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DETERMINATION METHOD OF FLORET NUMBER AND THEIR DENSITY IN SUNFLOWER HEAD

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SUMMARY

The aim of this work was to develop a simple method for calculating disk flower number and their density in sunflower head. The formula developed on the basis of the Golden section includes initial data of the number of small-short rows and the number of florets in a row. It takes no more than a minute to gain initial data for calculating the formula for one head.

Key words: disk flower, seed number, sunflower

INTRODUCTION

It is well-known that sunflower productivity depends primarily on achene number in sunflower head. However, this number varies greatly. It depends on genotypic and phenotypic flexibility, ranging from 60 to 3000 achenes or more. In this connection the research on the inheritance of the character is considerably hampered by the difficult floret calculation.

The aim of this work was to develop a method allowing to speed up the counting procedure.

MATERIALS AND METHODS

Experiments were conducted at Krasnodar in 1985-1990 with inbred lines of different origin - HA 232, HA 234, HA 301, K 1234, K 20, GR 457, GR 470 and large set of Russian genotypes.

Method description is given in the next section.

RESULTS AND DISCUSSION

In order to understand the principle of this method of floret number calculation, some structural features of sunflower head should be considered (Figure 1). We distinguish large (1, 3) and small (2, 4) clearly discernible floret rows in a head, which are divided into short (1, 2) and long (3, 4) rows. Short rows turn clockwise from the center and long rows turn counterclockwise.

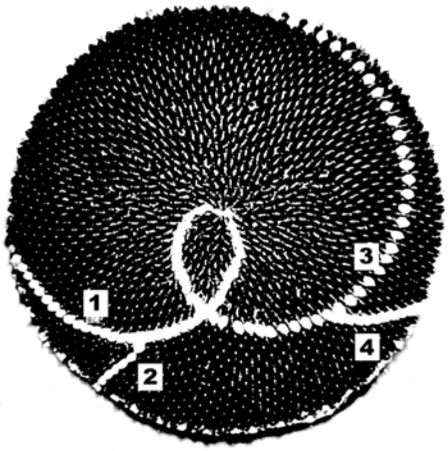

Figure 1. Arrangement of floret rows in sunflower head

If one counts the number of these rows and the number of florets in them, one can find the following regularities. The shorter the rows (be they small or large), the larger their amount. Short rows are always more numerous than long ones according to the Fibonacci sequence. Row number in the direction from the head edge to the center decreases and floret number increases strictly according to the Fibonacci sequence or to the ratio of the Golden section.

The Fibonacci sequence of numbers is a sequence in which the first two terms are equal to one and each following term is defined as the sum of its two predecessors (Vorobiev, 1984). Here are its terms: 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, *etc*. E. Luc (Vorobiev, 1984; Coxter, 1966) and we have found two more similar number sequences: 2, 1, 3, 4, 7, 11, 18, 29, 47, 76, 123... and 2, 2, 4, 6, 10, 16, 26, 42, 68, 110..., respectively, which also characterize the arrangement of florets in a sunflower head. However, they occur less often than the Fibonacci sequence. In field conditions the number of small-long and small-short rows or spirals in the peripheral head part is usually 89 and 144, less often 76 and 123 and 68 and 110. The Golden section is a division of the whole into two parts, in which the greater part is to the whole as the lesser part is to the greater one. In addition, the Golden section parts make approximately 62 and 38%, and the Golden section in itself (τ) is 0.618 (Bendukidze, 1973).

Thus, in spite of visual chaos in the head center, it has a strict mathematical form. It can be easily found when removing florets, (orient yourself to chaffy bracts), precisely indicating large rows, which are rather distinctive in the head center, but seem to dissolve in its peripheral part (since the distance between florets in a row increases). Small rows, on the contrary, are conspicuous in the peripheral part and they merge toward the center.

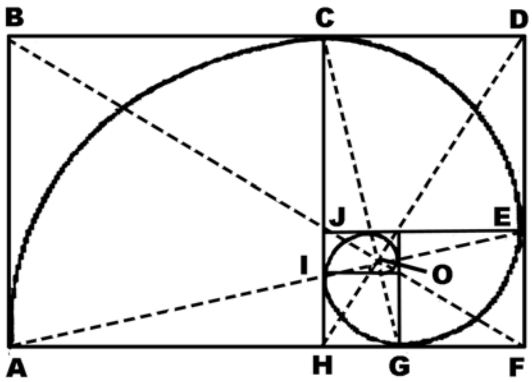

Figure 2. Equiangular (logarithmic) spiral constructed by means of rectangle, which sides are in the ratio of the Golden section

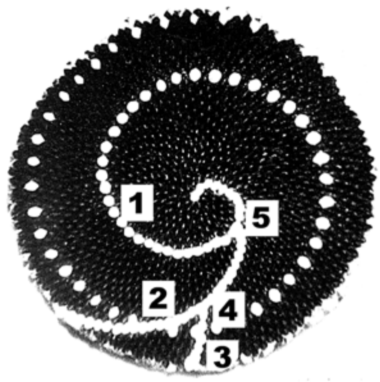

Figure 3. Splitting (or merging) scheme of floret rows in sunflower head

Such row arrangement is a proof of zonal structure of sunflower head. On this basis we can assume that large rows have an equiangular spiral form (Figure 2). In the certain zone they split up towards peripheral area forming new rows, which also split up in the next zone and so on. In addition, the splitting of rows or spirals occurs in points...I, G, E or in circles passing through these points. These zones are in the ratio of the Golden section. It means that width, or radius, of the first peripheral mergence zone (or the last splitting zone) is equal to the sum of radiuses of the next two zones, that is $r_1=r_2+r_3$; $r_2=r_3+r_4$, *etc.*

We have managed to calculate width, or radius, of the first mergence zone.

It is: $$r_1 = R\tau^2 = \frac{R}{1+\frac{1}{\tau}}$$

where

R - radius (OA) of the large circle, or head.

Width, or radius, of every following zone is calculated by multiplying the previous zone radius by τ. Figure 3 shows one of the schemes of the splitting of rows (or spirals) in a sunflower head.

According to our primary considerations, for example, 144 small-short rows should merge in the following zone into 55 rows instead of 89, which, in their turn, should merge into 21 rows instead of 34, *etc.* (in one term of the Fibonacci sequence). It means that the number of rows will decrease in $1+1/\tau$, or 2.618... times. 89 small-long spirals will merge into 34 ones instead of 55, which also will merge into 13 spirals instead 21, *etc.* If one considers this process in the opposite direction, one can assume that one row splits up into three, which split up into 8 rows instead of 5, the following rows split up into 21 rows instead of 13, 55, 144, *etc*. In this way the formula of logarithmic spiral splitting into zones was derived - 3-2-3. According to the formula, the first row splits up into three, the two of which also split up into three rows and one row into two. These two rows split up into two and three, respectively.

In order to calculate the number of florets in sunflower inflorescence it is necessary to know the number of zones formed after the splitting of large rows and the number of florets in every zone. The calculation of florets in the zones of splitting of rows is directed clockwise, *i.e.*, small-short rows (basic direction) are considered to be most accurate.

The formula for calculation of floret number in sunflower head (n) is as following:

$$n=(N_1 \times n_1)+(N_2 \times n_2)+(N_3 \times n_3)$$

where

N_1, N_2, N_3 - number of rows in the first, second and third zones, respectively; (N_1 - number of small short-rows);

n_1, n_2, n_3 - number of florets in a row according to zones.

In addition, initial data for calculation are the number of small-short rows and the number of florets (or achenes) in them. The other formula components are calculated:

$N_2=N_1\tau^2$;

$n_2 = n_1 \cdot \left(1+\frac{1}{\tau}\right)$

$N_3=N_2\tau^2$;

$n_3=n_1$.

If one substitutes these values into the formula for calculation of floret number, its final variant will be:

$n=N_1 \times n_1 \times 2.146$.

It is very important to do an accurate calculation of the number of florets in small-short rows. Usually they are from 3 to 6, the maximum amount is from 12 to 15. The error of 1 or 2 florets causes calculation error from 100 to 200 florets. Therefore, the formula $r_1=R\tau^2$ specifies precisely the floret which is on the boundary between the first and the second zone. In this area the so-called family (double, triple) achenes can be found. These achenes do not occur inside the zones since the splitting and merging of rows occur strictly on the boundary between zones, which result in the formation of such achenes.

Here we give an example of the calculation of floret number in a head of the most typical size. It has the following values: $N_1=144$, $n_1=5$. If we substitute these values into the formula for the calculation of achene number, the following result is obtained:

$n=144 \times 5 \times 2.146 \approx 1545$.

The actual number of achenes in the given sunflower head was 1486, meaning that the calculation error was 54 achenes or 3%. However, in our research the number of florets in the majority of heads has almost coincided with the value calculated according to the formula (the differences amounted to a few achenes). The largest divergences did not exceed 3 to 4%. They are not essential because of the large amount of florets (Table 1). Insignificant difference between the calculated and actual data may be caused by errors in hand calculation (control) and inaccuracies in the calculation of double and triple achenes. It can be also caused by the fact that theoretically there are at least six zones, whereas actually they were only 3 or 4. Though in the fifth and sixth zones there were few achenes they can be responsible for the experimental error.

Table 1: Results of floret number calculation in sunflower head obtained with different methods

Total floret number in head					Experiment error	
Actual number (control)	Number calculated under the formula proposed	Number calculated under the formula of Palmer (1985)	Number of small-short rows	Floret number in small-short rows	Under the formula proposed (%)	Under the formula of Palmer (1985) (%)
1827	1833	1196	123	7	0.33	34.54
1815	1870	1244	144	6	3.03	31.46
3078	3080	2022	144	10	0.06	34.31
1486	1545	1011	144	5	3.63	31.97

The results of the research have shown that the time necessary for the hand calculation of the number of florets per head (with the aid of tweezers) varies from 40 minutes to 2 hours. By contrast, it takes no more than a minute to gain initial data for the calculation under the formula.

Zonal structure of sunflower head accounts for variable density of florets in the zones, which resulted in different achene size. As a rule the largest achenes are located on the head edge and the smallest ones in the center. By means of experiment it was found that achene size was equal within a zone. The reduction in achene size from one zone to another was not smooth but spasmodic. The highest achene density per 1 cm^2 was observed in the second zone. In the third zone it was less probable because of the low density in the center caused by the lack of the fifth and sixth zones.

Thus, the first zone area is $S_1=\pi R^2\tau^2(2-\tau^2)$. The area of each following zone is equal to the product of the previous zone area and τ.

Therefore, if we know the area of any zone and the number of florets (or achenes) in it we can calculate their density in the head by dividing the second index with the first one.

EXAMPLE

Let us assume that the radius of the above-mentioned head (R) is 10 cm. Then the width of the first zone is $r_1=10 \times \tau^2=3.82$ (cm), and its area is:

$S_1=\pi R^2\tau^2(2-\tau^2)=194.08$ (cm^2).

Therefore, the area of the second zone is $S_2=S_1\tau=199.94$ (cm^2) and of the third one is:

$S_3=S_2\tau=74.12$ (cm^2).

Floret numbers in the first three zones are 720, 715 and 105, respectively. So, the density of achenes (P) in the three zones (achene/cm^2) is:

$P_1=720 / 194.08=3.71$

$P_2=715 / 119.94=5.96$

$P_3=105 / 74.12=1.42$.

The average floret density of the entire head is

$P_0=1545:3.14 \times 10^2=4.90$ (achene/cm^2).

It should be noted that the increase of head productivity under the breeding aimed at high seed formation is connected with the increase of seed amount and seed weight as well.

CONCLUSIONS

Use of the method for quick determination of floret number and their density in the head according to zones provides better understanding of complicated processes of interaction of sunflower yield structure components. It also provides an opportunity for making accurate yield estimates aimed at identifying valuable breeding materials.

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METODO PARA LA DETERMINACION DEL NUMERO DE FLORES Y SU DENSIDAD A LA CABEZA DE GIRASOL

RESUMEN

El objetivo de este trabajo es de desarrollar un metodo simple para la calculacion del numero de flores y su densidad a la cabeza de girasol. La formula creada a base del promedio dorado sobre el numero de hileras mas cortas y el numero de flores por hilera. Dentro de menos de un minuto es posible de obtenir los datos iniciales para la calculacion del numero de flores por una cabeza.

METHODE DE DÉTERMINATION DU NOMBRE DE FLEURS ET DE LEUR DENSITÉ SUR LA TÊTE DE TOURNESOL

RÉSUMÉ

Le but de ce travail était de développer une méthode simple pour le calcul du nombre de fleurs et l'évaluation de leur densité sur la tête de tournesol. La méthode développée sur la base de la section dorée comprend les données initiales sur le nombre de rangées courtes et le nombre de fleurs dans la rangée. En moins d'une minute, il est possible d'obtenir les données initiales pour le calcul du nombre de fleurs par tête.