Synthetic microbial community in pristine environment promotes the growth of the endangered plant *Lilium tsingtauense*

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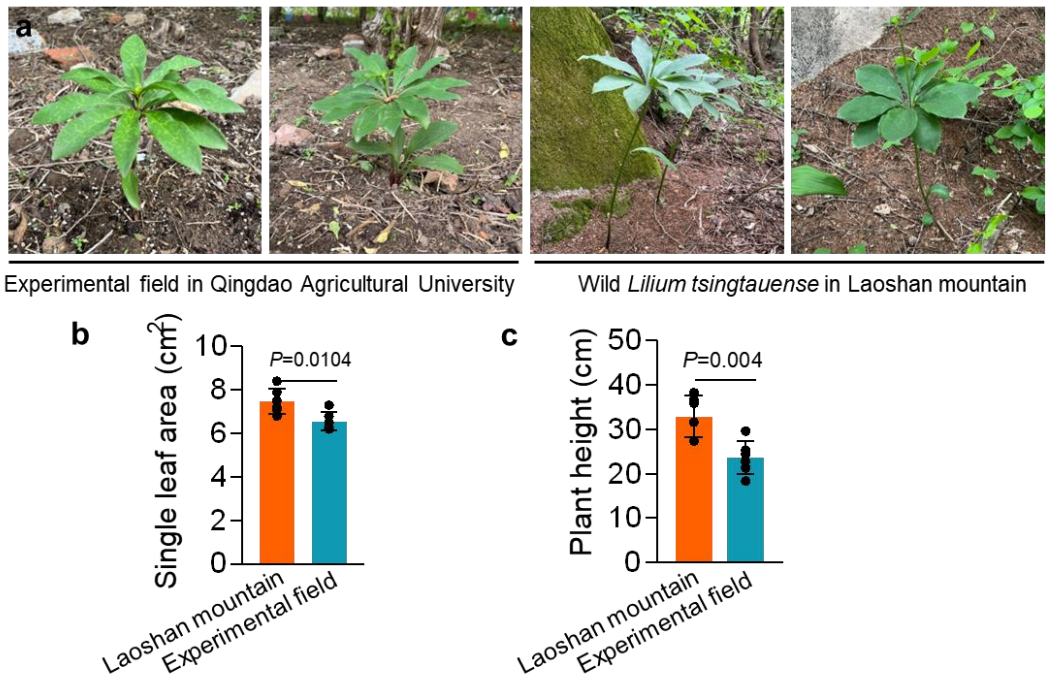
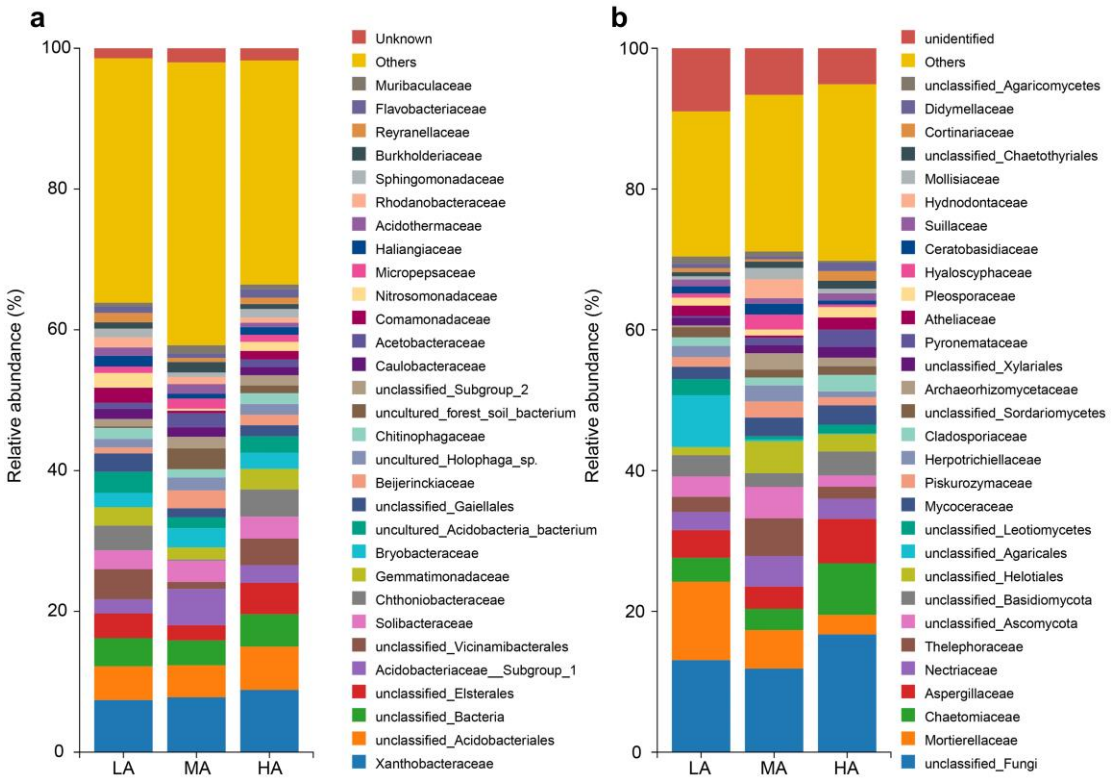
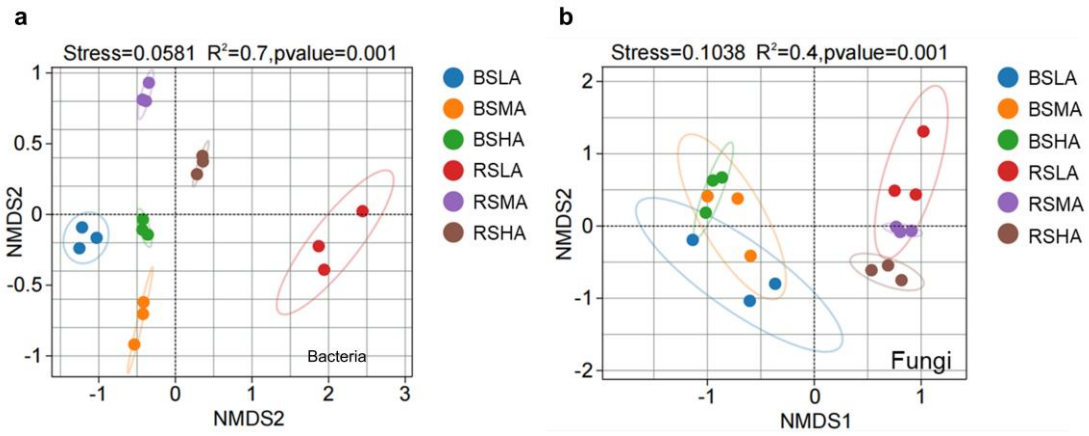


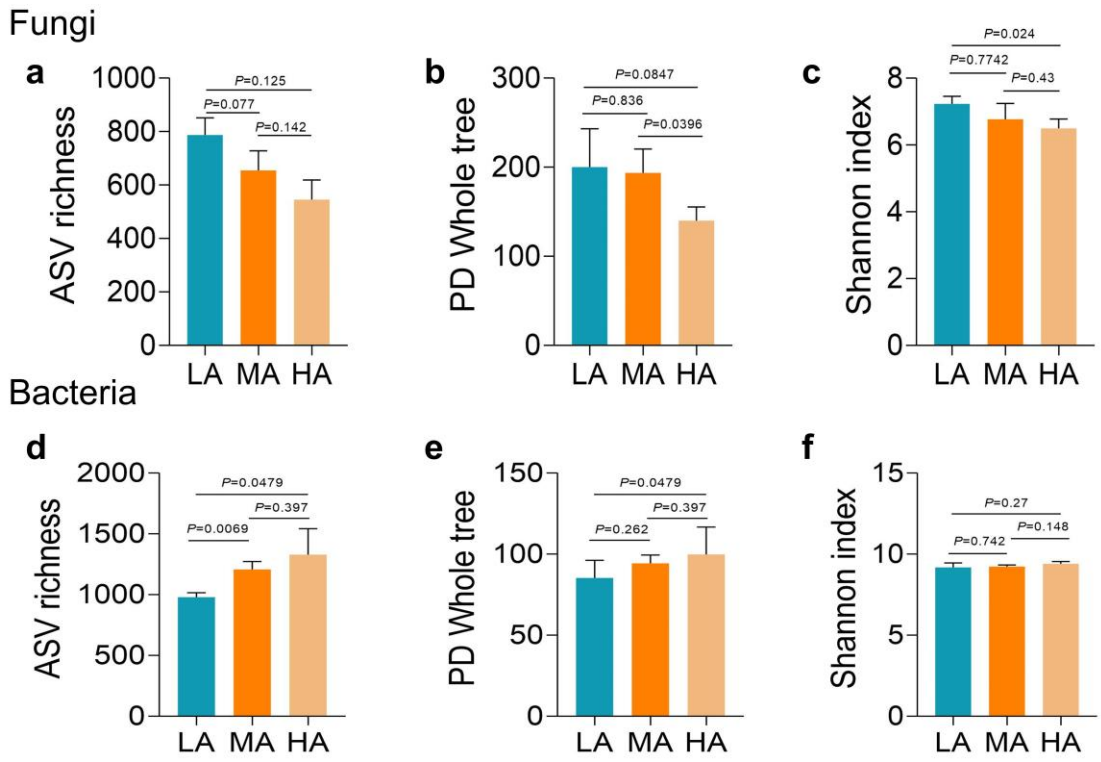
Supplementary Fig. 1. The growth status of Qingdao lily in experiment field and native environment. a *Lilium tsingtauense* growth condition in experimental field of Qingdao Agricultural University and Laoshan mountain region of Qingdao in May 2023. Single leaf area (**b**) and Plant height (**c**) of *L. tsingtauense* from the Laoshan mountain and experimental field. ($P < 0.05$, student's *t*-test, n = 6 biologically independent plants). Data bars represent means, and error bars represent the standard error of mean.



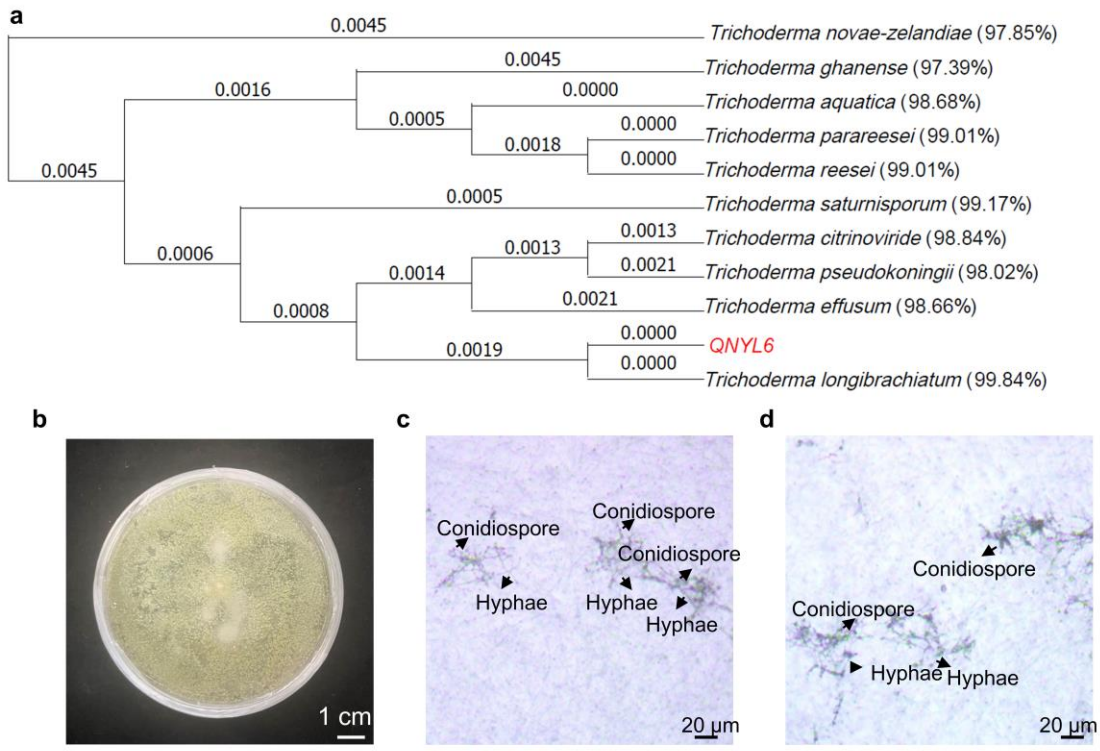
Supplementary Fig. 2. The relative abundance of rhizosphere bacteria (a) and fungi (b) at family level at three different altitudes. LA, MA, and HA indicate low altitude, middle altitude, and high altitude, respectively.



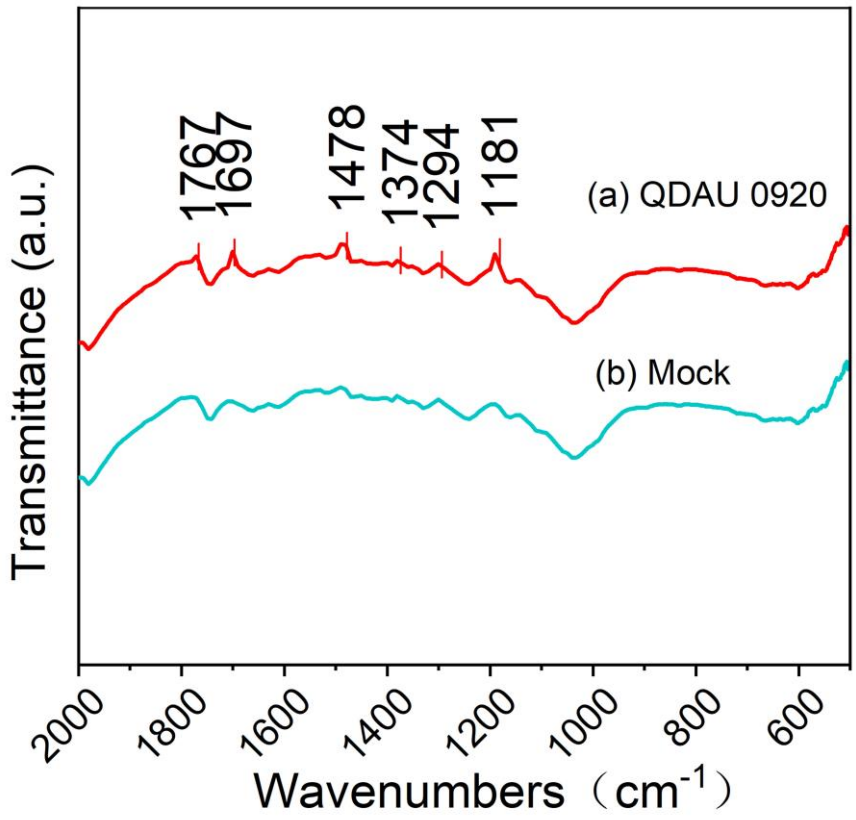
Supplementary Fig. 3. Nonmetric multidimensional scaling (NMDS) analysis of bacterial (a) and fungal (b) beta diversity from representative altitude gradients. BSLA, Low altitude bulk soil. BSMA, middle altitude bulk soil. BSHA, high altitude bulk soil. BSLA, Low altitude rhizosphere soil. BSMA, middle altitude rhizosphere soil. BSHA, high altitude rhizosphere soil.



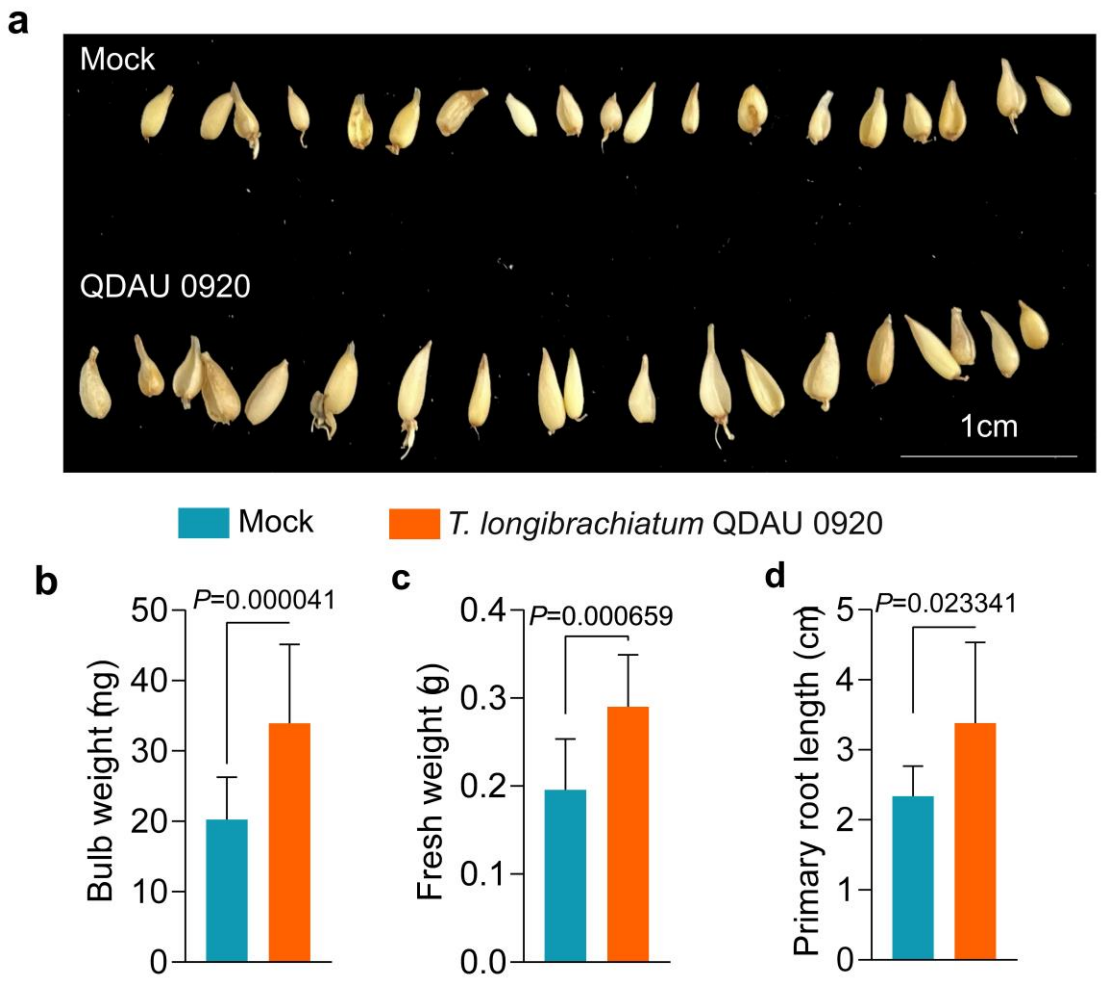
Supplementary Fig. 4. General patterns of fungal and bacterial alpha-diversity with bulk soil at three altitudes according to ASV richness (a, d), PD whole tree (b, e), and Shannon index (c, f). LA, low altitude. MA, middle altitude. HA, high altitude. Data represent means ± standard error (SE) of three biological replicates (n=3). Significant differences ($P < 0.05$) were determined by one-way ANOVA followed by Tukey's test.



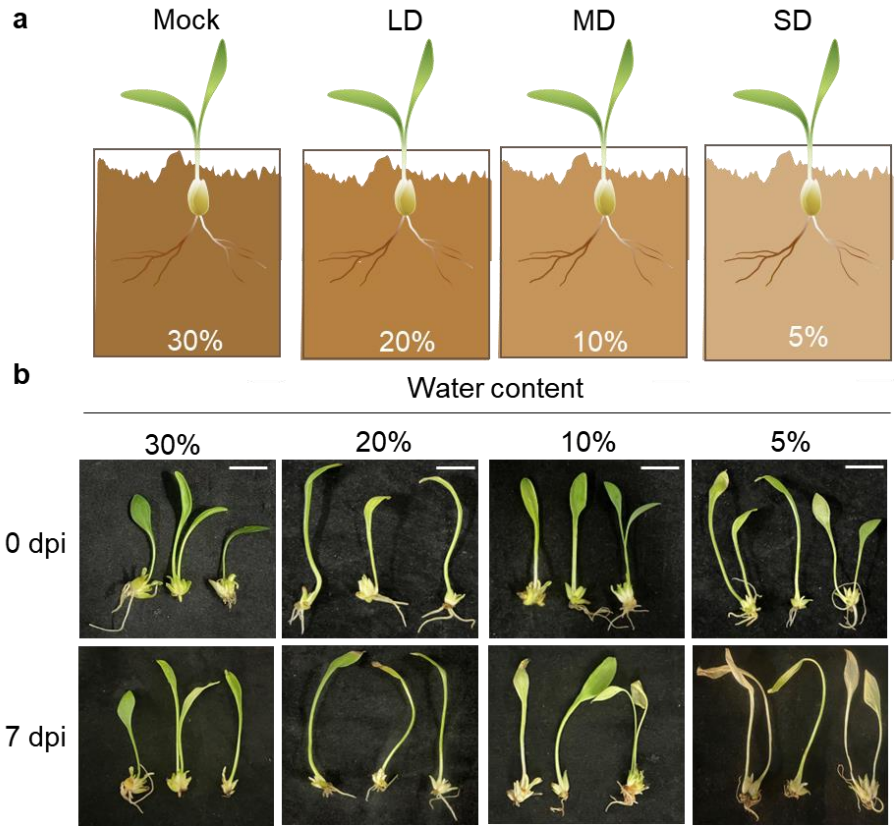
Supplementary Fig. 5. Morphogenesis of the strain QNYL6. a Maximum likelihood phylogenetic tree based on ITS gene sequences of QNYL6. Morphogenesis of colonies (**b**), hyphae and conidiospores (**c**, **d**) of QNYL6 grown on potato dextrose agar medium for 7 d.



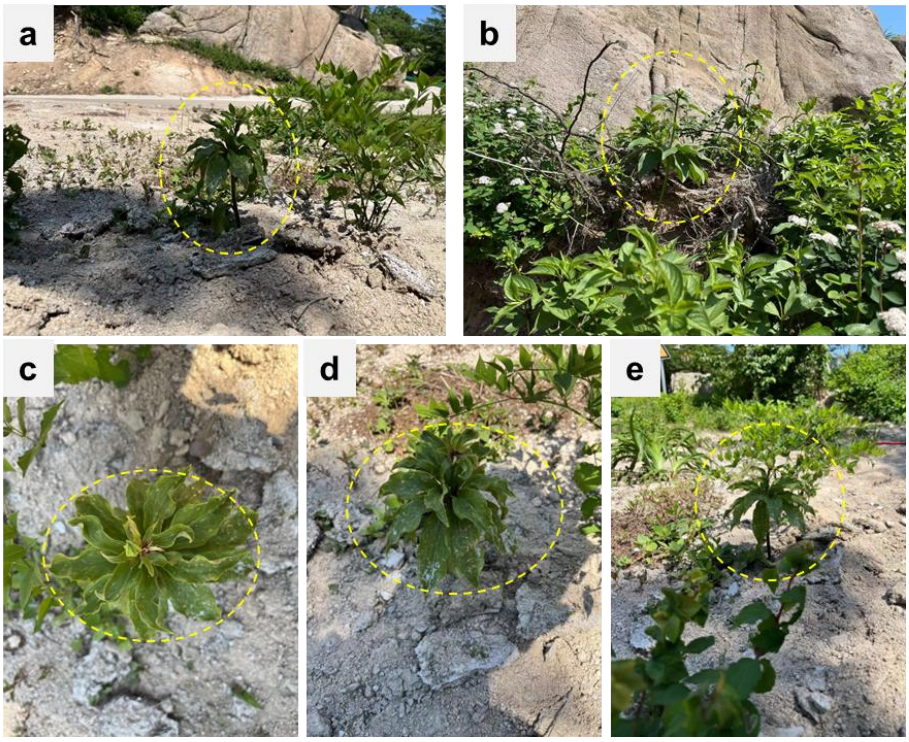
Supplementary Fig. 6. FTIR spectrum of roots of Qingdao lily under inoculation (QDAU 0920) and non-inoculation (Mock) within the region of 600-2000 cm^{-1}.



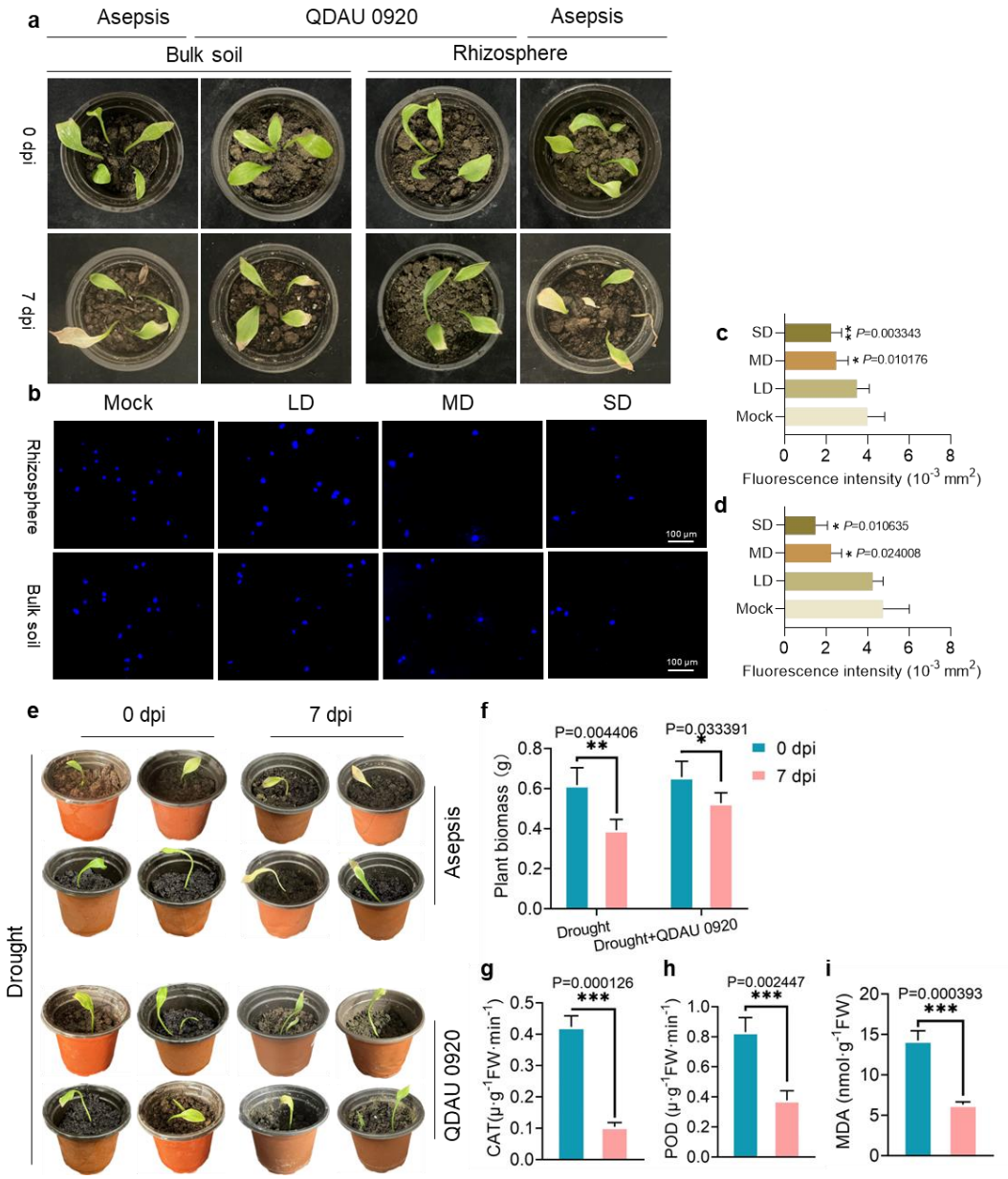
Supplementary Fig. 7. Inoculation of QDAU 0920 promoted Qingdao lily seedlings growth. a Bulb phenotype of Qingdao lily seedlings under inoculation and non-inoculation. Bulb weight (**b**), fresh weight (**c**) and primary root length (**d**) of Qingdao lily seedlings under inoculation and non-inoculation with QDAU 0920 ($P < 0.05$, student's *t*-test, n = 6 biologically independent plants, scale bars = 1 cm). Data bars represent means, and error bars represent the standard error of mean.



Supplementary Fig. 8. Performance of Qingdao lily under different water content conditions. (**a**) Schematic diagram of Qingdao lily under different drought stress conditions. (**b**) Growth status of tissue culture seedlings of Qingdao lily under 0 d and 7 d drought stress conditions. LD, low drought. MD, mild drought. SD, severe drought. Scale bars = 1 cm.

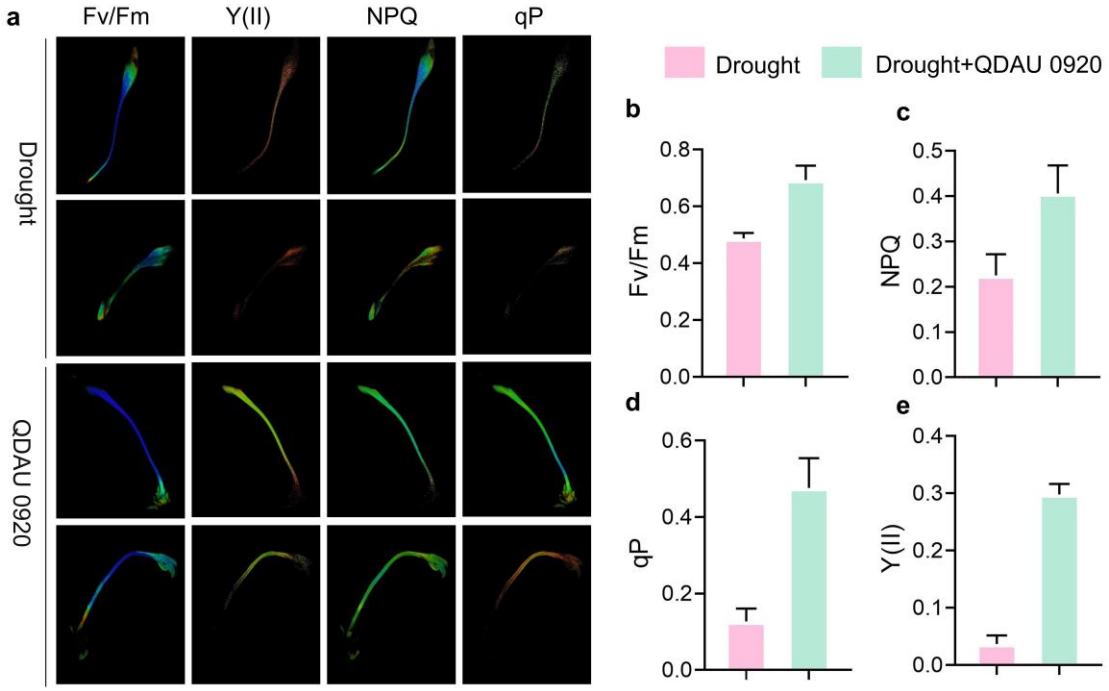


Supplementary Fig. 9. The growth status of Qingdao lily in the original arid soil environment. The yellow dashed circle indicates the different growth conditions of wild Qingdao lily in Laoshan mountain region.

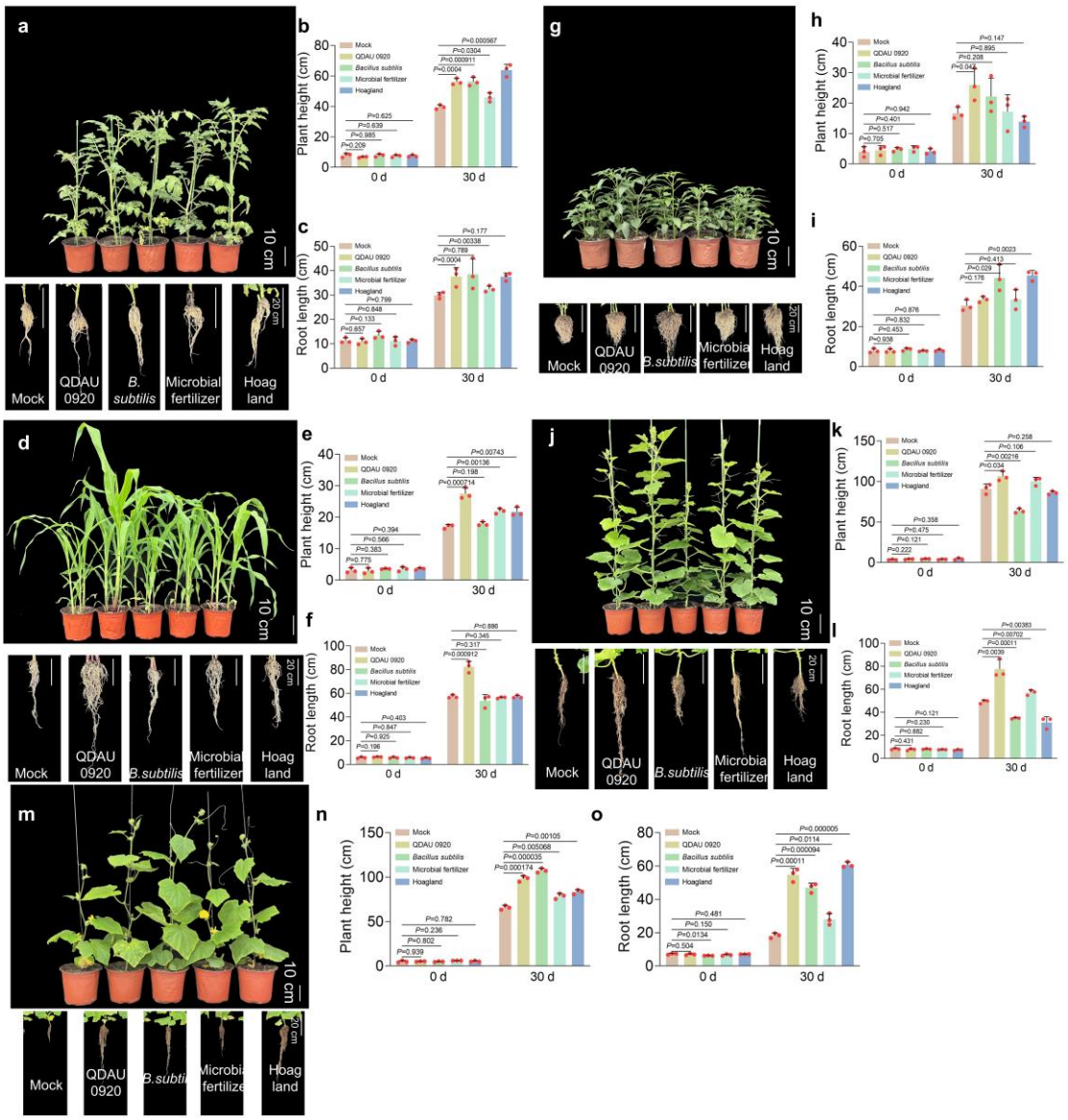


Supplementary Fig. 10 Effects of drought stress on Qingdao lily inoculation with and without strain QDAU 0920. a The growth status of Qingdao lily in different soil environments (Water content, 10%). (**b**) The activity of QDAU 0920 inoculated in sterile rhizosphere and bulk soils under different drought conditions. The fluorescence intensity in bulk soil (**c**) and rhizosphere soil (**d**). Data represent means ± standard error (SE) of four biological replicates (n=4). Significant differences were determined by one-way ANOVA followed by Duncan's test. * represents $P < 0.05$, ** represents $P < 0.01$, scale bars = 100

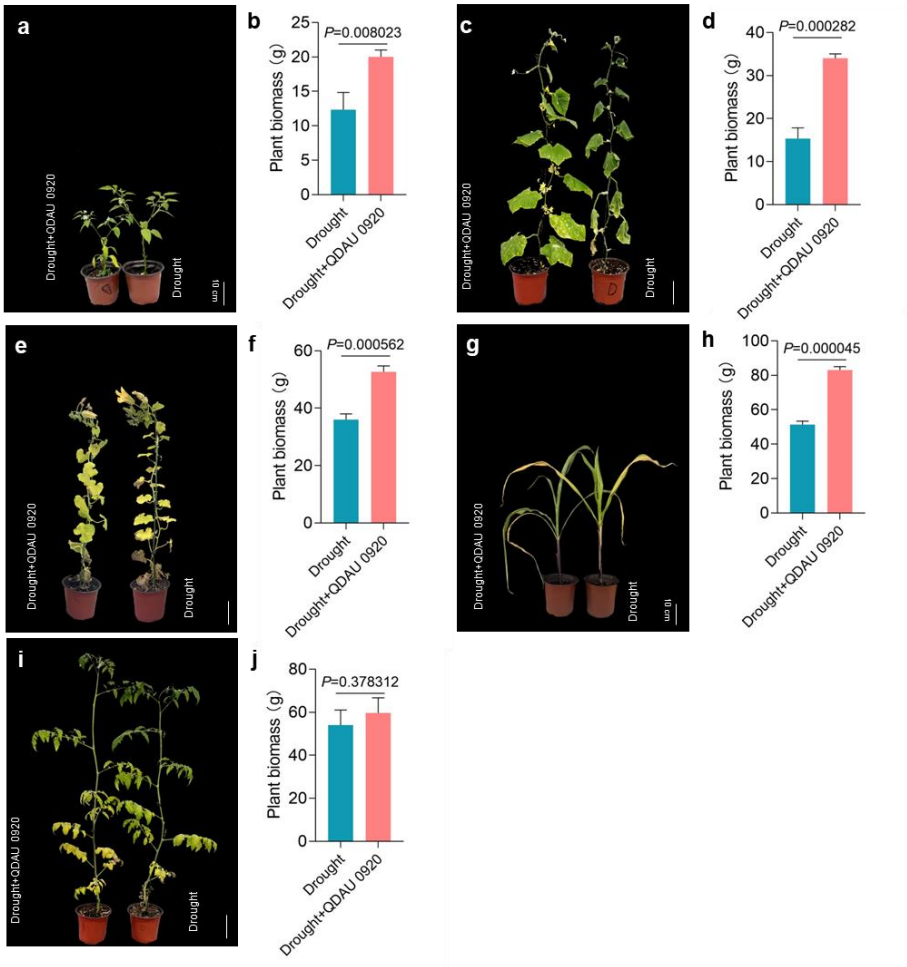
μm. LD, low drought. MD, mild drought. SD, severe drought. Morphological characteristics (**e**), biomass (**f**), CAT activity (**g**), POD activity (**h**) and MDA content (**i**) of Qingdao lily tissue culture seedlings under inoculation and non-inoculation of QDAU 0920 under drought stress condition. * represents $P < 0.05$, ** represents $P < 0.01$, Student's *t*-test, n = 3 biologically independent samples. Data bars represent means, and error bars represent the standard error of mean. CAT, catalase. POD, peroxidase. MDA, Malondialdehyde.



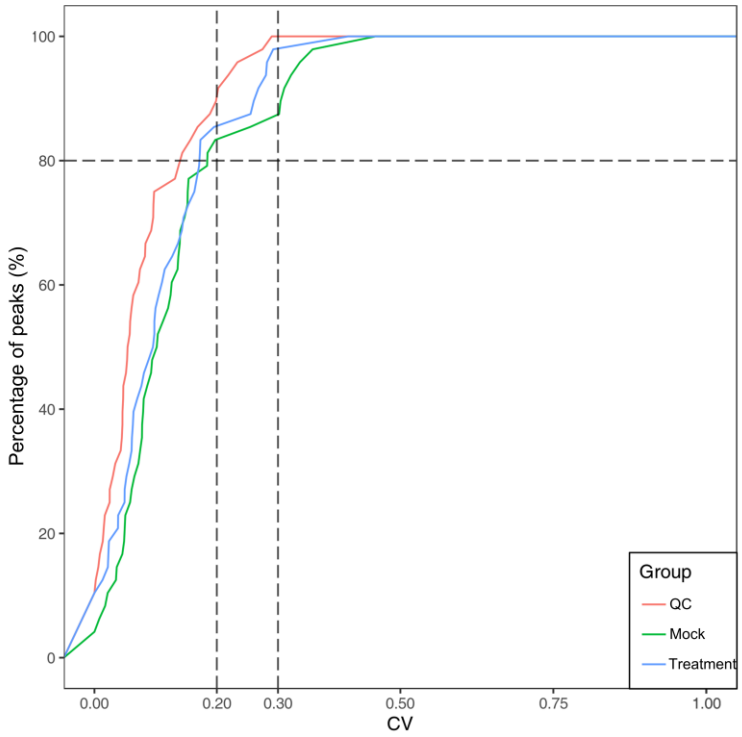
Supplementary Fig. 11. Chlorophyll fluorescence imaging of Qingdao lily inoculation with and without strain QDAU 0920 under drought stress condition. Chlorophyll fluorescence imaging (**a**), Fv/Fm (**b**), NPQ (**c**), qP (**d**) Y(II) (**e**) of *Qingdao lily* under inoculation and non-inoculation conditions. n = 3 biologically independent samples. Data bars represent means, and error bars represent the standard error of mean. Fv/Fm: maximum quantum efficiency, YII: quantum efficiency of electron transfer, NPQ: nonphotochemical quenching, qP: photochemical quenching.



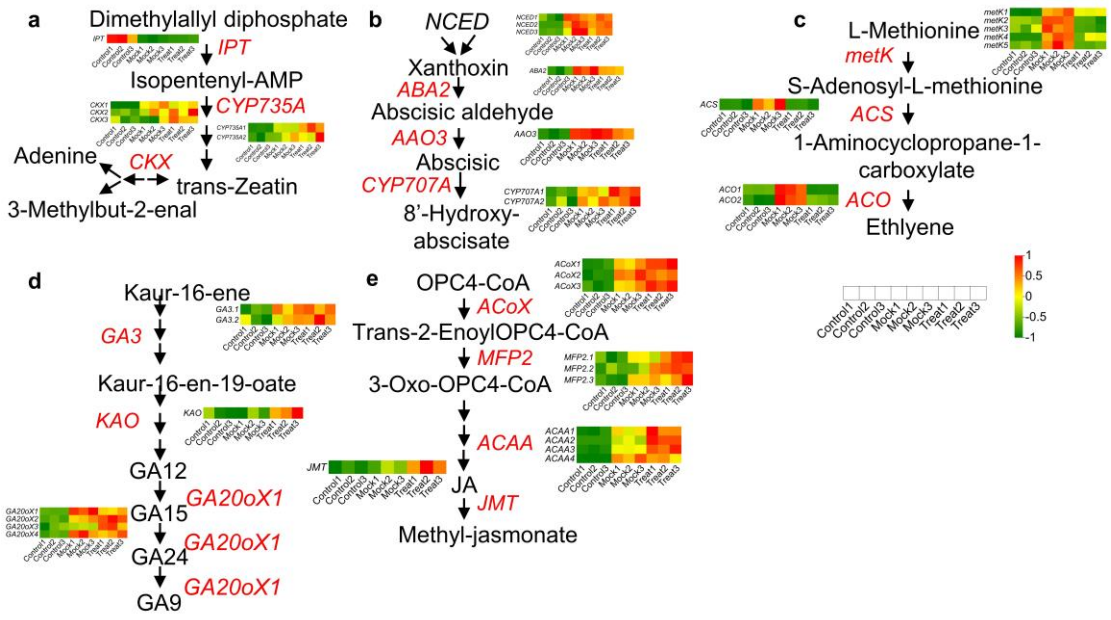
Supplementary Fig. 12. Inoculation of strain QDAU 0920 increased the growth of different plant species. Morphological (**a**, **d**, **g**, **j**, **m**), plant height (**b**, **e**, **h, k**, **n**) and root length (**c**, **h**, **i**, **l**, **o**) analysis of *Capsicum annuum*, *Zea mays, Cucumis sativus, Solanum lycopersicum, Cucurbita moschata* under inoculated and uninoculated with QDAU 0920. Data represent means ± standard error (SE) of four biological replicates (n=4). Significant differences were determined by one-way ANOVA followed by Duncan's test.



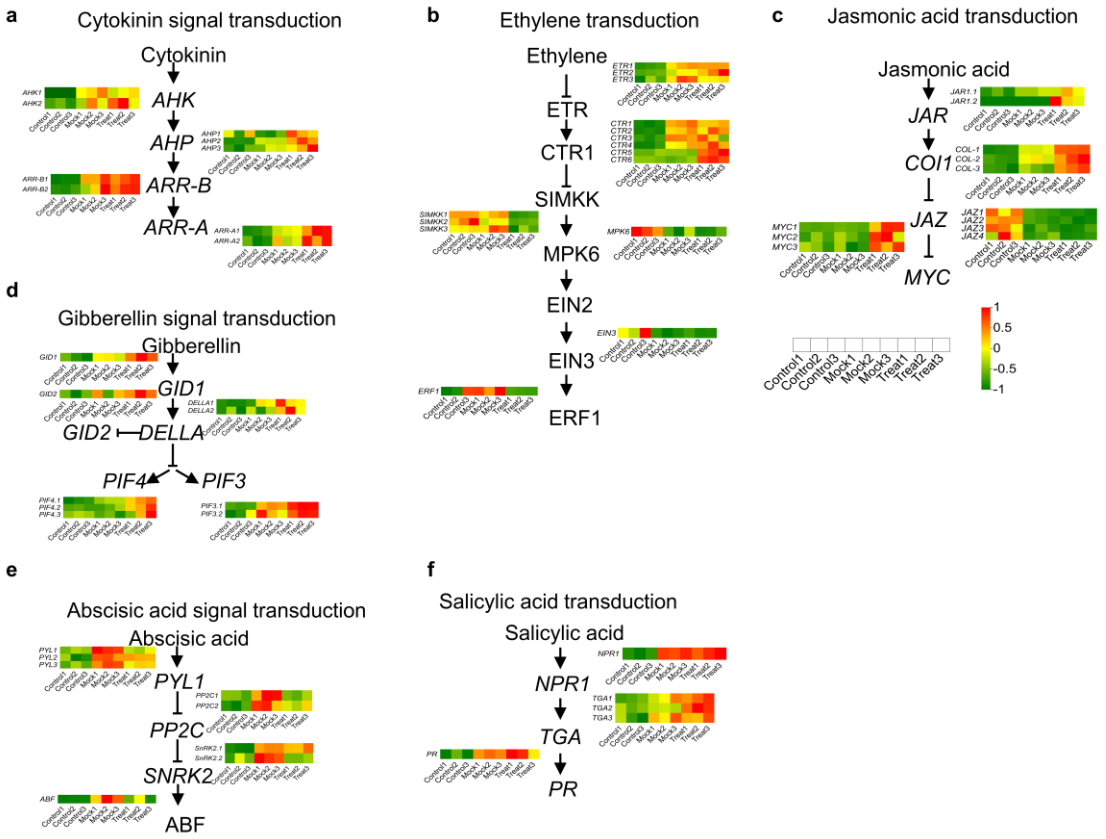
Supplementary Fig. 13. Inoculation of strain QDAU 0920 enhanced drought resistance of different crops. Morphological (**a**, **c**, **e**, **g**, **i**) and biomass (**b**, **d**, **f**, **h**, **j**) analysis of *Capsicum annuum*, *Zea mays, Cucumis sativus, Solanum lycopersicum, Cucurbita moschata* under inoculated and uninoculated with strain QDAU 0920. $P < 0.05$, Student's *t*-test, n = 3 biologically independent samples. Scale bars = 10 cm. Data bars represent means, and error bars represent the standard error of the means.



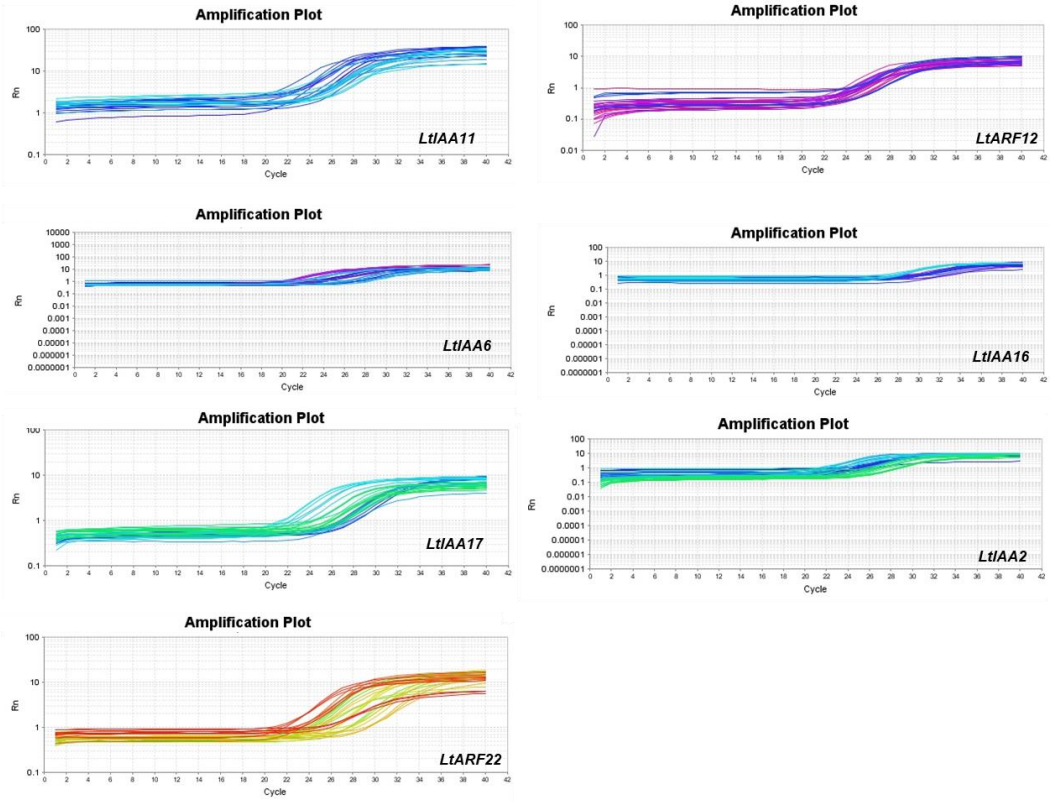
Supplementary Fig. 14. Coefficient of Variation (CV) distribution map of Qingdao lily under different treatments. Mock, non-inoculation of QDAU 0920. Treatment, inoculation of QDAU 0920. 'QC' means quality control to astern the reliability of the tested samples (Mock and treatment).



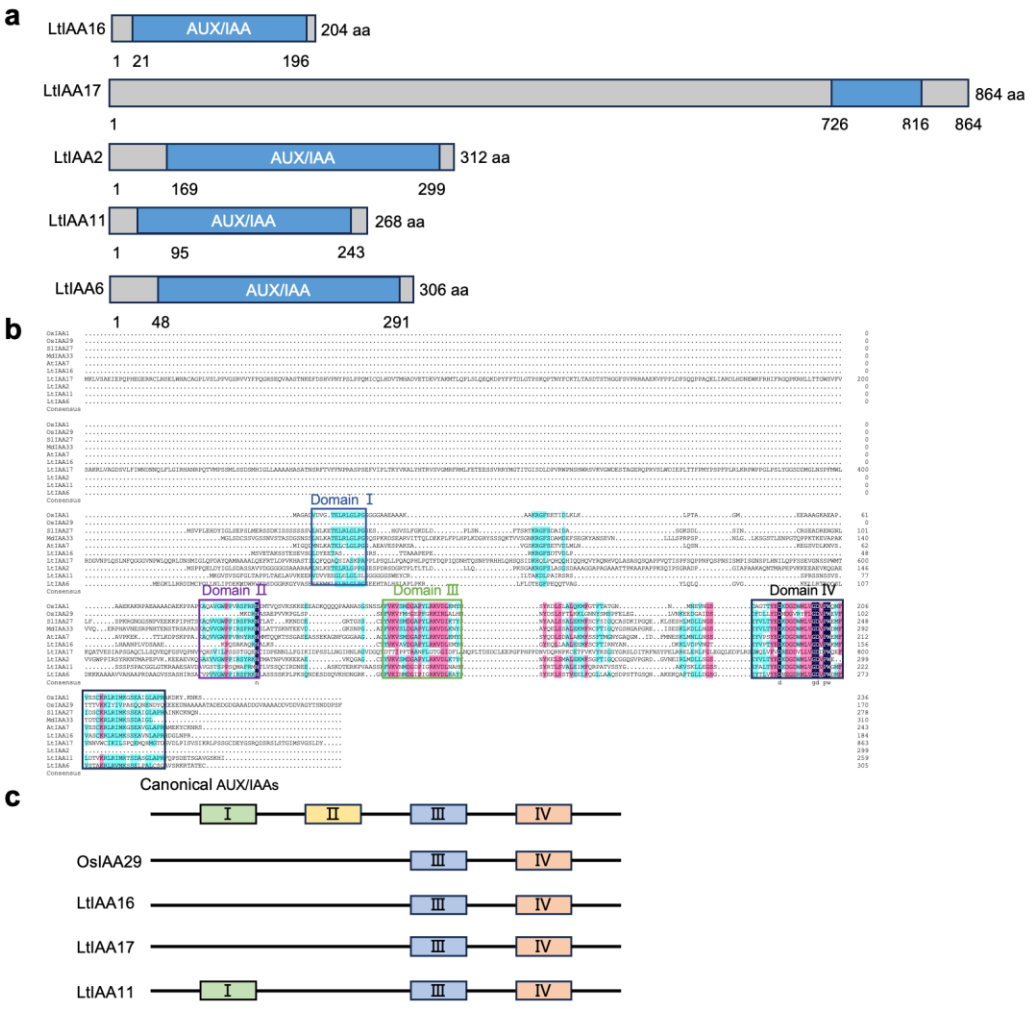
Supplementary Fig. 15. Heat map of differentially expressed genes involved in phytohormone biosynthesis under different treatments. Cytokinin (**a**), abscisic acid (**b**), ethylene (**c**), gibberellin (**d**), jasmonic acid (**e**) biosynthesis pathway genes expression under different treatments. Red fonts represent genes, and black fonts represent metabolites.



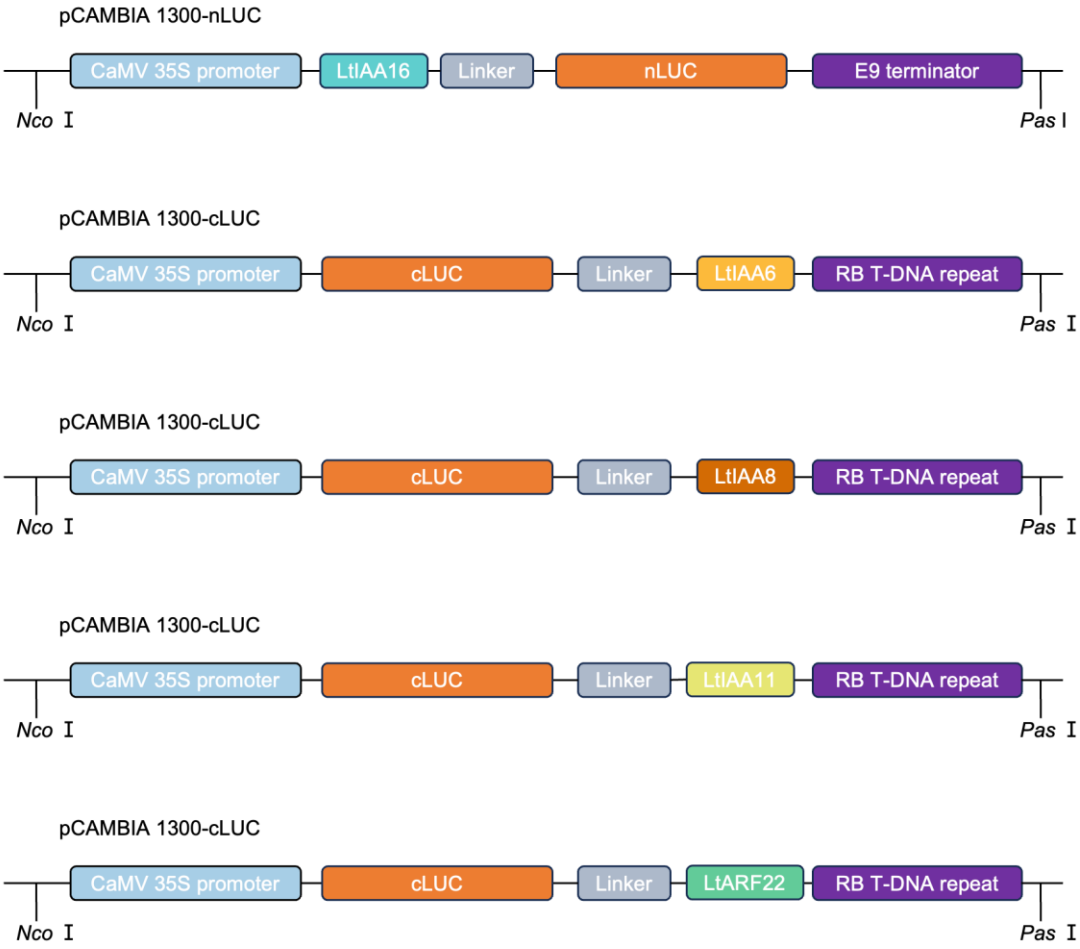
Supplementary Fig. 16. Heat map of differentially expressed genes involved in phytohormone signaling transduction under different treatments. Cytokinin (**a**), ethylene (**b**), jasmonic acid (**c**), gibberellin (**d**), abscisic acid (**e**), salicylic acid (**f**) signaling transduction genes expression under different treatments.



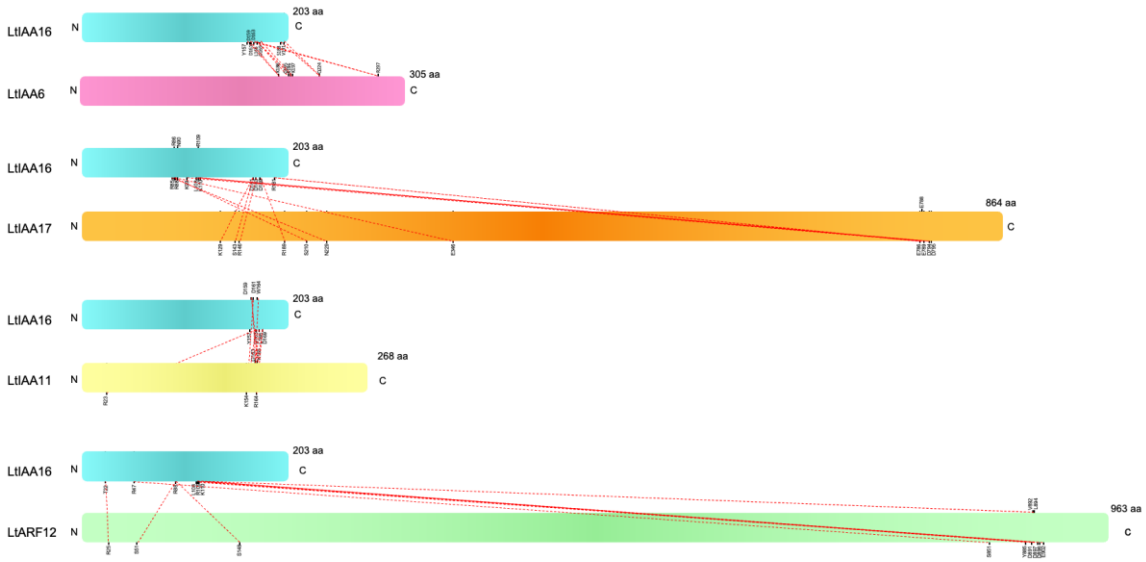
Supplementary Fig. 17. Amplification curves of LtIAA6, LtARF12, LtIAA17, LtIAA11, LtIAA16, LtARF22, LtIAA2 in Qingdao lily.



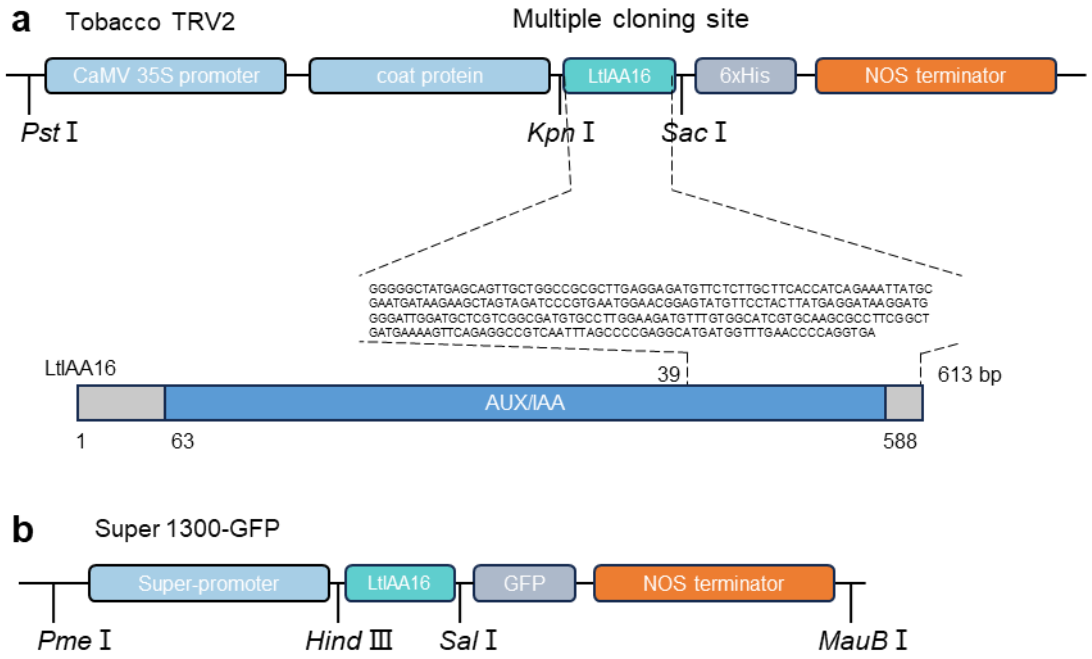
Supplementary Fig. 18. Domain analysis of LtIAA16, LtIAA17, LtIAA2, LtIAA11, and LtIAA6. a Schematic diagram of the domains of LtIAA16, LtIAA17, LtIAA2, LtIAA11, and LtIAA6. **b** Amino acid sequence alignment among LtIAA16, LtIAA17, LtIAA2, LtIAA11, LtIAA6 with other Aux/IAA family proteins. The conserved amino acid residues are represented by blue, purple, black, respectively. Domain I is represented by the blue box, domain II is represented by the purple box, domain III is represented by the green box, and domain IV is represented by the black box. OsIAA1 (CAC80823.1), OsIAA29 (KAF2910124.1), SlIAA27 (NP_001266034.1), MdIAA33 (AZI15343.1), AtIAA7 (NP_188945.1). **c** Comparative domain analysis of OsIAA19 with LtIAA16, LtIAA17, and LtIAA11.



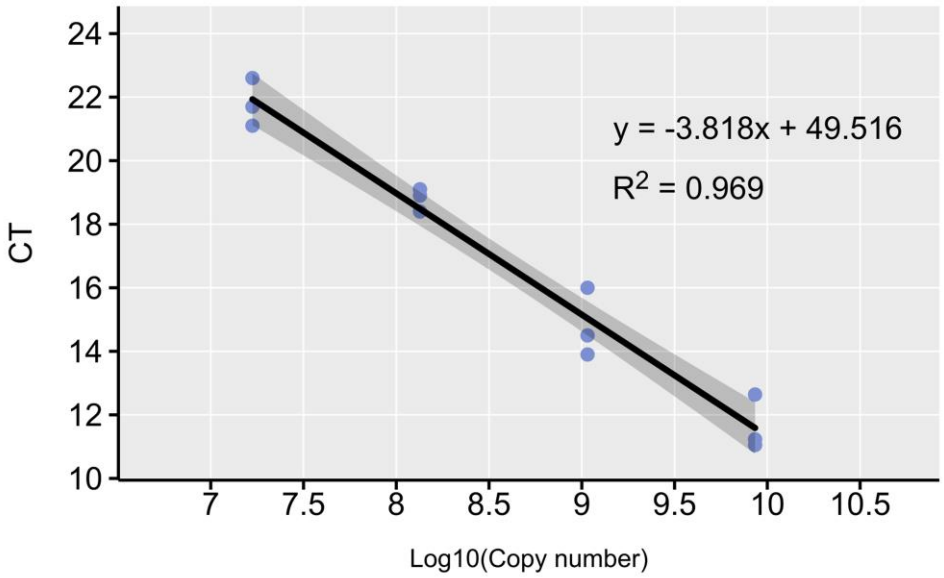
Supplementary Fig. 19. Schematic diagram for the construction of a dual luciferase complementation assay (LCA) detection vector.



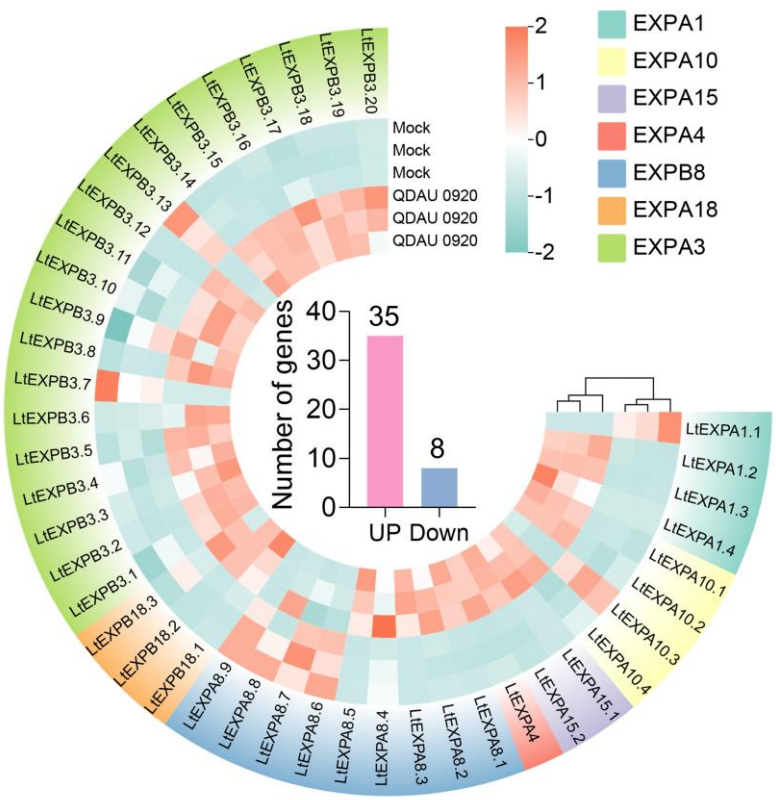
Supplementary Fig. 20. Predicting the amino acid binding sites of LtIAA16 and LtIAA6, LtIAA17, LtIAA11, LtARF22 based on AlphaFold 3.



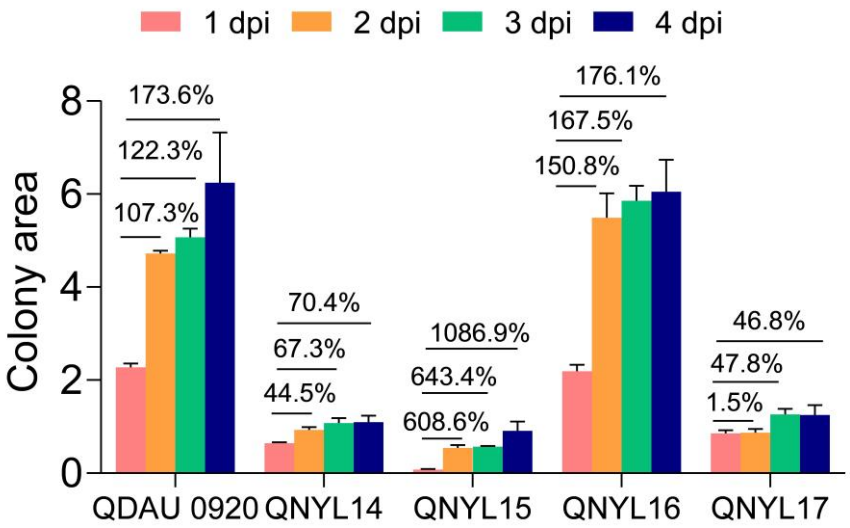
Supplementary Fig. 21. Vector schematic diagram for the constructs of TRV-*LtlAA16* (a) and OE-*LtlAA16* (b). The base sequence in the panel a show the silencing fragment of *LtlAA16*.



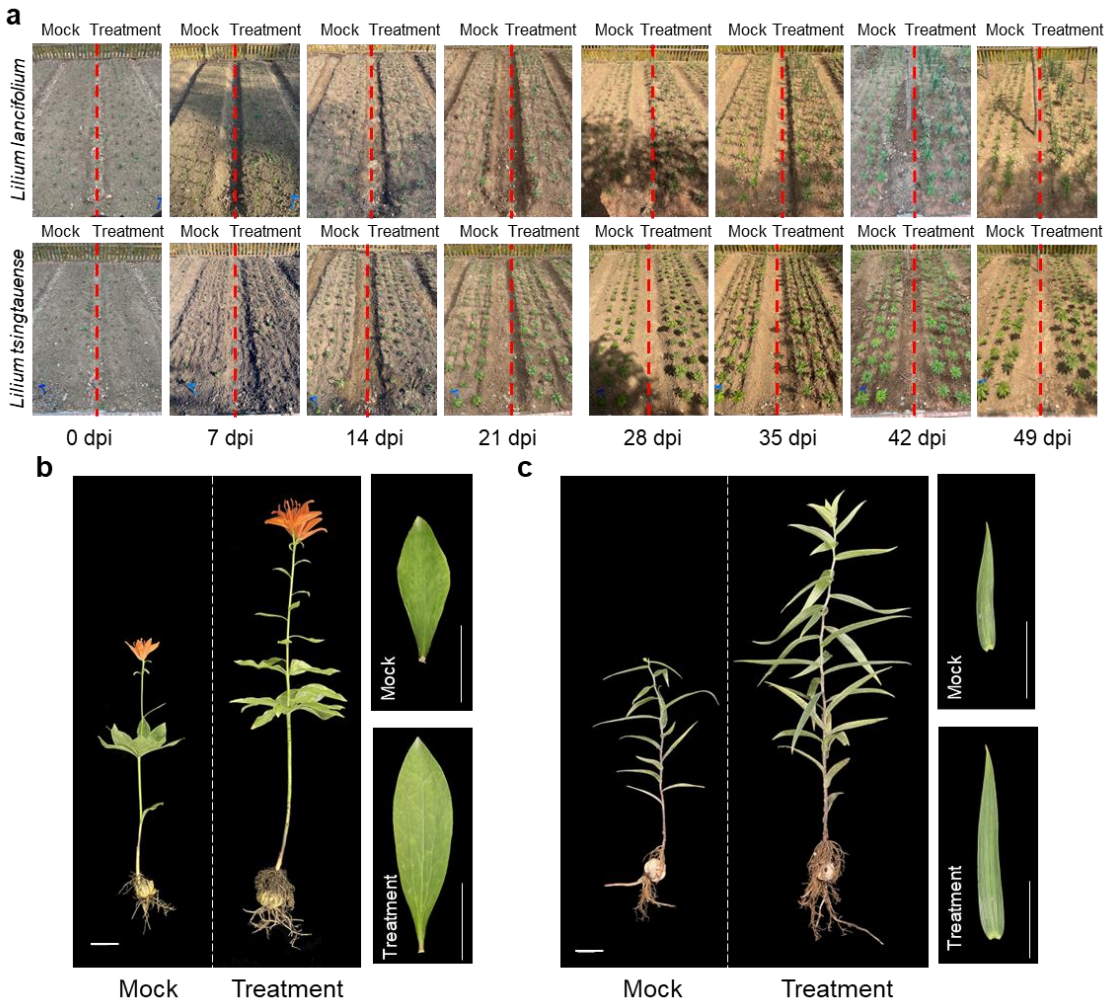
Supplementary Fig. 22. Labeling curve based on QDAU 0920 specific fragment obtained by ITS sequencing.



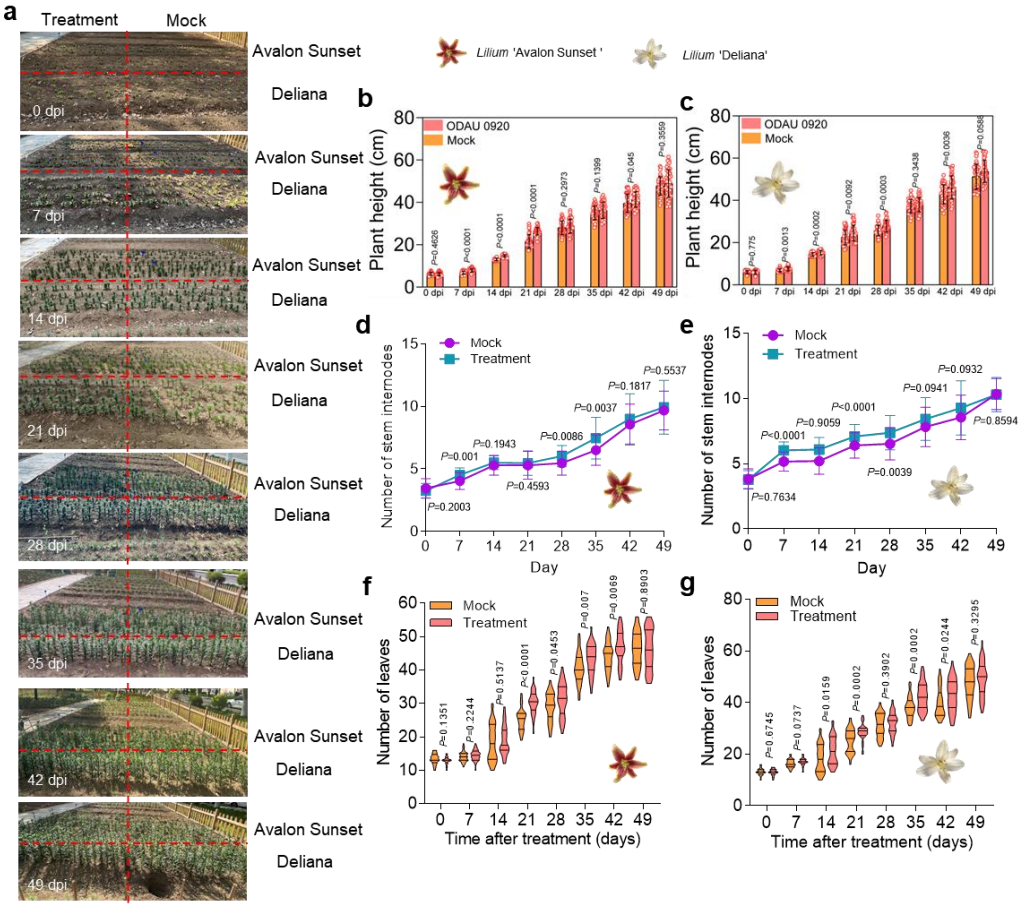
Supplementary Fig. 23. The expression levels of expansin-related genes in Qingdao lily based on RNA-seq.



Supplementary Fig. 24. Changes of colony area of fungi at different timepoints during co-culture of medium. The data on the figure indicate the proportion of the increase in colony area. n = 3 biologically independent samples. Data bars represent means, and error bars represent the standard error of the means.



Supplementary Fig. 25. Growth phenotypes of Qingdao lily and *Lilium lancifolium* in natural microbial community (Mock) and synthetic microbial community (Treatment). a The growth status of *Qingdao lily* and *L. lancifolium* under field experiment conditions with and without inoculation of strain QDAU 0920. Phenotypes of Qingdao lily (**b**) and *L. lancifolium* (**c**) after 49 days under different treatments. Scale bars = 10 cm.



Supplementary Fig. 26. Growth phenotypes of *Lilium* 'Avalon Sunset' and *Lilium* 'Deliana' in natural microbial community (Mock) and synthetic microbial community (Treatment). a The field experiment described the growth status of *Lilium* 'Avalon Sunset' and *Lilium* 'Deliana' under different days. Plant height of *Lilium* 'Avalon Sunset' and (**b**) and *Lilium* 'Deliana' (**c**) under different timepoints. Number of stem internodes of *Lilium* 'Avalon Sunset' (**d**) and *Lilium* 'Deliana' (**e**) after different treatments. Number of leaves of *Lilium* 'Avalon Sunset' (**f**) and *Lilium* 'Deliana' (**g**) after different treatments. $P < 0.05$, student's t-test, n = 40 biologically independent samples. Data bars represent means, and error bars represent the standard error of mean.

Supplementary experimental methods

Photosystem analysis

Chlorophyll quantification was conducted following the methodology described by previous procedure[1]. Chlorophyll fluorescence imaging was performed using the IMAG-MAX/L system (WALZ, Germany) to capture images and assess parameters including photochemical quenching (qP), non-photochemical quenching (NPQ), the maximum quantum efficiency of photosystem II (Fv/Fm), and the effective quantum yield of photosystem II [Y(II)]. Measurements were obtained for every set of three technical replicates and a minimum of three biological replicates.

Fourier Transform Infrared Spectroscopy (FTIR) analysis

The roots of Qingdao lily were collected after 7 days post-inoculation for further FTIR spectroscopy analysis. We first wash the ramets with sterile water and then dried them in an oven (50 °C) for 5 days. Following drying, the tissue samples were ground into a fine powder using a mortar. This procedure was systematically applied to various samples to assess the FTIR variations in plant tissues subjected to inoculation with and without *Trichoderma longibrachiatum* QDAU 0920.

Fungal fluorescence staining

1 g rhizosphere soil and non-rhizosphere soil of Qingdao lily under different treatments were collected. The soil samples were diluted 100 times with sterile water and fully mixed to prepare a soil suspension. After allowing the suspension to settle, an aliquot was stained with a fungal fluorescent dye (LiMING Bio, 503030, Nanjing, China) for 1 min. The Axio Scope upright fluorescence microscope (ZEISS, Axio Scope A103040108, Germany) was used for observation. The fungal fluorescent stain employed is a composite

solution comprising a fluorophore and agents that inhibit non-specific background fluorescence. In the presence of fungi, the fluorophore binds non-specifically to β-polysaccharides within the fungal cell wall, such as chitin and cellulose. Under fluorescence microscopy, fluorescence emission can be detected upon excitation at wavelengths between 320 and 340 nm. Regions exhibiting blue fluorescence were identified as fungal structures. Quantification of fluorescent signals was performed using ImageJ software (https://imagej.nih.gov/ij/).

Drought stress experiment

Qingdao lily seedlings were subjected to varying degrees of drought stress. After 7 days of treatment, their responses to the different drought conditions were observed. Additionally, maize, cucumber, pumpkin, tomato and pepper inoculated with strain *T. longibrachiatum* QDAU 0920 and non-inoculated cucumbers were subjected to drought stress to evaluate the mitigating effect of *T. longibrachiatum* QDAU 0920 on plant drought stress.

Reference

1. Zhao X, Lin S, Yu S, Zhang Y, Su L, et al. Exogenous calcium enhances the physiological status and photosynthetic capacity of rose under drought stress. *Hortic Plant J* **10**, 853-865 (2024) doi: 10.1016/j.hpj.2023.01.010.