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# How plasma activated water regulates plant development and growth

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Research on plasmas has been conducted for a variety of applications: various bio fields, biomedicine, plasma-based plant growth and germination, postharvest and food storage, and food safety including pesticide elimination[1]. Low temperature plasma has broadly been mentioned in the germination and growth of plants using different kinds of plasma devices [2,3]. Plasma treatment of seeds has been shown to activate the germination rate in crops and to alter the seed coat morphology of *Arabidopsis* by inhibiting bacteria on the seed surface that penetrate into the seed[2,4]. Plasma and plasma activated water (PAW) are actively involved in plant growth from a physiological and cultivation aspect; however, investigation on a genetic and cellular level of the underlying molecular mechanisms of plant growth due to PAW treatment remains largely undiscovered.

To produce the PAW, surface dielectric barrier discharge (sDBD) was used to produce 6 different PAW treatment conditions by varying the plasma treatment time of the water which is the plasma treatment time for the PAW : 0 min. (the control, deionized water (DW)) and 5, 7, 12, 32 and 40 min. (PAW5,7,12,32,40) (Fig. 1a and b). Interestingly, the PAW12 treated seedlings had an enhanced root hair length and more root hairs on the primary root compared with those treated with just DW (Fig. 1c). The tobacco seedlings had an elongated cotyledon when the 8 day-old seedlings were treated with the PAW12 condition (Fig. 1d). In the cellular level, the palisade leaf cell numbers were not different in the seedlings treated with DW and the PAW12 in the leaf length direction; however, the cell size of the cotyledons was dramatically elongated in the leaf length direction

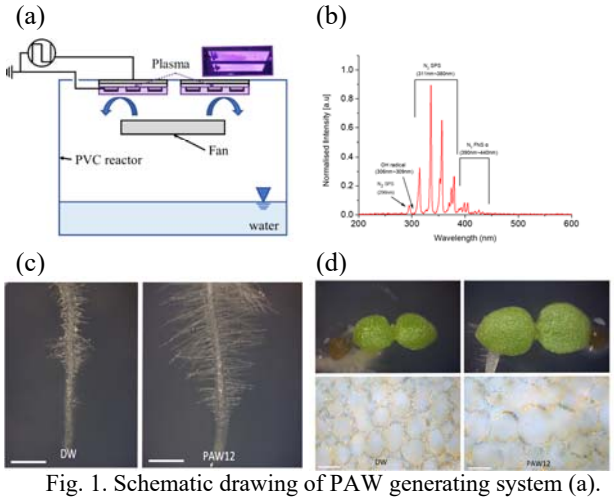


Fig. 1. Schematic drawing of PAW generating system (a). Optical emission spectrum of the sDBD with gas from 200 to 600nm (b). Treatment effect on tobacco (c,d)

To understand how the effect of the PAW regulates the plant morphology through target genes, we performed a qRT-PCR analysis to determine the molecular targets in the PAW treated tobacco using PAW12 and PAW40 and DW as the control. In Arabidopsis, the well-known *COBRA-LIKE 9* (*COBL9*) [*DEFORMED 9* (*DER9*), AT5G49270] is involved in root hair growth and elongation[5] and the orthologous gene for COBRA-LIKE 9 in Nicotiana tabacum was found to be a homologous gene to*NT_COBRALIKE*(*NT_COBL*,Nitab4.5_0000629g0010).

The Xyloglucan endotransglucosylase/hydrolases (*XTH*) gene family is a strong candidate gene family involved in cell wall modification and in regulating cell size, and several Arabidopsis *XTH* genes are involved in root growth[7,8]. This study concluded that *NT-XTH9* and *NT-XTH15* were positively regulated by the PAW12 and PAW40 condition in tobacco root tissue while *NT-XTH5* was negatively regulated by the PAW (Fig. 2).

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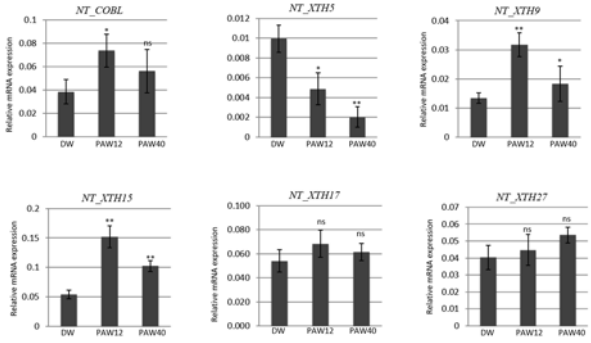


Fig. 2. Altered gene expression shown by qRT-PCR in the DW, PAW12 and PAW40 seedlings.

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