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Role of auxin and nitric oxide on growth and development of lateral root of plants: possible involvement of exogenously induced Phot1

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ABSTRACT: Development of root architecture including lateral root formation is a critical event for successful growth of plants. Auxin promotes the production of nitric oxide (NO) in roots, which is required for auxin-mediated root organogenesis. Inhibition of auxin transport reduced phototropin1 (Phot1)-GFP expression at the basal and central part of LRs, indicating role of auxin in Phot1 expression in lateral roots. However, the involvement of auxin-mediated NO on Phot1 expression in LR growth and development yet to be explored. This review gives an insight that auxin-mediated NO may lead to LR growth and development through interacting with Phot1.

KEYWORDS: Auxin, NO, Phot1, LR development

LATERAL ROOT IN PLANT GROWTH AND DEVELOPMENT

Lateral root (LR) development in Arabidopsis can be used as a model for the study of factors that regulate organogenesis of plants. Development of root architecture including LR formation is a critical event for successful growth of plants [1]. Whereas the structure of the LR itself is highly predictable, the number, placement and direction of growth of LRs in the system are all highly variable. Expansion of LRs in root system help to increase the surface area for absorption of water/nutrient from environment and enrich the capability to anchorage [2] ;[3]. Generally, LR primordia and the youngest LRs are located close to the root tip as well as older LRs are come upon higher in the root [4]. In most of the plants, LRs grow horizontally and then start to grow at vertically and however, this phenomenon is not because of gravitropic response in *Arabidopsis* plants [5].

PHOTOTROPIN1 IN PLANT GROWTH AND DEVELOPMENT

Plant growth is regulated by many kinds of factor including environmental and climatic. Generally, plants respond to stimuli or signals from their environment in order to live successfully. These include light, wind and gravity. Among them, light is the most important environmental signal that is involved in various responses. After receiving signals by photoreceptor, the plant converts them into different physiological responses. The nature of the photoreceptor depends upon the stimulus and the receptor is a pigment/molecule that absorbs light.

Phototropism is a process through which plant organs can respond to changes in light direction to maximize photosynthetic potential, and support root growth for water/nutrient acquisition [6]. The photoreceptor kinase phototropin 1 (Phot1) was the first of two phototropin photoreceptors mediating phototropism and other blue light responses described [7]. The *A. thaliana*Phot1-5 mutant was characterized as defective in both shoot and root phototropism [8]. Galen and co-workers showed that the abundance of blue light receptor Phot1 in roots is correlated with enhanced root growth efficiency [9]. As in the case for positive shoot phototropism in etiolated *Arabidopsis* hypocotyls, negative root phototropism is mediated by Phot1[8]. Another group reported that the endogenous Phot1 has negative effect on LR formation and root growth [10]. Inhibition of auxin transport by NPA reduced Phot1-GFP expression at the basal and central part of LRs, indicating role of auxin in Phot1 expression in LRs [11].

AUXIN IN PLANT GROWTH AND DEVELOPMENT

In multicellular organisms, growth and development, including proper pattern formation and organogenesis, must be tightly regulated. In plants, the phytohormone auxin plays a prominent role in controlling nearly every step in growth and development [12]. Additionally, auxin is an important mediator of LR development [13]; [14]. Considerable progress has recently been made describing the role of auxin during LR formation in *A. thaliana* [15]; [16]. In *Arabidopsis*, mutation in auxin regulatory genes are shown to arrest LR development at various stages [17].

The light environment has been known to regulate polar auxin transport that drives developmental programs of plants [18]. Pre-initiation, initiation, and post-initiation are considered as three major steps of LR formation [16]. The precise role of auxin deposition has been observed in LR initiation as well as in the production of a new root [19], and also measured in both pre- and post initiation actions including emergence [16]. LR initiation is regulated by auxin originating from the root tip [20] ; [21] , whereas emergence depends exclusively on auxin derived from the shoot [22]. In addition, after emergence LRs can synthesize their own auxin [23]. Further, inhibition of emergence is involved with elimination of the leaves and cotyledons [24]. Additionally (Utsuno *et al.[25]* and Marchant *et al. [26]* demonstrated that auxin transport plays an important function in root growth and development. Further, application of auxin transporter, IAA to plants enhance LR development and LR elongation [25]; [26]; [27]. On the other hand, use of auxin-transport inhibitors, NPA reduces the number of LR in tomato grown on agar [27]. Further, development of LR may be affected by variation in auxin transports and inhibitors. Normally, blue light induces Phot1 expression which ultimately inhibits LR formation through decreasing the effects of auxin. Phot1 and phot2 both are functional serine/threonine protein kinase photoreceptors [28]. The phototropins absorb blue light and activate the kinase domain [7]. Though perception of directional blue light leads to phototropic curvature through differential accumulation of auxin [29], the mechanism by which phototropin activation initiates signaling leading to this signal output remains elusive. However, recent report suggest that exogenous auxin and Phot1 directly helps in formation of blue light through binding auxin to Phot1 promoter region and mediates transcription of various effects on blue light formation [11]. Additionally, inhibition of auxin transport by NPA reduces Phot1-GFP expression at the basal and central part of LRs, indicating role of auxin in Phot1 expression in LRs [11].

In addition, fungal contamination is a common problem in culture of *Arabidopsis* seedling in laboratory condition and many phytopathogenic fungi produce most common natural auxin (indole-3-acetic acid, IAA) in culture [30] ; [31]. Therefore, it is suggested that the effects of fungal contamination on expression of 1 in LR at different developmental stages may occur. Surprisingly, we found that fungal contamination significantly decreased Phot1 expression with the progress of days (our preliminary data).

NITRIC OXIDE IN PLANT GROWTH AND DEVELOPMENT

Nitric oxide (NO) is a well-known stress signaling molecule that plays a crucialrole during plant defense against pathogens [14]. Recently, a more fundamental role in basic growth processes has been discussed. Rather surprisingly, NO has been reported to function as a downstream signaling molecule of auxin-induced lateral and adventitious root formation [32] ; [33]. Moreover, gravistimulation of roots not only induces auxin accumulation at the lower root flank, but also of NO [34] ; [35] ; [36], and a reduction in the NO level inhibits gravitropic bending of gravistimulated root apices [35].

Development of root architecture including LR formation is a critical event for successful growth of plants [1]. Auxin promotes the production of nitric oxide (NO) in roots, which is required for auxin-mediated root organogenesis [37] ; [38]. NO inhibits blue light-induced stomatal opening by regulating the K+ influx in guard cells. Inhibition of auxin transport by NPA reduced 1-GFP expression at the basal and central part of LRs, indicating role of auxin in Phot1 expression in LRs [11]. However, roles of auxin-mediated NO on Phot1 expression in LR growth and development need to be explored.

PROSPECTS AND FUTURE DIRECTIONS

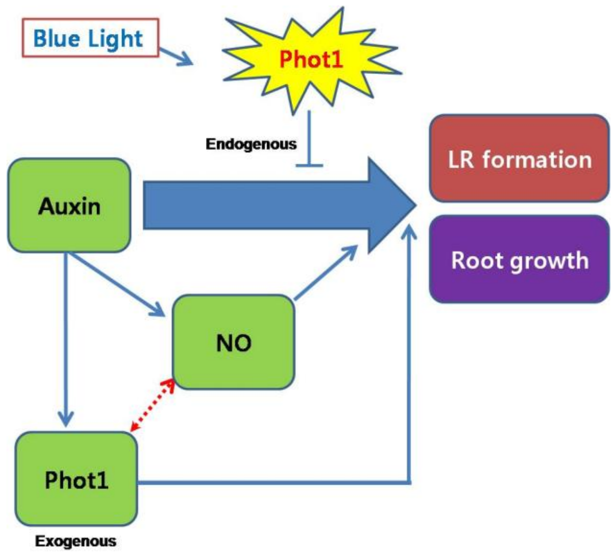

Figure 1. Suggested schematic diagram. Blue light induces Phot1 expression which inhibits LR formation. On the other hand, exogenous auxin and NO directly helps in formation of LR. Exogenous source of auxin enhances Phot1expression which helps LR formation. Evidences indicate that there is a functional involvement of Auxin, NO, and Phot1 in LR growth.

Throughout this review we highlighted the diverse mechanisms by which Phot1 has been involved in LR growth and development in plants. Blue light induces Phot1 expression which ultimately inhibits LR formation through decreasing the effects of auxin. On the other hand, exogenous auxin and NO directly helps in formation of LR. Auxin binds to Phot1 promoter region and mediates transcription of various effects on LR formation. These evidences suggest that auxin-mediated LR formation may be regulated by interact between Phot1 and NO (Figure 1). To advance our understanding on the mechanisms of LR formation through determining the role of NO to influence the regulation of Phot1 would be of matter of interest in order to develop strategy to enhance plant growth and development.

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CONFLICTS OF INTERESTS

None of the authors declared any competing interest.

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