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Dynamics of early embryo development in reference to endosperm and embryo types in angiosperms

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Abstract

The mitotic cycle of the endosperm cells is relatively short in the first phases of the postfertilization development. The endosperm type does not significantly influence the duration of the mitotic cycle; it might, however, influence the dynamics of zygote and embryo development. The quick development and early end of cellular endosperm proliferation is connected with the fact that it is, in most cases, bound to small, "spare" or "saving" tenuinucellate and unitegmic ovules. Structural differences in the behaviour of the endosperm of different types, in the phase of globular and early heart embryo, might point to differences in the time or way of transition of the embryo from suspensorial to surface nutrition.

INTRODUCTION

In studies of the dynamics of the embryo and endosperm development, a basic relation is well known: after fertilization the endosperm develops more quickly than the embryo. In most cases, the exponential phase of embryo development begins only after cessation of cell division and often also after the end of endosperm volume growth. Though this relation is not valid without exception, its validity is very wide and seems to be linked with the function of the endosperm as nutrient tissue of the embryo.

The embryo endosperm relation has been studied in most cases together with the dynamics of seed or fruit development of these species of cultivated plants, which have fruits and seeds used in food industry. Most of these species, belonging to the families *Poaceae*, *Viciaceae*, *Rosaceae* etc., have endosperm of nuclear type.

In microcinematographical studies of the dynamics of endosperm development of *Jasione montana* and *Galanthus nivalis* (Erdelská, 1973), the author suggests the dynamics of embryo development to be linked to with the endosperm type.

MATERIAL AND METHODS

The mitotic cycle duration (in *Jasione montana* and *Galanthus nivalis*) was directly measured by microcinematography, and (in *Linum usitatissimum*) by evaluating fixed material in paraffin sections. During the brief microcinematographic studies, the isolated living seeds were kept in a medium of silicone fluid MS 200 (Midland Silicones Ltd., England) at a temperature of 25° C.

RESULTS AND DISCUSSION

In evaluating the results of the microcinematographical and cytological analysis, it was proved that the mitotic cycle is very short, in the early endosperm development, as compared with the mitotic cycle of other somatic cells. In most cases its duration varies between 6 and 12 hours. E.g. the mitotic cycle of *Jasione montana* lasts 6-8 h at 25° C and that of *Galanthus nivalis* 12 h under the same experimental conditions. Similar values have also been obtained by cytological analyses of the fixed seeds of *Linum usitatissimum*. A short, 6-h mitotic cycle was also found by Luxová (1968) in *Hordeum distichum* endosperm and by Hoshikawa (1973) in rice.

Probably, full protein synthesis does not occur necessarily in the first phases of endosperm development. This might shorten the mitotic or cell cycle. A proof for this fact is also the gradual decrease of the volume of endosperm nuclei in some species. E.g. the endosperm nuclei of *Galanthus nivalis* have after five divisions only 55-60% of the volume of the first two nuclei which were produced by the division of the primary endosperm nucleus. A similar phenomenon was also observed by Kapoor (1966) in the endosperm of *Nigella damascena*. In the cellular type of endosperm, the volume of the cells diminishes during the first developmental phases, similarly as that of embryonal cells in early embryo development (Pollock, Jensen, 1964).

Although the mitotic cycle in the endosperm of cellular type might have been expected to be longer than in the nuclear type, it was found that this is not always the case. Comparing the duration of the mitotic cycle in the cellular type of endosperm in *Jasione montana* with the nuclear type, in *Galanthus nivalis* even the opposite has been found. The longer mitotic cycle in the endosperm of *Galanthus nivalis* is apparently connected with other endogenous factors influencing the mitotic cycle, such as higher DNA content of the nuclei etc. It seems that cell wall formation has no influence on the considerable prolongation of the cell cycle during early endosperm development.

As a matter of fact, what are the embryo dynamic kinds within the different endosperm types? Answering this, it is necessary to start from the different medium conditions which are at the disposal of the embryo within the endosperm of a definite type. Differences in the area belong to the characteristic dissimilarities. The developmental dynamics of the zygote, and of the globular and linear embryo, often reflects the fact that the zygote and the young embryo have no ability to dissolve cell walls in the cellular type of endosperm. The zygote of many species of the *Sympetalae* with cellular type of endosperm, therefore, occupies by relatively quick growth such an area in the embryo sac, which is, in general, sufficient for the linear and partially also for the globular phase of embryo development. E.g. in *Jasione montana (Campanulaceae),* the zygote begins to grow during the first two divisions in the endosperm, up to the formation of a protuberance reaching about one half of the embryo sac length. At 25 °C, the zygote grows at a rate of 5-6 μm/h for about 12 hours, forming a protuberance of 60-80 μm. In the area occupied in this way, or in an area somewhat enlarged, the linear and partially also the globular phase of embryo development occur. A zone of degenerating endosperm cells, indicating the start of the digestive activity of the embryo, begins to arise around the globular embryo, in most cases only after formation of the protoderm. At this time, the number of the endosperm cells reaches already its final or a nearly final value.

On the contrary, the development of the zygote and of the linear and globular embryo proceeds more uniformly in species with the nuclear endosperm type. An interesting structural difference in the embryo-endosperm relation can be observed at the phase of late globular and early heart-shaped embryo. Here, structurally opposite processes take place in the endosperm of the cellular and the nuclear type. In the cellular endosperm, a zone of destroyed endospermal cells forms around the embryo, whereas in the nuclear type of endosperm cellularization occurs around the embryo. This might eventually indicate differences in the time and in the type of transition of the embryo from suspensor nutrition to surface endospermal one, in different types of endosperm.

When comparing the developmental rate of the ambryo in the endosperm of nuclear type in *Linum usitatissimum* with that in the endosperm of cellular type in *Jasione montana,* it has been found that the linear phase of development lasts approximately the same time (36-48 h) in both the embryos. As early as in the linear, but first of all in the globular phase, the embryo endosperm cell number relation increases significantly in the species with cellular endosperm, as compared with the species with nuclear type of endosperm. At the time of embryo

protoderm formation, the cellular endosperm of *Jasione montana* already shows 80-90% of the final amount of cells, whereas the endosperm of *Linum usitatissimum* is only in the initial stage of its development.

The rapid achievement of proliferation in the cellular type of endosperm is, in most cases, connected with a low final number of endosperm cells and with relatively small volumes of mature seeds. The cellular type of endosperm is almost entirely bound to small "saving" or "spare' ovules, in most cases tenuinucellate and unitegmic ones, whereas, 90% of the species with crassinucellate and bitegmic ovules have an endosperm of nuclear type.

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ORAL DISCUSSION

M. Favre-Duchartre: The most valuable experimental data afforded by Erdelska's communication seem to me, more accurate than other ones, confirming? The theoretical joint of view I was presenting yesterday, i.e. the endosperms precipitated proliferation is to be homologated to that of gymnosperm proembryos: the new 3 n (or 2 n) DNA would not have time enough to be translated into new RNA allowing corresponding proteins to be synthesized, hense the undifferentiated, proembryo-like appearance of the endosperm.

J. P. Mascarenhas: In the sea urchin embryo during cleavage DNA synthesis and cell divisions occur very rapidly. However, RNA synthesis, i.e. nuclear RNA and messenger RNA synthesis still continues. You might see Chapter 5, Figures 5-5 and 5-6 and Table 5-2 in th book "Gene Activity in Early Development" by E. H. Davidson, Academic Press, N. Y., 1976.

I would tend to think that the nuclei in the endosperm are preprogrammed to behave the way they do, and this is not the result of rapid cell divisions. After all, the sea urchin egg for example, divides every 20 to 30 minutes during cleavage in some species, and the embryo still differentiates.