THE DEVELOPMENT OF ROOT CELLS IN RYE

by

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From life processes of cells the mechanism of division is probably best known and was studied also others by Hungarian research workers (G i m e s i and co-worker, 10, 11) as well. Recently Polish cytologists (24), especially B a j e r and co-worker (1, 2), obtained very important results which were even demonstrated by excellent cinematographical methods.

However, despite the data hitherto published (3, 6, 8, 9, 22, 23) the mechanism of growth and development of plant cells, the causes inducing these processes are not sufficiently known. Among the reasons responsible for division, growth and development attention was also paid lately to nucleic acids as substances having a considerable part in cell formation (7, 8, 12, 13, 14,24)

Out of the author's investigations dealing with these problems the present paper reports on correlations found between division rhythm, growth and development of root cells in rye seedlings of different polyploidy stage on the one hand and the nucleic acid phosphorus (NA – P) content of cells on the other.

Material and methods

For the examination of cell growth and cell development root cells proved very suitable being in different stages of growth and development according to their distance from the apex. Thus various zones may be differentiated in the root and the stages of cell development can easier be analysed and located (4, 8, 9,25).

As experimental material diploid and tetraploid forms of the rye variety Kisvárdai *(Secale cereale* ,,kisvárdai" 2 x = 14 and 4 x = 28) was chosen, in order to observe the correlation between chromosome number and developmental state of root cells.

The seeds chosen for examination were germinated in Petri dishes on filter paper moistured with tap-water; the samples were held in a dark thermostate at 28±2 °C. From the equally long seedling roots 2 and 5 mm thick segments were sectioned with a special slicing device (18). Number, weight and NA–P content of cells in the different root segments were regarded as indicators of growth, development and metabolism (4, 8, 14,24). Cell number was established according to B r o w n – R i c k l e s s (5), and NA-fractions were determined on the basis of their phosphorus content by the method of O g u r – R o s e n (19). Total NA–P resulted as the sum of ribose nucleic acid phosphorus (RNA–P) and desoxyribose nucleic acid phosphorus (DNA–P).

Average cell values were obtained by dividing the quantity of substances in various segments by the number of cells. The results presented here are arithmetical means of five parallel measurements (21), differing from each other by no more than 10 per cent.

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Results

Absolute data on analysis of root segments are shown in Table I.

Table I.

Number, weight and NA—P content of cells in root segments of rye seedlings

(2x = diploid, 4x = tetraploid variants)

Distance from the apex	Number of cells		Fresh weight		Dry weight		RNA–P		DNA–P	
			mg·10^{-2}				$\gamma \cdot 10^{-2}$			
mm	2x	4x	2x	4x	2x	4x	2x	4x	2x	4x
0 – 2	13 650	18 275	23,41	33,62	2,59	5,70	13,24	26,44	10,89	14,83
2 – 4	3 225	3 125	22,70	28 13	1,70	2,72	2,94	8,50	5,83	3,71
4 – 6	1 900	2 675	19,75	30,41	1,59	2,48	5,67	8,99	4,97	–
6 – 8	1 875	2 400	22,40	31,22	1,49	2,39	4,74	4,83	4,24	7,66
8 – 10	1 850	1 975	22,53	29,80	1,89	2,70	–	3,21	3,24	5,24
10 – 15	3 325	3 275	53,00	82,03	4,67	5,83	6,53	–	6,34	6,55
15 – 20	3 025	3 625	60,00	90,32	4,76	6,21	6,56	5,77	–	6,88

The number of cells is highest in the first segment and decreases to one quarter in the second; after the fourth millimeter the quantity of cells may practically be looked upon as constant. Data of the last two rows in Table I pertain to 5 mm thick segments. It may be seen that in diploid variants the number of cells drops to the seventh part of that in the first segment. In tetraploid variants the initial cell quantity is 50 per cent higher, but in the second segment a decrease similar to that in diploid forms may be observed. In the other segments of tetraploids this decline is suggestive of that in diploids but is somewhat slower falling to the tenth of the initial value in the last segment.

Fresh weights of examined root segments are nearly equal, ranging from 0.20 to 0.25 mg. This, too, indicates that the root has hardly thickened at a distance of 20 mm from the apex. In the root of tetraploid variants fresh weight is about 50 per cent higher than in diploids, but along the root it does not change considerably in this case either. The dry weight of segments reaches generally 6 to 11 per cent of the fresh weight in diploid variants and ranges from 6 to 16 per cent in tetraploids containing accordingly more dry matter, than the former. Greatest quantities (11 to 16 per cent) of dry matter are to be found in the apical segment; proceeding basipetally after the 3rd millimeter the dry weight remains below 10 per cent.

NA – P measurements revealed that in diploid forms RNA – P content of the apical segment is at least the double of the amount in successive ones; in tetraploids a triple surplus was found. Similarly the quantity of DNA – P is highest in the first segment amounting to about the double of that in the others.

A real picture on growth and development of cells may be obtained by expressing the results in terms of average cell data; these are presented in Table II.

Table II.

Weight and NA—P content in root cells of rye seedlings

(2x = diploid, 4x = tetraploid variants)

Distance from the apex	Fresh weight		Dry weight		RNA – P		DNA – P	
	per cell							
	$mg \cdot 10^{-5}$				$\gamma \cdot 10^{-5}$			
mm	2x	4x	2x	4x	2x	4x	2x	4x
0 – 2	1,71	1,83	0,19	0,31	0,96	1,44	0,79	0,81
2 – 4	7,04	8,99	0,52	0,87	0,91	2,72	1,80	1,18
4 – 6	10,36	11,36	0,83	0,92	2,98	3,36	2,61	–
6 – 8	11,94	13,00	0,79	0,99	2,52	2,01	2,26	3,19
8 – 10	12,16	15,08	1,02	1,36	–	1,62	1,75	2,65
10 – 15	15,93	25,03	1,40	1,78	1,96	–	1,90	2,00
15 – 20	19,83	24,91	1,57	1,71	2,16	1,59	–	1,89

In diploid variants fresh and dry weight of cells are lowest in the apical segment; the former increases in the second (2 to 4 mm) section to quadruple, the latter only to double or treble value, indicating that gain in weight results partly from water uptake. In the third (4 to 6 mm) segment fresh weight shows only a moderate ascent, remaining nearly on the same level in the consecutive sections (exactly to the 10th mm), rises again considerably between the 10th and 20th mm surpassing finally eleven times the initial stage. In tetraploid forms the fresh weight of cells in the apical segment is nearly identical with that in diploids and the increase is of uniform degree along the whole root; in the last (15 to 20 mm) section one fresh cell weighs thirteen times more than in the first.

Dry weight rises more consistently but considerably slower: in the last segment of the diploid variants it exceeds eight times, in tetraploids five and a half times the apical value. Accordingly, the increase of fresh weight is of a notably higher degree than that of dry weight and may be explained by water uptake and vacuoles formation in the cells.

The RNA – P content of diploid cells does not rise over the first four millimeters but trebles in the 3rd segment and shows subsequently a slight decrease so that its quantities in the last and first segments are nearly identical. To sum up: in dividing cells RNA – P has a minor, in growing ones a major and in developed cells a lower weight again.

The changes of DNA – P according to the different place of cells may be illustrated by a one-peak curve culminating with cells of the 3rd (4 to 6 mm) segment in diploid forms and with the fourth (6 to 8 mm) section in tetraploids; these cells contain the triple and fourfold quantity of DNA – P measured in meristematic apical cells. As compared with the maximum of DNA – P in the cells of the last segment a decrease of about 30 per cent may be observed.

Discussion

As to order of magnitude the metabolism indicators measured in root cells of rye seedlings correspond partly to results of earlier investigations conducted by the author with cereals (15, 16, 17) and partly to data of other research workers (8, 22, 23, 24, 25).

The changes of cell number in different rootsegments revealed that in rye seedlings – similarly to other cereals – the majority of cell divisions occur in the 0 to 3 mm section, which represents, therefore, the division zone. Because of all segments of about equal length und weight most cells are found in this zone, naturally the weight of individual cells in the lowest here. Cell growth starts at a distance of 2 to 3 mm from the apex as it is shown by weight data; accordingly this is the zone of expanding growth reaching to 5 to 6 mm and based principally on dry matter augmentation.

On further increase of fresh weight, however, probably water uptake has a considerable effect. Therefore, in the zone of vacuolization, the increase of dry matter continues too, but not so intensively as in cells nearer to the apex. This statement is also confirmed by the fact that dry matter content (expressed in per cent of fresh weight) is greatest – 10 to 16 per cent – in apical segments and decreases in the last sections to 6 to 10 per cent. These results agree with those of Burström (6) and Ziegler (22, 23).

The correlation between growth and protein content of cells was demonstrated by many authors (8, 22, 23), but the direct role of nucleic acids in cell growth is not sufficiently clarified as yet. Its indirect effect could be proved in protein synthesis, but a closer, direct influence on growth and development of cells can also be assumed. The author's data reveal that during division the RNA – P content of cells – at least in diploid variants – hardly changes, but suddenly trebles simultaneously with cell expansion (i. e. in the expansion zone). The same is true for tetraploids. In cells terminating their longitudinal growth the quantity of RNA – P does not continue to rise, but proceeding basipetally a slight reduction occurs in compliance with the progress of differentiation and the degree of vacuolization. The changes of RNA content according to cell development were also established by several authors, who, however, did not separate strictly the zones of cell division and cell growth. In the former the quantity of RNA – P is constant, in the latter it increases and in the vacuolization zone it remains unchanged or decreases.

In DNA – P content of cells changes of similar nature but of lesser degree were established by the author. His observations are contrary to most data of literature (9, 12, 13, 14), according to which an increase and doubling of DNA can take place between two divisions only. On the strength of the author's experimental results the different amounts of DNA – P in cells may be explained either by endopolyploidy or by the possibility that these quantitative changes can be induced not only by division but also by growth and development of the cell (8). The author tends to the latter hypothesis because neither diploid nor tetraploid variants do show the expected proportional alterations of DNA – P, and other experimental results have also proved its quantitative changes in cells of higher plants.

Summary

The author examined root cells in rye seedlings of different polyploidy and analyzed the correlations existing between growth and development of cells on the one hand and their nucleic acid phosphorus (NA – P) content on the other. He pointed out that the zone of cell division may be separated from those of growth and differentiation on the basis of changes in weight and NA – P content of cells in different root segments. Weight increase and dry matter augmentation can also be observed in vacuolized cells. In dividing cells NA – P content does not change, but becomes multiplied in growing ones and diminishes again in cells which had terminated their elongation. Desoxyribose nucleic acid phosphorus (DNA – P) content of cells changed as well and was not proportionate to the degree of polyploidy.

РЕЗЮМЕ

Автором была проанализирована связь между ростом клеток, развитием клетки как и содержанием фосфора в нуклеиновых кислотах клеток в клетках зародышевых корней ржаного растения на двух различных степенях полиплоидии. Им установлено, что зоны деления клеток, роста клеток и дифференциации можно выделить в сегментах корней на основе меры прибавления в весе клеток и изменения их содержания NS – P. Прибавку в весе и рост сухого вещества можно наблюдать даже и в вакуолизированных клетках. Содержание NS – P в разделяющихся клетках не изменяется, оно растет многократно в растущих клетках, а в клетках, у которых рост в длину уже закончен, оно снова уменьшается. Содержание DNS – P в клетках также изменилось и не было пропорциональным со степенью полиплоидии.

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