

Overdominance at the Gene Expression Level Plays a Critical Role in the Hybrid Root Growth of *Brassica napus*

Nesma Shalby ^{1,2}, **Ibrahim A. A. Mohamed** ^{2,3}, Jie Xiong ¹, Kaining Hu ¹, Yebitao Yang ¹, Elsayed Nishawy ⁴, Bin Yi ¹, Jing Wen ¹, Chaozhi Ma ¹, Jinxiong Shen ¹, Tingdong Fu ¹ and Jinxing Tu ^{1,*}
¹ National Key Laboratory of Crop Genetic Improvement, Hubei Hongshan Laboratory, Huazhong Agricultural University, Wuhan 430070, China; nas05@fayoum.edu.eg (N.S.); xiongjie307@webmail.hzau.edu.cn (J.X.); hukaining@gmail.com (K.H.); yybt1234@163.com (Y.Y.); yibin@mail.hzau.edu.cn (B.Y.); wenjing@mail.hzau.edu.cn (J.W.); yuanbeauty@mail.hzau.edu.cn (C.M.); jxshen@mail.hzau.edu.cn (J.S.); futing@mail.hzau.edu.cn (T.F.)
² Faculty of Agriculture, Fayoum University, Fayoum 63514, Egypt; iaa04@fayoum.edu.eg
³ MOA Key Laboratory of Crop Ecophysiology and Farming System in the Middle Reaches of the Yangtze River, College of Plant Science and Technology, Huazhong Agricultural University, Wuhan 430070, China
⁴ Desert Research Center, Genetics Resource Department, Egyptian Deserts Gene Bank, Cairo 11735, Egypt; elnishawy@mail.hzau.edu.cn

* Correspondence: tujx@mail.hzau.edu.cn; Tel.: +86-027-8728-1819

Abstract: Despite heterosis contributing to genetic improvements in crops, root growth heterosis in rapeseed plants is poorly understood at the molecular level. The current study was performed to discover key differentially expressed genes (DEGs) related to heterosis in two hybrids with contrasting root growth performance (FO; high hybrid and FV; low hybrid) based on analysis of the root heterosis effect. Based on comparative transcriptomic analysis, we believe that the overdominance at the gene expression level plays a critical role in hybrid roots' early biomass heterosis. Our findings imply that a considerable increase in up-regulation of gene expression underpins heterosis. In the FO hybrid, high expression of DEGs overdominant in the starch/sucrose and galactose metabolic pathways revealed a link between hybrid vigor and root growth. DEGs linked to auxin, cytokinin, brassinosteroids, ethylene, and abscisic acid were also specified, showing that these hormones may enhance mechanisms of root growth and the development in the FO hybrid. Moreover, transcription factors such as MYB, ERF, bHLH, NAC, bZIP, and WRKY are thought to control downstream genes involved in root growth. Overall, this is the first study to provide a better understanding related to the regulation of the molecular mechanism of heterosis, which assists in rapeseed growth and yield improvement.

Keywords: heterosis; *Brassica napus*; root growth; overdominant; plant hormones; carbohydrate metabolism; transcription factors