Auxin makes the spirals in gerbera inflorescences follow the Fibonacci sequence

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When people are asked to draw the flower of a sunflower plant, almost everyone draws a large circle encircled by yellow petals.

"Actually, that structure is the flower head, or the capitulum, which may be composed of hundreds of flowers, also known as florets. The surrounding 'petals' are florets different in structure and function to those closer to the center," says Professor of Horticulture Paula Elomaa from the Faculty of Agriculture and Forestry, University of Helsinki, Finland.

A giant inflorescence is beneficial, as it is effective in attracting pollinators. When pollinators move around the inflorescence, they pollinate hundreds of individual florets over the course of their journey.

The order of the florets in a flower head is not random. Instead, they are patterned into regular spirals whose number follows the Fibonacci sequence familiar from mathematics. Fibonacci numbers are the sum of the two preceding numbers in the sequence: 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144...

In the flower head, the number of left- and right-winding spirals is always two consecutive Fibonacci numbers. Sunflower flower heads can have as many as 89 right-winding and 144-left winding spirals, while the gerbera, another much-studied plant from the Asteraceae plant family, has fewer spirals (34/55).

The geometric regularity of nature has fascinated both biologists and mathematicians for centuries.

"The gerbera is a favorable study subject, because we can use transgenic plants grown in a greenhouse as tools when investigating the functions of individual genes, for example, during the development of the plant. In the case of sunflowers, gene transfer is not yet a routine procedure. The gerbera genome, which is close to the size of the human genome, is currently being sequenced. Experience has shown that the gerbera is an excellent model plant," says Elomaa, who has contributed to Finnish gerbera research ever since its infancy in the late 1980s.

Now, for the first time, the researchers have been able to examine on the molecular level how floral primordia are patterned into spirals in the growing point, or the meristem, of gerberas. They have had available to them a technical solution whose utilization in plant science could only be dreamed of a couple of decades ago.

With the help of X-ray tomography, the researchers scanned three-dimensional images of the different stages of meristem development. Using confocal microscopy, they surveyed meristems as small as under one millimeter in size to determine where the plant hormone auxin, which determines the position of the primordia, is located.

Finally, the researchers applied mathematical modeling to the data gained in cooperation with Professor Przemyslaw Prusinkiewicz from the University of Calgary. The end result was a three-dimensional computer model that emulates the patterning of a real flower head.

The researchers found that the meristem of the gerbera is patterned on the molecular level already at a stage where no primordia or other changes are discernible by even an electron microscope.

"During growth, auxin levels rise to the maximum simultaneously in several locations of the meristem. The number of these clustered spots, which are called auxin maxima, increases rapidly as the diameter of the meristem grows, following the Fibonacci numbers. A new auxin maximum is always formed between two neighboring maxima and moves so that it is always closer to the older of the neighbors. This is why the spirals are regular even in meristems that are not entirely symmetric."

The findings demonstrate that the expansion growth of the meristem is the factor that affects, for example, the eventual number of florets in the flower head.

"Among other things, this effect is seen in seed yield, an important factor for the sunflower, as it is specifically cultivated as feed and food. It is also possible that the same model explains the number and patterning of floral organs. In the future, this information will be applied to, for instance, the strawberry. In strawberry the size of the fruit is regulated by the number of pistils," Elomaa notes.

More information: Teng Zhang et al, Phyllotactic patterning of gerbera flower heads, *Proceedings of the National Academy of Sciences* (2021). DOI: 10.1073/pnas.2016304118

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