Hydro-Electro Hybrid Priming Promotes Carrot (Daucus carota L.) Seed Germination by Activating Lipid Utilization and Respiratory Metabolism in Advance

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Introduction

Carrot (Daucus carota L.) seed coat is poorly water permeable and seed germination is slow and patchy, causing obstacles to the large-scale cultivation. The application of high voltage electrostatic field (EF) for seed pre-sowing treatment belongs to the research field of agriculture physics. Researches on a variety of crops have shown that EF was able to improve seed vigor in a short time with simple device and operation. In addition, seed priming enables seeds to reach the pre-germination state when the radicle is about to break through the seed coat, allowing the seeds to carry out the metabolic process related to germination in advance. Here we have combined EF and hydro-priming (HYD) to form a hydro-electro hybrid priming (HEHP), one method without intervention of any exogenous chemical agent or plant growth regulator, in order to realize the superposition of the advantages of the two single initiation modes. Furthermore, through observation on subcellular structure of endosperm, physiological determination and transcriptome analysis, we focused on the lipid utilization and respiratory metabolism related to the response of carrot seed germination to seed priming. This study set out with the objectives of investigating the metabolic pathway related to carrot seed germination induced by priming treatments, and the reason of the optimal effect in HEHP among all treatments.

Methods

Carrot cultivar Naasis was used in this study. For HYD and HEHP treatments, the carrot seeds were first soaked in distilled water at 20 °C for 6 h. Then for HEHP, the positive and negative electrodes of a BM-201 electrostatic field generator (made in Jiangsu, China) were connected to two 10 cm × 10 cm copper plates placed 1 cm apart; the seeds were placed on the lower plate (cathode) and exposed to a 2 kV/cm EF for 90 s after absorbing the surface moisture with absorbent paper. The EF parameters were widely selected by pre-experiment. Then HYD and HEHP were imbibed in a climate chamber (QIX-300BSIII, made in Shanghai, China) set at 22 °C at 98% humidity for 48 h in dark, and then desiccated at 25 °C in a drum wind dryer until the initial weight was achieved. For EF, the seeds were only exposed to a 2 kV/cm EF for 90 s. The control (CK) was not treated in any way. The detailed treatment procedures are listed in Table 1.

Table 1. Priming treatments and processing protocols.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soaking</th>
<th>Electrostatic field irradiation</th>
<th>Incubation</th>
<th>Desiccation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>X</td>
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<tr>
<td>EF</td>
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<tr>
<td>HYD</td>
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<tr>
<td>HEHP</td>
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</table>

Results

Compared to control seeds, HEHP enhanced GP and GR by 219.6% and 22.2% respectively. The Gl and VI of HEHP were 3.1 folds and 6.8 folds higher than that of CK. At 120h after sowing, the cotyledons of carrot seedlings treated with HEHP were almost exposed, while the radicle of CK and EF just extended out of the seed coat (Fig 2B).

Conclusion

HEHP contributed to promoting the germination of carrot seeds to a greater extent, of which the effect was better than HYD and EF alone. The followed determination demonstrated that priming treatments especially HEHP promoted the utilization of storage lipid in carrot seeds. The key enzyme activities of glyoxylate cycle, glycolysis, tricarboxylate cycle and anaerobic respiratory metabolism were significantly increased by HEHP treatment. Furthermore, the above metabolic pathways were significantly enriched by transcriptome analysis and qPCR analysis confirmed the expression pattern of critical DEGs in different processes involved in the enriched pathway. One significant finding to emerge from this study is that the transformation of malate, oxalacetate, phosphoenolpyruvate and pyruvate occurred in cytoplasm may be pivotal for the regulation of carrot germination, maybe acting as a pivot from lipid utilization to respiratory metabolism. Taken together, the effect of HEHP is to improve the efficiency of energy supply in the early stage of germination by mitrating the storage lipid utilization and respiratory metabolism pathways related to the germination of carrot seeds in advance, and then promote germination.

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