two Algerian Cultivars 'Deglet Nour' and 'Litima'

[1]Khaled Atallaoui, [2]Radhouane BenMehaia, [3]Ahmed Simozrag, [4]René Lecoustre and [4]Hervé Rey

[1]Master 2, Faculty of Natural Sciences and Life, University of Djelfa, Algeria
[2]Faculty of Natural Sciences and Life, M'sila University, Algeria
[3]Faculty of Natural Sciences and Life, Biskra University, Algeria
[4]UMR AMAP CIRAD-BIOS, Boulevard De la Lironde TA A51 / PS2-34398 Montpellier Cedex 5, France

Abstract: The study focuses on an architectural description of two Algerian cultivars of *Phoenix dactylifera* L. The observations were conducted at the Wilaya of Biskra on Deglet Nour and Litima's palms. The MOCAF/OMAM application protocol based on metric and geometric parameters of the vegetative part and reproductive part., in particular by its aspects morphometric allow realistic 3D simulation mockups. The architectural analysis of the cultivars showed a wide angle of insertion for Litima's cultivar palms, this character is well expressed on the 3D mockup. As for the reproductive aspect, it was found a special character for Deglet Nour cultivar, which was clearly seen in a very long spikelet, as well as a long sterile portion. This has given us a simulation of the reproductive organ very close to reality.

Key words: Date palm · *Phoenix dactylifera* L. · Architecture · Simulation · Algeria

INTRODUCTION

The date palm, *Phoenix dactylifera* L. (*Arecaceae*) is a subtropical palm formerly domesticated [1]. It is widely cultivated for its multiple uses and ecosystem services, especially for its edible fruit with thousands of varieties that have been selected [2] and for its ability to adapt to the conditions of the most severe arid climates [3]. Its presence creates a microclimate enabling the development of various forms of life necessary for animals and plants and the maintenance and the survival in desert populations [4].

According to recent studies, in simulation [5] and then modeling of Memadji-le-Allah *et al.* [6] and Gammoudi *et al.* [7] on the vegetative part of the date palm we are proposing the implementation of the architecture Simulation of two Algerian cultivars. It was done thanks to the application of a measure protocol established and validated by the MOCAF and OMAM network partners regarding aerial vegetative and reproductive architecture palms grown in Biskra (Algeria).

For this, on the aforementioned parts of identified plants, regarding the phyllotactic organization and morphometric measurements of the palm, the metric and geometric measures of inflorescence axis are also collected.

The simulator AMAPsim could produce sufficiently precise 3D models to be used in different areas where obtaining a precise architecture is required [8].

It is now replaced by a simulative structural model for palms, PRINCIPES, interfaced through XPLO software of AMAPstudio suite [9]. The objective of this study is to collect the morphometric and geometrical data for two date palm cultivars, which are used for virtual reconstruction of these two varieties and subsequently contributes to enrich the database with these Algerians cultivars.

MATERIALS AND METHODS

Plant Material: Studied plant material is composed of two cultivars: 'Deglet Nour' and 'Litima'. Both cultivars grown

Corresponding Author: Khaled Atallaoui, Master 2, Faculty of Natural Sciences and Life, University of Djelfa, Algeria.

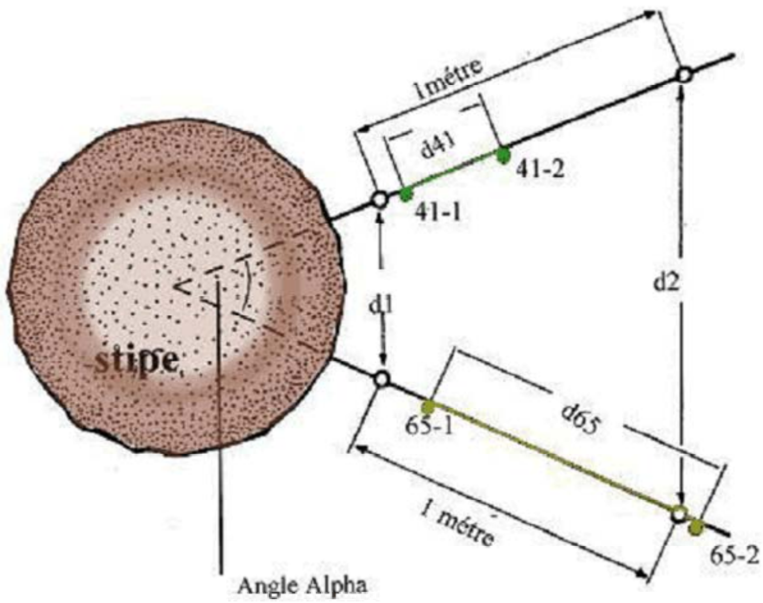

Fig. 1: Angle of phyllotaxy measurement [10]

under similare cological conditions and received the same farming services. Our selection of the tree is based on accessibility (essentially the date palm height) to facilitate the work and avoid any kind of inconvenience (nacelle) to reach the heart of the crown.

For each tree, the essential observations and measures are carried for modeling there for focuses on the vegetative system (phyllotaxy, number and morphological structure of the fronds, morphology and geometry of pinnae) and also on the reproductive system (geometrical and metric measurements of stalk).

The measurements were performed in two steps:

- The vegetative part measures have been made in May 2014.
- The reproductive part measures have been taken in August2014.

The measurements were performed on two pairs of fronds per sampled plant.

The Vegetative Part: The angle of phyllotaxy is formed by two consecutively sprouted fronds. The frond rank numbering starts from the first frond upon the top (frond1) to the oldest along the 8 phyllotactic order parastiche one. The angle is measured between two fronds of an order 8 parastiche, for instance fronds 54 and 62 of 'Deglet Nour'.

A metal rod of one meter length is placed on the first level at point C (position of the first pinnae) of each of these fronds and allows the plumb line to dangle down based on these levels; the markers are then placed on the earth at the points indicated by the plumb line contact. Metal rods of one meter length are aligned with stakes and fixed to the ground by passing a peg in each ring and then the distance between the projections of two fronds d1 and d2 are measured through these rings (Fig. 1). This distance is used to calculate the angle alpha.

The angle of phyllotaxy, phi, is calculated based on alpha.

$\Phi = 135 + \alpha / (62\text{-}54)$ with
$\alpha = 2 * \text{arc sin} \{(D2\text{-}D1) / 2\}$

135 is the theoretical angle of phyllotaxy for a 3/8 phyllotactic organization, which means that in a first approximation, it takes 8 palms to rotate 3 times around the stem and ends up substantially in vertical alignment with the first frond [4].

The number of present stumps along the stem is estimated by counting those of one order 8 parastiche. The total number of petiole bases is obtained by multiplying by eight the number of recorded stumps on one order 8 parastiche. The number of stumps at 20, 50, 100 cm off ground is also recorded. This will allow us to calculate the evolution of the length of the internodes during growth.

All these parameters are described to understand the general characteristics of the plant studied. The bulk of the proposed work concerns the date palm and geometric structure. To restore flexion and rotation of the frond:

- We took photography of the bending and rotation of the frond to the end with a vertical note provided by the plumb line at the end of a pole.
- The direction of horizontal deflection is marked at point A and then photographed on the laying position on the floor and head to the stem.
- Locating the culmination of the rachis using a pole with a plumb line, then a photograph or a note attached to an extremity.

The angle measurements are made in the laboratory using Mesurim software.

In some date palms, the culmination of the rachis point is located at the end of the rachis, so the bending angle at the end and the angle at the highest point are identical.

Measures on Frond after Cutting: In total two pairs of fronds in the same order 8parasticheare cut for measurements: The frond rank 67 and 75 for ‘Litima’ cultivar and palm rank 54 and 62 for ‘Deglet Nour’ cultivar.

Description of the Shape of Rachis (Length, Width and Height): Before cutting the frond, the angle of insertion and the angle at point C are measured using a protractor and a plumb line. These measures will also help to restore the bending of the palm. The frond is cut between 20 to 30 cm before point C.

Length of Frond: Measurement of the Nerve Total Length (estimated remaining part from the stem + the cut off part) = NTL and of the Nerve Pinnate Length (from point “C” to point “A”) = NPL

Dimensions of the Frond (Width and Height) of the Insertion End: The measurement is made every 50 cm using a caliper in a group level in each section to the fronds of rank 54, 62 (‘Deglet Nour’) and 67, 75 (‘Litima’).

Description of the Simplified Form of Limb (Length and Width of the Leaflets): The measurements are performed on all these pinnae of each half-palm.

Length of Pinnae: The measurement is performed using a ruler or meter if the leaflets are very long while marking the positions 1/3 and 2/3 for measuring apertures and widths.

Apertures of Pinnae at 1/3 and 2/3of Their Lengths: Using a caliper, apertures of third 1 and third 2 are measured

Inserting Half-Width 1/3 and 2/3: The measurement of the half-width at the insertion is carried out using a caliper and the half width in the third 1 and 2 of a graduated ruler or meter.

Description of the Geometry of Pinnae along the Rachis: The measurements of the pinnae insertion angles are performed on photographic projections. The sections of the palm cut every 50cm for each of the two palm cultivars with groups of 3 or more pinnae are photographed and measurements are performed using image software.

From the pictures taken in technical premise or laboratory (Mesurim software):

- Measurements of the axial angles of the pinnae on the nerve
- Measurements of the radial angles of the pinnae on the nerve
- Rotation angle measurement.

For angles of rotation, measurements are made on insertion scars after removing the leaflets.

The Reproductive Part: According to Zango [11] and Atallaoui *et al.* [12] the metric measurements on the reproductive part are based on the length, width and height of the peduncle, length and diameter of spikelets and fruits at several checkpoints.

The geometric measurements are based on the lateral deviation, flexion and rotation around the stem, rachis and spikelets, the angle of insertion (peduncle and spikelet), the angle of divergence between spikelets, as well as pseudo-verticille and spikelet angles of phyllotaxy, in addition to measuring the angle of fruit on spikelets.

Simulation: The palm architecture simulation is done through XPLO software, which integrated a specific extension palm model (PRINCIPES).

The object is the morphometric knowledge to compare the architectural parameters of the virtual simulated palms with the real date palm observed in the field to see if the result is satisfactory.

RESULTS AND DISCUSSION

Phyllotactic Angle: The angle of phyllotaxy values of both cultivars ('Deglet Nour' and 'Litima') are respectively 137.88° and 138.21°. These results are close to the results obtained previously in Morocco by Elhoumaizi *et al.* [10]. This suggests that the angle of phyllotaxy value is an intrinsic character in the specie *Phoenix dactylifera* L. and which slightly varies depending on the cultivar. This parameter defines the palms layout against each other.

The results regarding phyllotaxy and leaflet group homogeneity are in part similar to those obtained by Elhoumaizi [4], on other date palms varieties grown in Morocco. This arrangement of the leaflets on the rachis appears to be similar regardless of the varieties of the species of these two grown palm trees. Therefore, these parameters can be considered as intrinsic characteristics.

Morphometrical Analysis: The analysis of these two palm cultivars has allowed us to demonstrate the relationship between some parameter characteristics on the palm and the stalk.

Dimension of Rachis: It should be noted that the measurements were taken every 10% of the actual metric position (the total length) and are represented in relative position in all histograms that follow.

The first scatter plot graphs show the width and the height of the rachis.

It is observed that the normalized width and standard height of the rachis depend on the relative length position

Length of Pinnae: The next scatter plot graphs show the lengths of pinnae. It was observed for both cultivars a change in the length of pinnae along the rachis. The transition zone spine-pinnae are marked by a sudden change of length. For 'Deglet Nour' the maximum length of pinnae (71.7 cm) is observed in absolute position 373 cm (about 50% of the limb length), then this length gradually decreases to the terminal pinnae. Also in 'Litima', the maximum length of pinnae (81.6 cm) is observed in the absolute position 213 cm (about 40% of the limb length). Moreover, one notices a strong similarity between the lengths of pinnae on the two sides of the frond.

Regarding the length of the pinnae, it seems that the pinnae field in antrorse position is shorter than those in introrse or retrorse positions but the graph shows a generally progressive length, it does not show a significant difference between the length of the pinnae from their position, printing is probably related to the fact that we are in the phase of rapid increase in length and antrorse pinnae is always the first one in a pinnae group.

Aperture of Pinnae: The following scatter plot graphs show the pinnae aperture. This graph shows the pinnae aperture having ordinate points and there is symmetry between the respective apertures of third 1 and third 2.

These pinnae apertures are important in the first third. This result is similar to the first result when measuring the length of pinnae.

The pinnae aperture is greater at the second third but in some cases, due to the leaflets tendency to dry out toward the end and also to close slightly.

In 'Litima', we observe a huge aperture in the second third due to the large leaflets' half-width and this opening may be related to the effect of wind

Width of Pinnae: The following scatter plot graphs showing the width of pinnae. Pinnaes are wider in the second third of 'Litima' cultivar, this width is (1.7 cm) and we observe a similarity of width in the first third and the third third.

'Deglet Nour' leaflets are wider in the second third; this width is (1, 3cm).

The Figures show the relationship between the three thirds of the leaflets and the second third being the largest area in both cultivars.

Analysis of the Pinnae Insertion Geometry: The following scatter plot graphs present pinnae insertion angles. This is the relative angle to the longitudinal axis of the relative position on the rachis.

A priori, observing a palm, it seems that the radial angle and the rotation angle are related. To establish this relationship, we have shown the points that represent the rotation angle according to the radial angle of each pinnae to each cultivar on the previous graphs (Fig. 7). These graphs show a relationship between these two angles.

Studies of Memadji-le-Allah *et al.* [6] in San Remo, Italy and Gammoudi *et al.* [7], resulted in the good correlation between the radial angle (A) and the rotation angle (B) pinnae will determine one of them depending on the other for the simulation, we prefer to measure the rotation angle easier to accurately measure than the radial angle, precision difference highlighted by more variations on cloud points. Moreover scars insertion pinnae are a good indicator of the pinnae position.

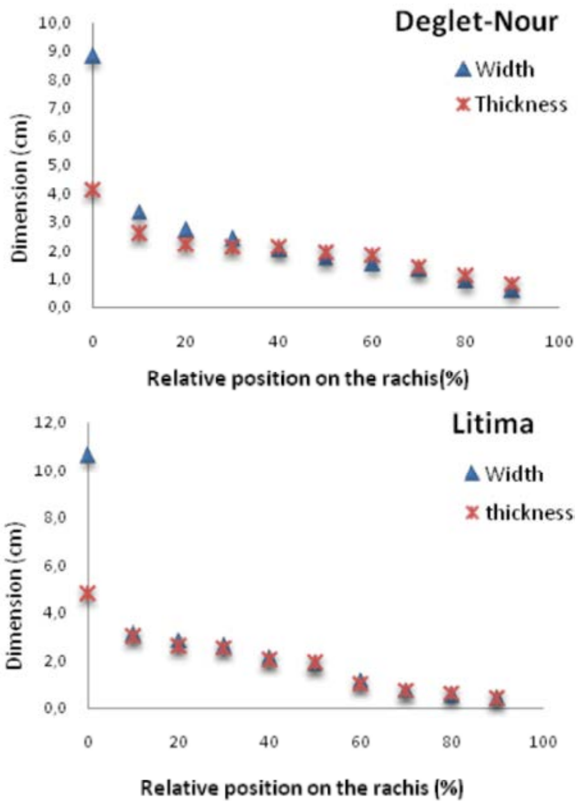

Fig. 2: Dimensions to the relative position of each section

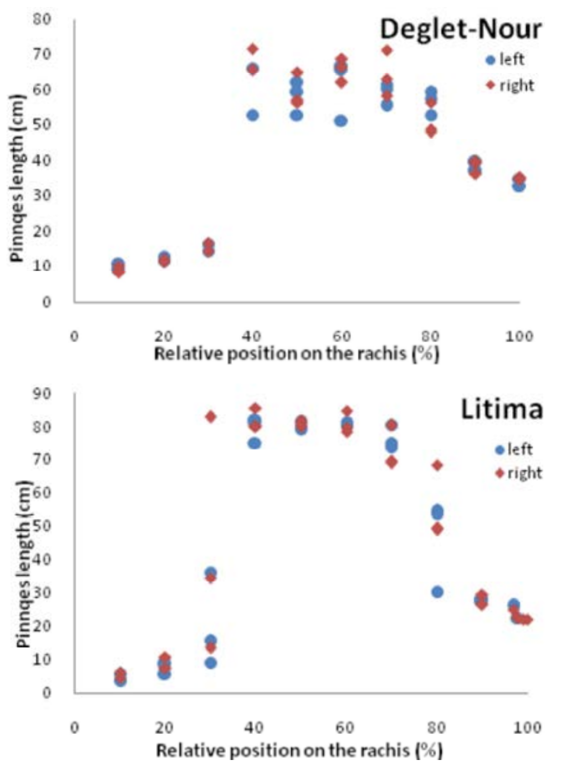

Fig. 3: The lengths presented by the relative positions of each section

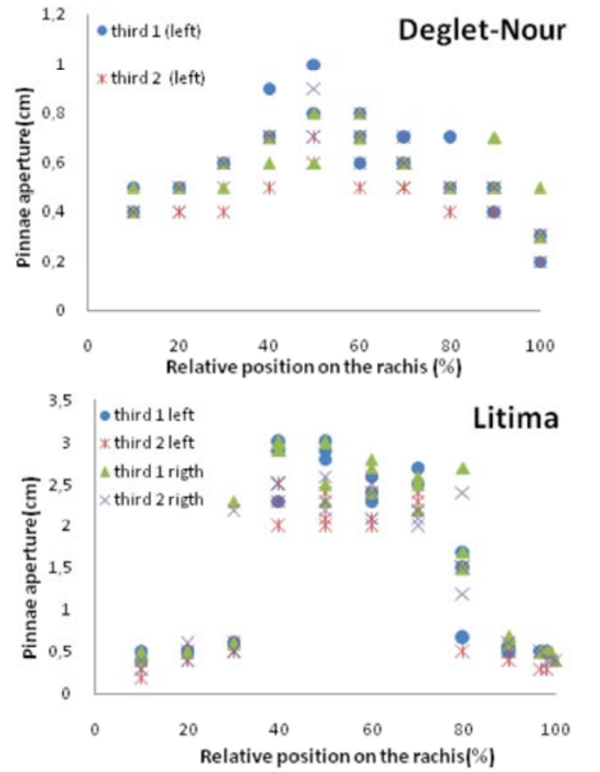

Fig. 4: The aperture presented in the relative positions of each section

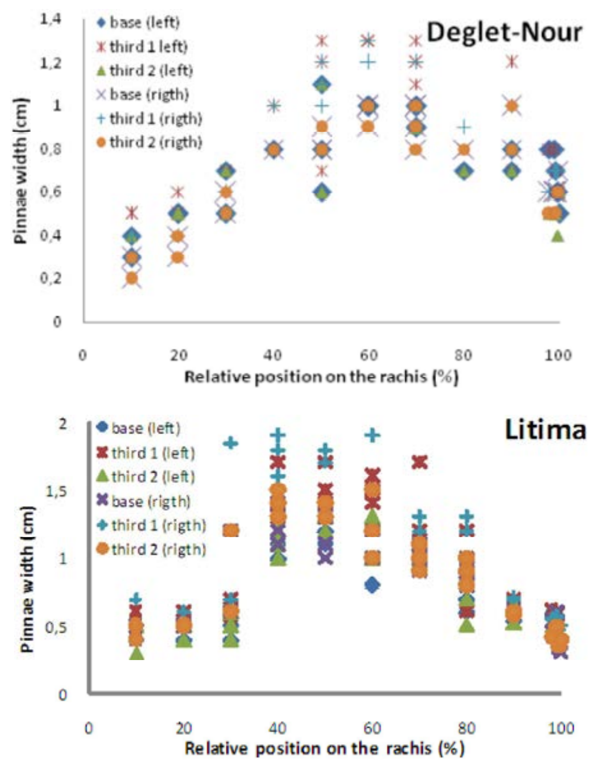

Fig. 5: The width presented in three situations according to the relative positions of each section

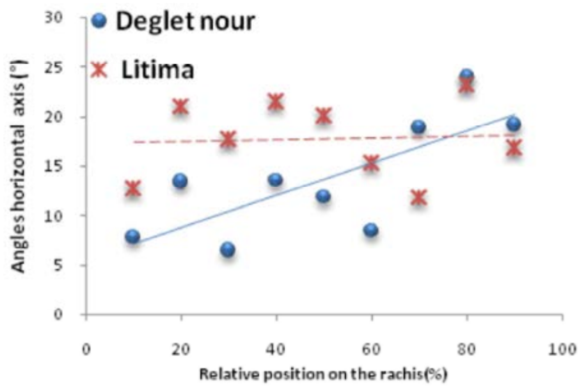

Fig. 6: The axial angle

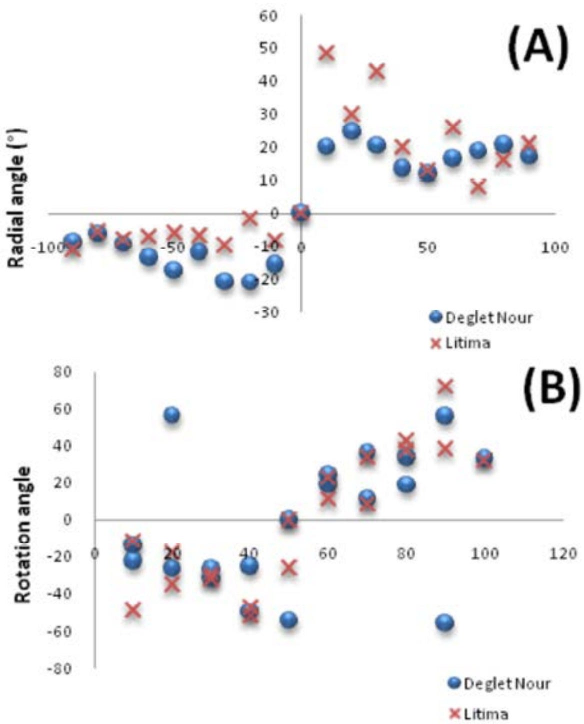

Fig. 7: Radial and rotation angles

A. The relative angle to the vertical axis of the relative position on the rachis.

B. The insertion angle of the relative pinnae to the longitudinal axis of the relative position on the rachis.

The axial angles are independent from the vertical position of the pinnae and depend only on the relative position along the frond.

Simulation: According to the study [9], AMAPstudio is a software suite dedicated to plants architecture modelling, designed for botanists and agronomists, providing features to edit, visualise, explore and simulate multi-scale plant descriptions.

Principes brings a generic, multi-scale, structural model for palm-trees based on the organization of the various organs. Each organ carries its own attributes (lengths, diameters, branching or deviation angles, inter organs distances, etc.).

Studying plants at the individual or at the scene level (several plants) raises different kinds of issues. To better address these issues, AMAPstudio was designed as a software suite.

The Xplo software is designed to handle single plants. It has given us the following results.

The Vegetative Part: For each parameter characteristic of the palm tree in the simulation, a graph was made ccording to the relative position of the pinnae on the stem.

The analysis of the architectural parameters enables us to characterize cultivars in question. These characters are quantitative (number), metric (dimensions) and geometric (angles).

The figures below show the schematic representations from the simulation.

On a global level, the arched palms on the date palm, as shown in Fig. 9, this is identical to the real arched palms. Similarly, the height of the stem also appears similar to reality.

The Reproductive Part: The stalk length is very close between the two varieties studied ('Deglet Nour' and 'Litima'), at the other hand, width and height of the stalk are different from each other.

The number of spikelets and their lengths is also very different in both date palms; this difference appears on the length of the sterile part of spikelets and also on the number of fruits.

Fruit size is substantially similar in the two cultivars.

Reproductive part angle characteristics are also different.

'Deglet Nour' is characterized by a wide angle of stalk flexion (the angle of insertion + the bending angel), as for 'Litima' cultivar in terms of deployment is a little lower. The axial angles of insertion in 'Litima' spikelet are very large compared to 'Deglet Nour' ones. This difference may be related to the effect of the number of fruit on the spikelet.

'Litima' which is also characterized by a shorter spikelet than the one of 'Deglet Nour'.

Fig. 10 shows the simulation of 'Deglet Nour' stalk in comparison to the real one.

If the photo is slightly rotated to the direction of the clock hand, one notices the resemblance between the two pictures.

Fig. 8: Simulation of fronds "a" 'Deglet Nour' and "b" 'Litima'

Fig. 9: The Palm trees of 'Deglet Nour' and 'Litima'
Left: real date palm Right: simulated date palm

Fig. 10: Stalks of 'Deglet Nour' and 'Litima'
Left: real stalk right: simulated stalk

The shape of 'Litima' stalk bottom in Fig. 10, which is characterized by a high density related to the shape of dates along the length of the sterile part of the spikelet.

CONCLUSION

The MOCAF/OMAM protocol is based on two main axes: the morphometric analysis and the geometric analysis. This method has been successful in estimating the minimum number of pinnae for morphometric measurements.

This work can participate in the prediction of future crops in order to reduce the area of the implantation and also to win some additional time on the operating life thanks to the predictive capabilities of the simulation that anticipates the production of next year, on top of that, it estimates leaf surfaces to calculate radial transfer which gives the amount of energy intercepted by the plant... Etc.

This preliminary study, conducted over two cultivars, requires further study on other Algerians cultivars and to be performed by the researchers involved in this modeling.

REFERENCES

1. Munier, P., 1973. The date palm. Maisonneuve and Larousse, Paris, pp: 221.
2. Bouguedoura, N., 1979. Contribution to the knowledge of the date palm. *Phoenix dactylifera* L.. thesis of the third cycle biological science, University Montpellier II, France.
3. Benaissa, I., S. Bourfa and A. Perrier, 2008. Using the thermal flow measuring sap for evaluating the sweat of a date palm « Saving water systems irrigation in the Maghreb, Mostaganem.
4. Elhoumaizi, M.A., 2002. Modling the architecture of the date palm (*Phoenix dactylifera* L.) and Application to Simulation the Radiation Budget in Oasis, pp: 162.
5. Dror, R. and I. Shimshoni, 2009. Using Phyllotaxis For Date Palm Tree 3d Reconstruction From A Single Image. University of Haifa, Haifa, Israel.
6. Memadji-le-Allah, S., S. Gammoudi, H. Rey, M. Bensalah and R. Lecoustre, 2011. Modeling of Arecaceae architecture, example of *Phoenix dactylifera*, descriptions of the characteristics autocorrelation functions of parameters and of the correlations between some of these parameters, in: 1st International Symposium Palmier, Alger: The Date Palm: Review of 50 Years of Work-What Research for Its Preservation and Enhancement?, Nov. 13-14, Alger, Algeria.

7. Gammoudi, S., R. Lecoustre and M. BenSalah, 2014. Modeling of Date Palm (*Phoenix dactylifera* L.) Vegetative Aerial Architecture, Example of Two Tunisian Cultivars, Journal of Life Sciences, ISSN 1934-7391, USA, 8(5): 418-424.
8. Barczi, J.F., 2008. A software contribution dedicated to the simulation architecture and plant growth. Doctoral thesis (Specialty: engineering sciences) central school of Arts and Manufactures, Paris, France.
9. Griffon, S. and F. De Coligny, 2014. AMAPstudio: An editing and simulation software suite for plants architecture modeling, Ecological Modelling, 290: 3-10.
10. Elhoumaizi, M.A., R. Lecoustre and A. Oihabi, 2002. Phyllotaxy and handness in data palm (*Phoenix dactylifera* L.), Fruit, 57(5-6): 297-303.
11. Zango, O., 2011. Comparative study architecture and geometry of the male and female palm inflorescence date palm. Thesis of Master study (Tropical Plant Biodiversity), Montpellier, France.
12. Atallaoui, K., R. Benmehaia and A. Simozrag, 2015. Simulation of production of two Algerian cultivars of Date palm: Deglet Nour and Litima, Revue Agriculture, Setif, Algeria, (10), 89-93.