Lignification commencement in roots is controlled by the time after elongation completion

N.V. Obroucheva

Institute of plant physiology, Botanical street 35, Moscow 127276, Russia

Phone 7(499)2318330, fax 7(495)9778018, e-mail: n.obroucheva@mail.ru

ABSTRACT

Common event is that deceleration of root growth results in cell differentiation closer to the root tip. In tree roots, autumn appearance of xylem behind several remained meristematic cell is an extreme case. This phenomenon is usually considered an acceleration of cell differentiation. To verify this opinion, the time course of lignification was investigated in rapidly growing roots of maize seedlings as compared with roots slowly growing in chloramphenicol solution (0.05 mg/ml) and roots irradiated by X-rays (10 kR) which extended only a day and then stopped. The appearance of lignin precursors (free coniferyl and syringyl groups) was examined histochemically. Lignification started in protoxylem (both groups), in Casparian strips and middle plates of endodermal cell walls (coniferyl groups) and then in exoderm (coniferyl groups).The slower root growth was, the nearer to root tip lignification began. However, we related the commencement of these processes to the completion of cell elongation. The time scale showed that in fully-elongated cells lignin precursor appearance is almost similar in all treatments. Therefore, the deceleration or cessation of cell division in root meristem results in elongation deceleration, but after completion of elongation the lignification occurs at almost the same rate. No acceleration of cell differentiation was observed, its program starts to progress independently of root growth rate, just after root cells fully elongated.

KEYWORDS: growth rate, cell differentiation, lignification, completion of elongation

INTRODUCTION

Lignification is a particular case of cell differentiation occurring in growing roots. The relationship between cell growth and differentiation needs a special investigation because the general opinion claims that growth retardation leads to accelerated differentiation. For example, in tree roots arrested their growth in autumn, xylem vessels approached several remained meristematic cells, giving the impression that xylem differentiation speeded up. To check the validity of this conclusion, we compared the time course of cell wall lignification in rapidly and slowly growing maize roots as well as in roots with arrested growth.

METHODS

Zea mays 25-40-mm long roots were grown for three days in Petri dishes in water (control roots), in chloramphenicol solution (50 mg/l) or were preliminarily irradiated with X-rays at the dose of 10 kR and then incubated in water. Every day the sections hand-made along the root were examined under microscope for cell wall lignification. Coniferyl lignin groups were visualized after treatment with 1% floroglucin solution and concentrated HCl (Wisner reaction), whereas Mäule reaction indicated the syringyl groups of lignin.

RESULTS

In control roots growing at constant rate, lignification started first of all in Casparian strips of endodermal cell walls due to the appearance of coniferyl groups of lignin at the distance of 60 – 80- mm from the root tip. Later, at the distance of 80 – 100- mm, coniferyl groups became visible in the endodermal middle lamellae. No syringyl groups were found in these cell walls. A bit later coniferyl lignin groups were synthesized in protoxylem vessels (70 – 100- mm) and then syringyl groups appeared (90 -- 120-mm). The colored cell walls were visible at first in the smallest vessels situated close to pericycle, and then the color reactions spread to the large vessels. No lignin groups were recognized in metaxylem and xylem parenchyma, their differentiation did not begin up to the end of experiment. The latest tissue in seedling roots, in which the color reaction for coniferyl lignin groups was visualized in cell walls, is exoderm (at the distance of 90 – 120-mm from the root tip). Apparently, in maize roots lignin biosynthesis begins by obligatory formation of coniferyl groups, and only in protoxylem cell walls they are supplemented with syringyl groups.

Slowly growing roots in chloramphenicol solution were 100-mm long in average, as compared to the control roots grown up to 200-mm for three days. In these roots, the order of lignification commencement remained the same and lignin composition did not change. However, the appearance of coniferyl and syringyl groups occurred much closer to the root tip. For example, the coniferyl groups appeared in protoxylem at the distances of 50 – 70-mm during two days, and at 22 – 32-mm on the third day, when root growth rate declined.

The roots irradiated with high dose of X-rays were growing slower then the roots in chloramphenicol solution and ceased their growth on the second day due to division arrest, exhaustion of meristematic pool and almost total transition of meristematic cells to elongation.

Lignin biosynthesis was not disturbed in these roots, but lignification approached the root tip.

For illustration, coniferyl groups in protoxylem vessels became visible during two days at 40 – 60- mm from root tip, but after growth cessation they revealed themselves even at 3 – 7- mm distance and the following syringyl groups were seen at 15 – 35-mm.

To properly compare the results obtained, we analyzed them in temporal terms since the completion of elongation by root cells, i.e. zero point was the time when the cells finished their elongation and became mature. In control roots, zero point was at the distance of 8-10-mm from root tip. In irradiated and chloramphenicol-treated roots zero point gradually displaced to the root tip due to arrested or hindered cell divisions. If the root growth rate and the distance of the place of interest behind the end of elongation zone (zero point) are known, it easy to calculate how many hours passed after elongation completion till the appearance of one or other lignin group. It turned out that within the accuracy limits used, lignin groups appeared at the same time after elongation completion independent of growth rate, i.e. in rapidly or slowly growing roots and after growth cessation too. Coniferyl groups appeared in Casparian strips during 15 – 30 h after elongation completion, in protoxylem cell walls at 25 – 40 h, in endodermal middle lamellae at 30 – 50 h and in exoderm at 35 – 55 h. The syringyl groups of lignin were synthesized in protoxylem by 30 – 60 h.

The conclusion is that cell differentiation, lignification in particular, starts in growing roots after cell growth termination, its program being realized after the end of cell elongation at the same constant rate, independent of root growth rate, i.e. the rates of cell division and elongation.