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Research Article

Geometric Models of Some Microstructures

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Abstract

Macro structures on our planet that we can see with the naked eye or microstructures that we can only see with a microscope; They have a certain structure that allows them to settle and perpetuate in the environment they live in. These structures are not random, they are placed in a certain order. It is possible to observe them in objects that we can see with the naked eye. For example, this situation can be observed in the placement of fruits and flowers on the plant. These layouts provide them with advantages such as minimum space occupancy and maximum stability. People use these settlement forms, which we give as examples in plants, in architecture, industry, and in different areas such as the design of many products. Essentially, the geometrical rules of mathematics form the basis of these settlements in plants. In this study, it was tried to determine the definitions of geometric structures based on mathematical rules in some plant structures that we can only observe with a microscope. In the study, different plant samples were used to define the geometric models. In mathematical evaluations, mathematical concepts determined in the light of the literature were used to describe the geometric models of microstructures. In the study, literature information about geometric structures and their mathematical formulas was evaluated.

Keywords: Geometric model, Mathematical formula, Microstructure

Bazı mikro yapıların geometrik modelleri

Öz

Gezegenimizde çıplak gözle görebildiğimiz makro yapıların ya da ancak mikroskopla görebileceğimiz mikro yapıların; içinde bulundukları ortama yerleşmelerini ve devamlılıklarını sağlayan belli bir yapıları vardır. Bu yapılar rastgele olmayıp belli bir düzen içerisinde yerleşmişlerdir. Gözle görebildiğimiz nesnelerde bunları gözlemek mümkündür. Örneğin bu durum bitkide meyve ve çiçeklerin yerleşim biçimlerinde gözlenebilir. Bu yerleşim biçimleri onlara minimum yer kaplama ve maksimum sağlam durma gibi avantajlar sağlamaktadır. İnsanlar bitkilerde örneğini verdiğimiz bu yerleşim biçimlerini mimaride, sanayide, birçok ürünün dizaynı gibi değişik alanlarda kullanırlar. Esasen bitkilerdeki bu yerleşim biçimlerinin temelini matematiğin geometrik kuralları oluşturur. Bu çalışmada ancak mikroskopla gözleyebileceğimiz bazı bitki yapılarındaki matematik kurallara dayalı geometrik yapıların tanımları belirlenmeye çalışıldı. Çalışmada geometrik modellerin tanımlanmasında farklı bitki örnekleri kullanılmıştır. Matematiksel değerlendirmelerde, mikro yapıların geometrik modellerini tanımlamak için, literatür ışığında belirlenen matematiksel kavramlar kullanıldı. Çalışmada geometrik yapılar ve bunların matematiksel formülleri ile ilgili literatür bilgileri değerlendirildi.

Anahtar Kelimeler: Geometrik model, Matematik formül, Mikro yapı

1. Giriş

The physical, biological and functional properties of many macrostructures that we can see in our environment depend on the size, shape, spatial distribution of their constituent parts, as well as their layout. These properties are very important in terms of the quality of physical properties of structures such as durability, feature of occupying the smallest spaceand mass transfer. These macro structures that we can see with the naked eye on our planet or microstructures that we can only see with a microscope; They have a certain structure that allows them to settle and perpetuate in the environment they live in. These structures are not random, they are placed in a certain order. It is possible to observe them in objects that we can see with the naked eye. For example, this situation can be observed in the placement of fruits and flowers in the plant. These layouts provide them with advantages such as minimum space occupancy and maximum stability. People use these settlement forms, which we exemplified in plants, in various fields such as architecture, industry, and the design of many products. Essentially, the geometrical rules of mathematics form the basis of these settlements in plants. A plant part is usually made up of an aggregation of cellular that make up its microstructure and largely govern its physical properties. Each tissue grows to meet specific functional requirements that guarantee plant survival in a particular environment. The way multiple tissues come together geometrically within an organ helps determine mechanical performance, which is important for structural support. Plant structures often exhibit excellent mechanical properties. This feature is largely controlled by the geometrical structures of their micromorphologies [1].

In this study, it was tried to determine the definitions of geometric models based on mathematical rules in some plant micromorphological structures that we can only observe with a microscope.

2. Material and Method

Different plant samples were used as study material. These plant specimens were indicated in the photographs of their microstructures. In order to obtain the microstructures to be used in defining the geometric models of these samples, cross-sections of 10-20 µm were taken from different parts of the plant samples with the help of a microtome. Paraffin method was used for this process [2]. These sections obtained were colored with safranin and fast green double staining. In addition, hand sections were taken for the microstructure of the samples. The preparations prepared from the sections were examined using Leica DM 3000 motorized microscope objectives and their photographs were taken at different magnifications. In mathematical evaluations, mathematical concepts determined in the light of the literature were used to describe the geometric models of microstructures. In the study, literature information about geometric structures and their mathematical formulas was evaluated.

3. Results and Discussion

In our research, we determined that the microstructures of some parts of the plants whose microscopic structures we examined have different geometrical arrangements. We observed that some of these arrangements of microstructures belong to different types of the geometric concept of tessellation (mosaicing, flooring). In geometry, tessellation is the overlapping or covering of a surface, usually a plane, in a certain order, using one or more geometric shapes. In mathematics, tessellation can be generalized to higher dimensions and various geometries [3].

Geometric mosaic types are primarily discussed in two main groups.

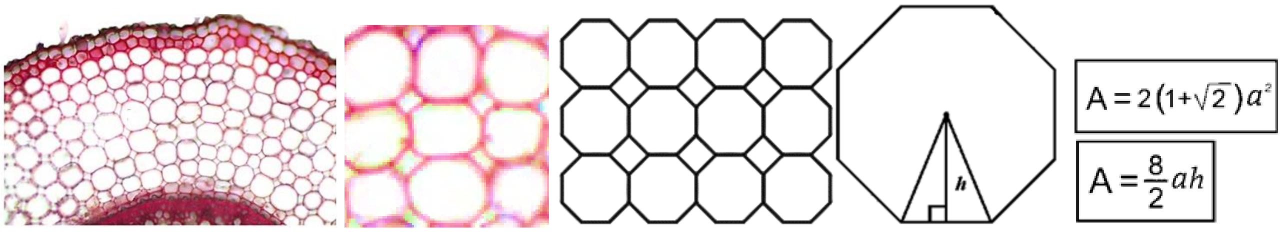
1. Two-Dimensional Tessellation: Mosaicing in two-dimensional space refers to the tessellation of a plane or two-dimensional surfaces and can be simplified to some basic geometries called "prototypes".

2. Three-Dimensional Tessellation: Three-dimensional tessellation, also called spatial tessellation, has more dimensional variation than two-dimensional ones.

It was determined that the samples we examined in our study had a two-dimensional tessellation geometric model. Microstructures of some of them show Two-Dimensional Mosaic feature in Semi-Regular Mosaic (semi-regular) form. It was determined that the root micromorphological structure of the Hyparrhenia hirta (L.) Stapf plant, which is one of the samples with a semi-regular pattern, has a geometric structure in the form of octagonal mosaicism, which is one of the two-dimensional mosaic types. Octagonal tessellation is the tiling of the plane with similar octagons (Figure 1).

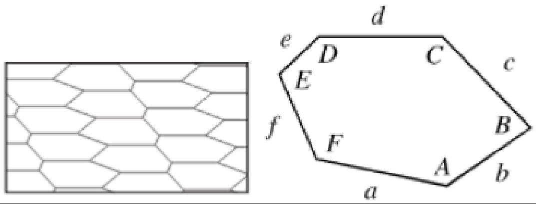
Some of the plant specimens in our study have a hexagonal tessellation model and are defined with one of the Two Dimensional Mosaicing types. Hexagonal tessellation is the tiling of the plane with the same hexagons. In geometry, a hexagonal tiling or hexagonal tessellation is a regular tiling of the Euclidean plane where exactly three hexagons meet at each vertex. Hexagonal tessellation is divided into two main groups as regular and irregular. A regular hexagon creates a regular mosaic, also called a hexagonal grid. In our samples, on the other hand, irregular hexagonal mosaicing was observed. There are three distinct types of irregular hexagons whose types and general formulas are shown in figures 2, 4, and 6 [4],[5].

In our study, we detected all three types of tessellations in the microscopic structures of some of the plants we examined. The appearance of these structures under the microscope and the mosaicing types are shown in figures 3,5 and 7 (Figure 3,5,7).



a b c d e

Figure 1. Semi-regular octagonal mosaic geometry model in *Hyparrhenia hirta*
a: Microscopic view of root b: Placement of cells c: Geometric model of microstructure d, e: Area formula



$$A + B + C = 360^\circ \qquad a = d$$

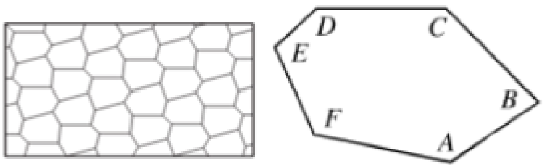
$$A + B + D = 360^\circ \qquad a = d, c = e$$

$$A = C = E = 120^\circ \qquad a = b, c = d, e = f$$

Figure 2. The appearance and general formula of the first type of irregular hexagonal mosaicing [5].

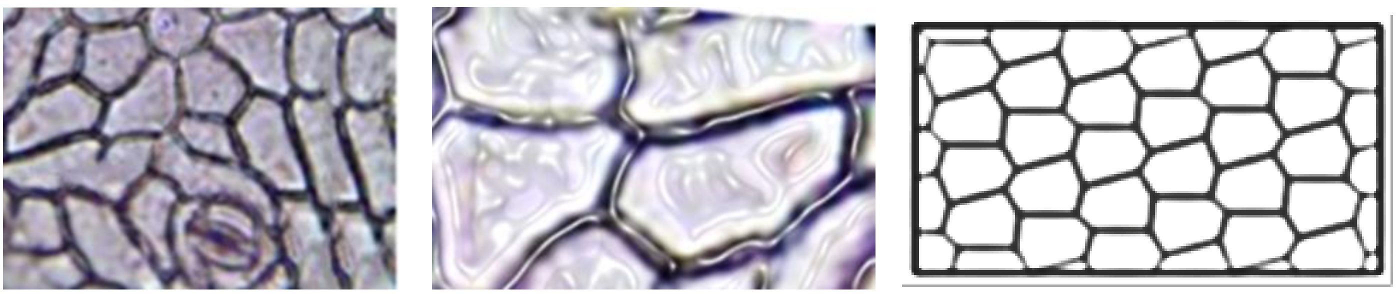
a b c

Figure 3. First type irregular hexagonal mosaic geometry model in *Muscari parviflorum*
a: Microscopic view of leaf b: Placement of cells c: Geometric model of microstructure



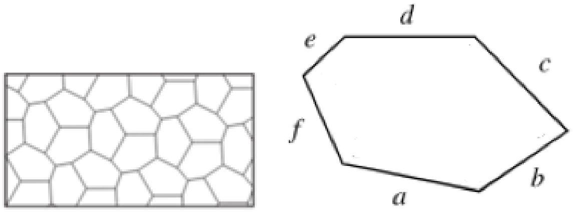
$$A = B = C = D = E = F$$

Figure 4. The appearance and general formula of the second type of irregular hexagonal mosaicing [5].



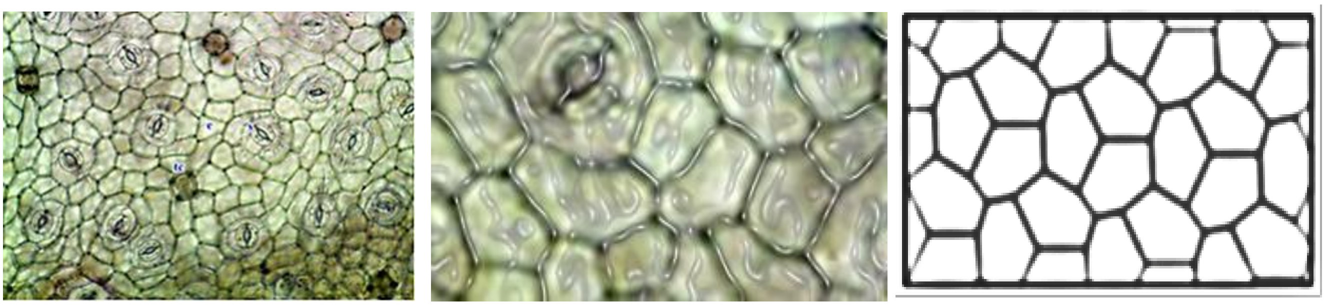
a b c

Figure 5. Second type irregular hexagonal tessellation geometry model in *Limonium gmelini*
a: Microscopic view of leaf b: Placement of cells c: Geometric model of microstructure



$$a = b = c = d = e = f.$$

Figure 6. The appearance and general formula of the third type of irregular hexagonal mosaicing [5].

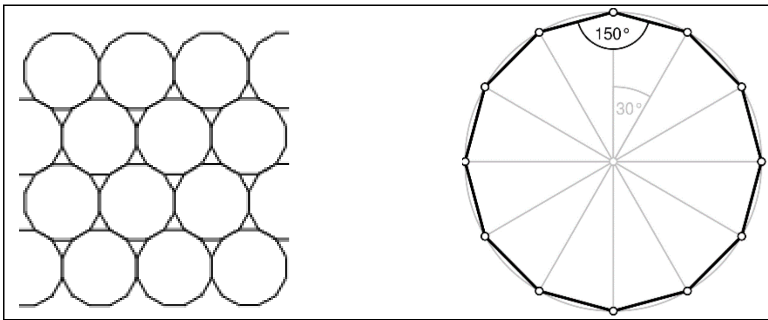


a b c

Figure 7. Third type irregular hexagonal tessellation geometry model in *Limonium gmelini*
a: Microscopic view of leaf b: Placement of cells c: Geometric model of microstructure

On the other hand, we found that some of the microstructures we examined showed mosaicism, also called Archimedean mosaics in geometry. Regular tessellations of the plane by two or more convex regular polygons such that the same polygons surround each polygon vertex are called semi-regular mosaics or sometimes Archimedean mosaics [6-8].

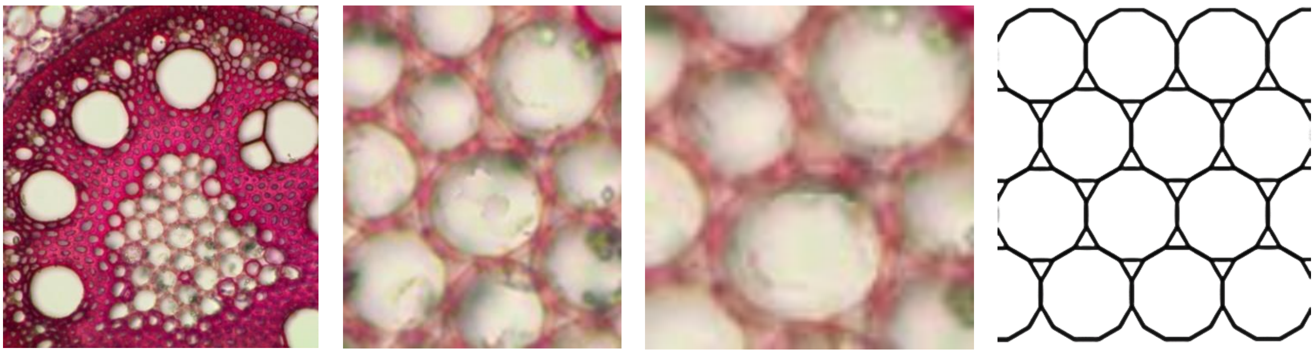
There are eight such tessellations in the plane. One of them is the dodecagonal semi-regular mosaic that we observed in our study. It has twelve lines of reflective symmetry and rotational symmetry of order 12. The interior angle at each vertex of a regular dodecagon is 150° [8]. Its type and general formulas are shown below (Fig. 8).



$$A = 6sin\left(\frac{\pi}{6}\right)R^2 = 3R^2$$

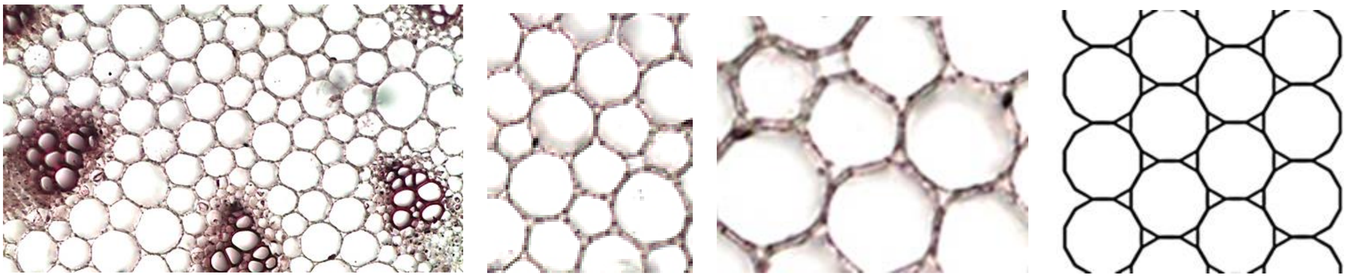
$$p = 24Rtan\left(\frac{\pi}{12}\right) = 12R\sqrt{2-\sqrt{3}}$$

Figure 8. General formulas and representations of the Dodecagon mosaicism model [8].
(A) : Area in terms of circumferential radius R
(R) : Circumferential radius
(p) : The circumference of the Dodecagon tessellation model in terms of circumferential length



a b c d

Figure 9.a: Microscope view of root *Hyparrhenia hirta* b,c: Placement of cells d: Geometric model of microstructure



a b c d

Figure 9.a: Microscope view of *Muscari parviflorum* stem b,c: Placement of cells d: Geometric model of microstructure

As a result of this study, it has been seen that some micromorphological structures of plants have properties that can be defined in geometry and expressed with parametric formulas.

Plants are made up of many cells that make up their whole. The coming together of the cells is not random, they are placed in a certain order. Cells form the micromorphological structures of plants and can only be observed with a microscope. The properties of the plant depend not only on a single cell, but also on the connections, locations and interactions between cellular components.

In this study, it was determined that some plant specimens have different geometric patterns in their micromorphological structures that we observed under the microscope.

At the same time, the equivalents and definitions of these structures in geometry were determined. Such mathematical studies of micromorphological structures are very limited in the literature [9,14]. In this study, a different perspective was provided by evaluating the micromorphological structures of some plants mathematically. Thus, it creates a new comparison opportunity for future research on the relevant subject.

4. Conclusions and Recommendations

In this study, the layout of the cells in the microstructures of plants was tried to be revealed by using the definitions corresponding to the geometrical rules.

The geometrical rules of mathematics form the basis of these settlement forms belonging to the microstructure of plants. Within the framework of these rules, the plant has advantages such as durability, support, standing firm, and occupying the least amount of space. Similarly, geometric models of plant micromorphological structures can help us understand how microstructure determines mechanical properties. It can also help us develop predictive models of known mechanical behavior. From this perspective, we believe that our study will lead to new studies.

References

[1] R. Tanvir Faisal, H. Nicolay, L. Tamara, A. Western D. Rey, P. Damiano, “Computational study of the elastic properties of Rheum rhabarbarum tissues via surrogate models of tissue geometry”. Journal of Structural Biology 185: 285–294. 2014.

[2] G. Algan, Bitkisel Dokular İçin Mikroteknik. Fırat Üniv. Fen-Ed. Fak.Yayın. Bot. No:1, İstanbul. 1981.

[3] R. Conway, H. Burgiel, G. Goodman-Strauss “The Symmetries of Things”. Peters.D. Pasini, Journal of Design & Nature and Eco dynamics 3, 1. 2008.

[4] M. Gardner. Tilings with Convex Polygons. Ch. 13 in Time Travel and Other Mathematical Bewilderments. New York: W. H. Freeman, pp. 162-176.1998.

[5] Weinstein, Eric W (2007). Hexagon Tiling. From Math World--A Wolfram Web Resource. https://mathworld.wolfram.com/HexagonTiling.html.

[6] Ghyka, M. C .1977. The Geometry of Art and Life, 2nd ed. New York: Dover.

[7] Williams, R 1979. The Geometrical Foundation of Natural Structure: A Source Book of Design. New York: Dover.

[8] Weinstein, Eric W (2020). "Dodecagon." From Math World--A Wolfram Web Resource. https://mathworld.wolfram.com/Dodecagon.html.

[9] A. Özdemir, “Geometric Modelling and Statistical Comparison of Some Sage Glandular Hair. Fresenius Environmental Bulletin Vol. 27, 9: 6417-6421. 2018.

[10] W.R. Korn and R. M. Spalding. “The Geometry of Plant Epidermal Cells” New Phytol. 72:1357-1365. 1973.

[11] A Özdemir, AY Özdemir, K Yetisen, “Statistical comparative petiole anatomy of Salvia sp.” Planta Daninha 34 (3), 465-474, 2016

[12] A. Özdemir, C. Özdemir, “Numerical Comparison of Anatomical Features In Some Allium L.” Fresenius Environmental Bulletin 27 (2), 1183-1190. 2018.

[13] A. Özdemir and A. Özdemir, “Statistical Study on Some Micromorphological Characters”, Avrupa Bilim ve Teknoloji Dergisi 34: 135-141, 2022.

[14] A. Özdemir.Minimal surface micmicromorphological structures of plants” Fresenius Environmental Bulletin 29: (08), 7065-7070.2020.