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Article

A Geometric Modeling of Tracheal Elements of the Chard (*Beta vulgaris*) Leaf

*Uma Modelagem Geométrica de Elementos Traqueais da Folha de Acelga (**Beta vulgaris**)*

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ABSTRACT- In this study, we give a geometric description of the tracheal elements of the chard (*Beta vulgaris* var. *cicla* L.), which is a widespread cultivated plant in Turkey. It is used as an edible plant and its leaves are used as antidiabetic in traditional medicine plant. We have shown that the tracheal elements, which are taxonomic value of the plant, can be considered as a surface of revolution or a tubular shape along a special curve.

Keywords: chard, tracheal elements, geometric model.

*RESUMO - Neste estudo, fornecemos uma descrição geométrica dos elementos traqueais da acelga (**Beta vulgaris** var. **cicla** L.), que é uma planta cultivada amplamente difundida na Turquia. É utilizada como planta comestível, e suas folhas têm uso antidiabético na medicina tradicional. Mostramos que os elementos traqueais, que são o valores taxonômico da planta, podem ser considerados como uma superfície de movimento ou forma tubular ao longo de uma determinada curva.*

Palavras-chave: acelga, elementos traqueais, modelo geométrico.

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INTRODUCTION

The Chard (*Beta vulgaris* var. *cicla* L.) is a herbaceous biennial leaf vegetable cultivated in many parts of the World because of its year round availability, low cost and wide use in many traditional dishes (Gao et al., 2009). The chard has highly nutritious leaves making it a popular addition to healthful diets. The leaves of the chard contain nutritionally significant concentrations of vitamins A, C and B, calcium, iron and phosphorus (Pyo et al., 2004). It is used as a popular folk remedy for liver and kidney diseases, for stimulation of the immune and hematopoietic systems, and as a special diet in the treatment of cancer (Kanner et al., 2001). The chard is widely spread in Turkey and used as an edible plant and an antidiabetic in traditional medicine (Saçan and Yanardag, 2010). Bolkent et al. (2000) reported that laves of the chard may decrease blood sugar by increasing insulin secretion from the pancreas.

Tracheary elements are found in the xylem of all vascular plants. They are highly specialized cells. Their cells die at maturity but lignified cell walls remain as the conduits through which the water is carried in the xylem vessel. So they serve for upward conduction of the water and dissolved in plants. Tracheary

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elements, which are the distinctive cells of the xylem are characterized by the formation of lignified cell wall with annular, spiral, scalariform and reticulate (Fukuda, 1992; Höfte, 2010; Devillard and Walter, 2014). In anatomical studies, it was proved that the formation of lignified cell wall of tracheal elements are mostly annular, spiral and scalariform types whereas reticulate type is rare in surface sections of the leaf.

In this study, a geometric recognition of the tracheal elements, which are taxonomical value of the plant, is presented. We have shown that the tracheal elements of the plants can be considered as a surface of revolution or a tubular shape along a special curve.

MATERIALS AND METHODS

Anatomical work

The Chard (*Beta vulgaris* var. c*icla* L.) leaves were carefully washed with tap water, then were fixed in 70% ethanol and were taken surface sections of the leaf. Anatomical studies were carried out following Bozdag et al. (2016). Hand cuts were stained with safranin and fast green. Preparates were photographed with a motorized Leica DM 3000 microscope. Measurements were taken using ocular micrometer of tracheal elements.

Geometric work

Surface of revolution and tubular surfaces have an important role in 3D shape modelling.

Definition 1. Let $\alpha: (a,b) \rightarrow R^2$ be a regular planar curve given with the parametrization $\alpha(t) = (f(t), g(t))$. When α revolved in $\mathbb{R}^3$ about z-axis the resulting point set M is defined by

$$M: \quad x(t,s) = (f(t)\cos(s), f(t)\sin(s), g(t))$$

is called the *surface of revolution* generated by the profile curve α. The z-axis is called *axis of revolution* (Gray, 1993).

In the present study, we have shown that the scalariform type tracheal elements of the chard leaf is considered a certain part of surface of revolution about a plane curve $\alpha(t) = (f(t), g(t))$.

To draw these kind of surfaces, we use the Maple plotting command as follows:

```
plot3d([f(t),g(t)*cos(s),g(t)*sin(s)],t = a..b, s = c.. d).
```

Definition 2. Let $\beta: (a,b) \rightarrow \mathbb{R}^3$ be a regular space curve $\beta(t) = \big(f(t), g(t), h(t)\big) \in \mathbb{R}^3$. For the normal, N, and binormal, B, vectors of the curve β, the circle $s \rightarrow \cos(s)N(t) + \sin(s)B(t)$ is perpendicular to at point . When this circle moves along it traces out a surface called *tubular surface*. This surface has a parametrization

$$x(t,s) = \beta(t) + r\big(\cos(s)\,N(t) + \sin(s)\,B(t)\big),$$

where r is the radius of the circle (Gray, 1993).

In the present study we have shown that the annular type and spiral tracheal elements of chard leaf are considered a certain part of surface of revolution about a space curve $\beta(t) = (f(t), g(t), h(t))$.

To draw these kind surfaces we type into the Maple command (Gray, 1993):

```
tubeplot([f(t),g(t),h(t)],t = a...b, radius = c, numpoints = d).
```

RESULTS AND DISCUSSION

Anatomical work

In anatomical studies, it was shown that the formation of the lignified cell wall taken from different parts of the leaf (*Beta vulgaris*) are mostly annular, spiral and scalariform types in surface sections. The length and the width sizes of these cells vary. The width sizes vary between 150 µm and 10 µm. The results of the experimental analyses and measurements were shown by photographs (Figure 1A, C).

(A)

(B)

(C)

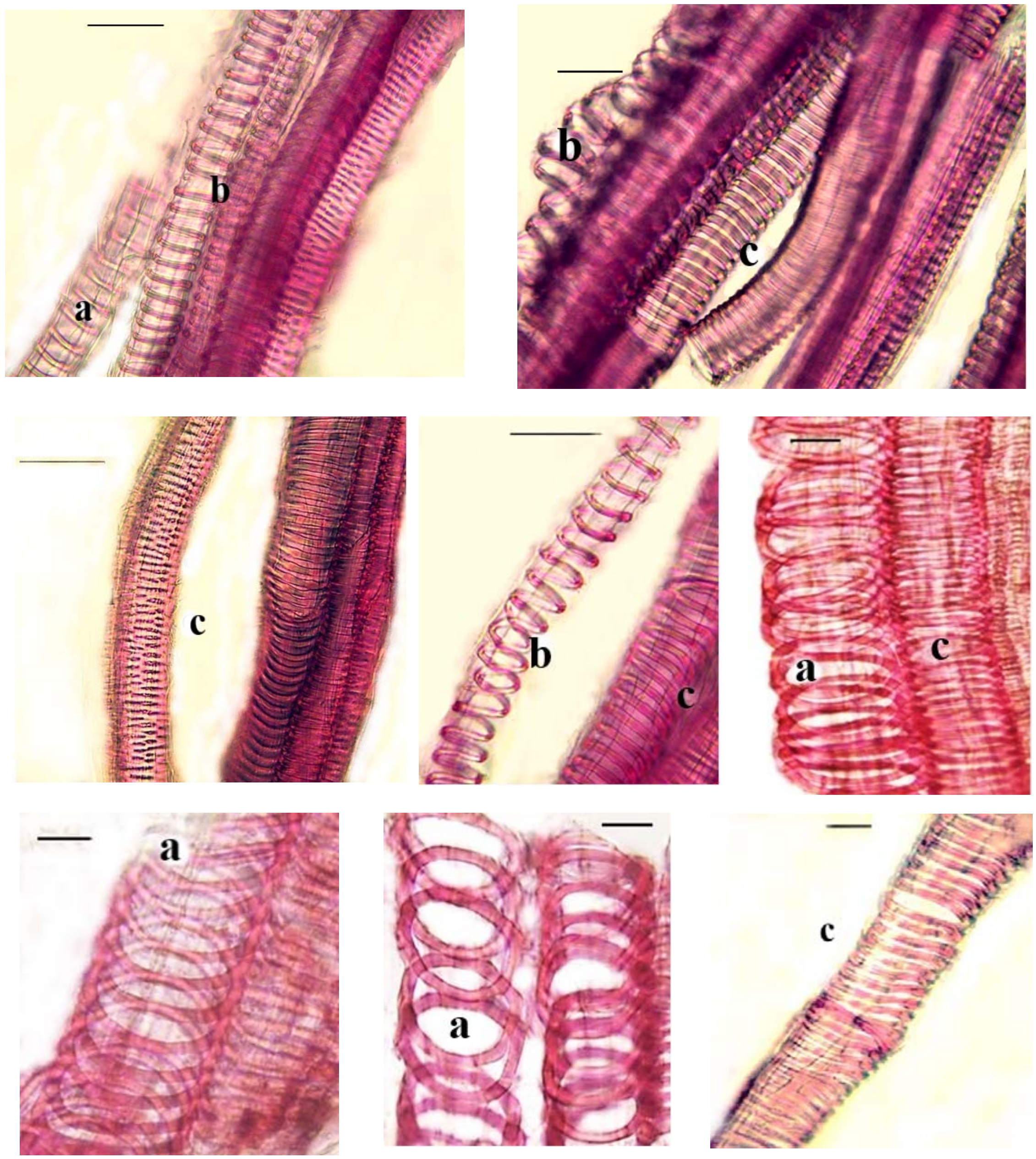

Figure 1 - The lignified cell wall types of tracheal elements in surface sections taken from different parts of leaf (*Beta vulgaris* var. *cicla* L); (**A**) annular type, (**B**) spiral type, (**C**) scalariform type (Scala Bar: 50 µm).

Geometric work

In the present study, we give a geometric recognition of three types tracheal elements of the chard leaf; annular type, spiral type and scalariform type.

Firstly, we describe the annular type tracheal element of the chard leaf as a collection of tubular surfaces about the space curves

$$\beta(t) = (\cos(t), \sin(t), b),$$

where b is a real constant.

To draw this surface, we use the Maple plotting command (Figure 2A):

```
K: = tubeplot([cos(t),sin(t),−3],t = 0..2*Pi,radius = 1/4):
A: = tubeplot([cos(t),sin(t),−2],t = 0..2*Pi,radius = 1/4):
B: = tubeplot([cos(t),sin(t),−1],t = 0..2*Pi,radius = 1/4):
C: = tubeplot([cos(t),sin(t),0],t = 0..2*Pi,radius = 1/4):
E: = tubeplot([cos(t),sin(t), 1],t = 0..2*Pi,radius = 1/4):
F: = tubeplot([cos(t),sin(t), 2],t = 0..2*Pi,radius = 1/4):
G: = tubeplot([cos(t),sin(t),3],t = 0..2*Pi,radius = 1/4):
H: plot3d([1.27*cos(s),1.27*sin(s),t],s = 0..Pi,t = −Pi..P.color = pink):
display({K,A,B,C,E,F,G,H});
```

Secondly, we construct a geometric model for the spiral type tracheal element of the chard leaf. We describe this type of shapes as a tubular surfaces over a curve helix

$$\beta(t) = (a\cos(t), a\sin(t), bt),$$

where $a, b \in \mathbb{R}$. To draw the modelled shape, we use the Maple plotting command (Figure 2B):

```
P: = tubeplot([−2*cos(t),−2*sin(t),t/2],t = −2*Pi..4*Pi,radius = 0.4,numpoints = 120):
R: = plot3d([2.43*cos(s),2.43*sin(s),t],s = 0..Pi,t = −2*Pi..2*color = pink)
display({P,R});
```

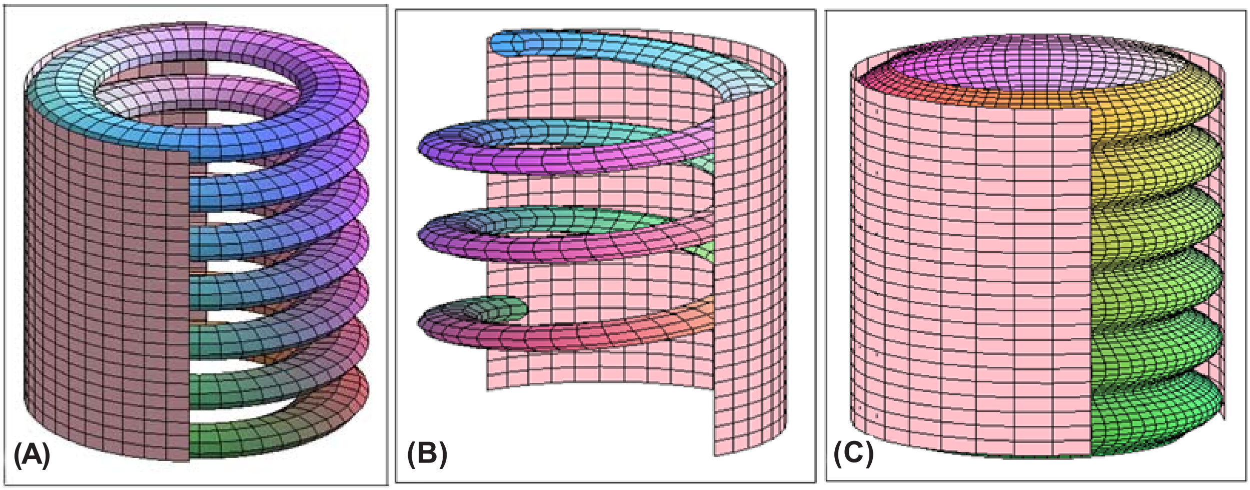

Figure 2 - The model surfaces (A) annular type, (B) spiral type, (C) scalariform type.

Finally, we construct a geometric model for the scalariform type tracheal elements of the chard leaf. We describe this type of shapes as a surface of revolution about an epicycloid as follows:

$$\alpha(t) = (9t - \sin(3t), 9 - \cos(3t))$$

To draw these kind of surface, we type into the Maple plotting command (Figure 2C):

```
S: = plot3d([9*x − 1*sin(3*x), (9 − 1*cos(3*x))*cos(y), (9 − 1*cos(3*x))*sin(y)], x−=
−2*Pi..2*Pi, y = 0..2*Pi, grid = [80,80]) :

T: = plot3d([t, 10.1*cos(s), 10.1*sin(s)], s = 0..5, t = −17*Pi..17*Pi. color = pink):

display({S, T})
```

Tracheary elements are highly specialized cells. These non-living cells are elongated with lignified cell walls. The tracheal elements form geometric shapes such as spiral, ring by accumulation of lignin in cell walls. In this study, we aim to demonstrate the anatomical characteristics of tracheal elements of the chard (*Beta vulgaris*) as geometrical.

Anatomical structure is most likely used to provide evidence concerning the interrelationships of larger groups such as families, or in helping to establish the real affinities of genera of uncertain taxonomic status. But in some cases, it is not sufficient to examine the anatomical structure of the plants. Therefore, it is of special importance that the anatomical structures of different plant groups are examined in a comparative and scientific discipline (Özörgücü et al., 1991). The shape and location of the anatomical structure in plants are very important for taxonomic studies (Metcalfe and Chalk, 1983; Fahn, 1990; Yentür, 1995).

The structure of the tracheal elements in plant vascular system, which is examined in this study, is very important in terms of taxonomy. We try to find an evidence which can be used in addition to morphological characters to distinguish plant using geometric modeling of the anatomical features of tracheal elements. This can be used as taxon-distinguishing feature. Thus, the geometric model of the tracheal elements can be viewed as a taxonomic character for the classification of the plants.

We think that this work will bring a different perspective to future researchers working on similar issues therefore it will provide a new comparing opportunity for the future researches on the related subjects.

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