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Article

Effects of urban traffic noise on the early growth and transcription of *Arabidopsis thaliana*

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SUMMARY
Man-made noise in cities has been recognized as one of the major contributors to a range of adverse health outcomes, including heart disease. Besides the detrimental effects on human health, noise can act as a potential threat to other organisms in the ecosystem. Despite the growing concern, the biological effects of noise pollution on plants, in particular, remain largely obscure. Therefore, this study aimed to investigate the impacts of urban traffic noise on the growth of *Arabidopsis thaliana* (*A. thaliana*). We hypothesized that traffic noise could stimulate plant growth (seed germination and seedling growth) since noise treatment has been reported to improve immunity and drought tolerance in *A. thaliana* (1, 2). Seeds in the experimental group were exposed to 48 hours of traffic noise recorded in a highly congested area of Seoul, while the control group was exposed to background white noise. Compared with background white noise, traffic noise exposure had no effects on seed germination but significantly increased the growth of seedlings by 39%. We further investigated the traffic noise-induced molecular changes in the *A. thaliana* seedlings by employing RNA sequencing. We detected aberrant expression of 690 genes in traffic noise-exposed seedlings. The differentially expressed genes were enriched for various biological pathways, such as stress response and auxin signaling. The observed molecular changes suggest profound impacts of traffic noise on the physiology of *A. thaliana*. The results of our research can help shed light on the fundamental principles underlying the noise-plant interaction as well as provide a further basis for conserving our ecosystem.

INTRODUCTION
With rapid urbanization, the emergence of vast transportation systems and industries gave rise to new acoustic conditions. Noise affects animal behavior, including vigilance, movement, foraging, and acoustic communication, and induces changes in animal physiology, population dynamics, fitness, and the ecosystem (3, 4). For example, a previous study that examined the effect of noise on ecological services found that noise increased flower pollination by hummingbirds but decreased seed dispersal, thereby influencing ecosystem structure and diversity (5). Considering its varied impacts on ecosystems, environmental noise is receiving substantial attention from not only biologists but also policymakers and resource managers, who all strive to grasp a more comprehensive understanding of the field.

Sound is physical energy in which acoustic, oscillatory pressure waves are transmitted. Numerous organisms, specifically plants, have evolved the ability to react to different ambient sounds and sound waves that have specific intensities and frequencies. Such responses trigger a range of molecular, cellular, and physiological responses in plants (6). In cities, plants are frequently exposed to white noise and noise pollution. White noise is a complex sound that covers a wide range of audible frequencies, while noise pollution is unfavorable noise caused by human activities such as road traffic and construction, as defined by the World Health Organization (WHO) (7, 8).

Sound can have multiple potential health impacts on plants. Previous studies on the physiological impacts of noise on plants have revealed mixed results. On one hand, a previous study reported the harmful effects of traffic noise on *Tagetes patula* and *Salvia splendens* (9). Compared with the control group placed in complete silence, the experimental group, which was exposed to 16 h of road traffic noise for 15 consecutive days, experienced a notable decrease in growth indices. This observation suggests that traffic noise may cause oxidative damage and disrupt the hormonal balance of plants (9).

On the other hand, more studies have indicated the beneficial effects of sound on plant physiology, resulting in enhanced growth, development, and disease resistance (1, 2, 10). For example, insects' chewing sound induced plant immunity-related chemicals such as glucosinolates in *Arabidopsis thaliana (A. thaliana)* (10). Exposure of 6-week-old *A. thaliana* plants to 100 dB of white noise for 10 h resulted in the upregulation of genes involved in pathogen response and promoting improved drought tolerance (1). The production of plant defense-related hormones, including salicylic acids, also increased when *A. thaliana* plants were exposed to 1000 Hz sound with 100 dB (2). Thus, it has been observed that noise treatment, when used as a physical stimulant, may bring key adaptive advantages to plant physiology.

Given the inconclusive findings in the literature, there is a need for more research on the effects of noise on the early growth of *A. thaliana*. Consequently, we investigated how traffic noise affects the growth and gene expression of this plant. *A. thaliana* has been a widely used experimental model organism since the 1980s, especially since researchers merged genetics with robust molecular biology methods. In 2000, the *A. thaliana* reference genome became the first publicly available genome sequence of a flowering plant, allowing scientists to make significant progress in understanding molecular principles (11). This plant is also

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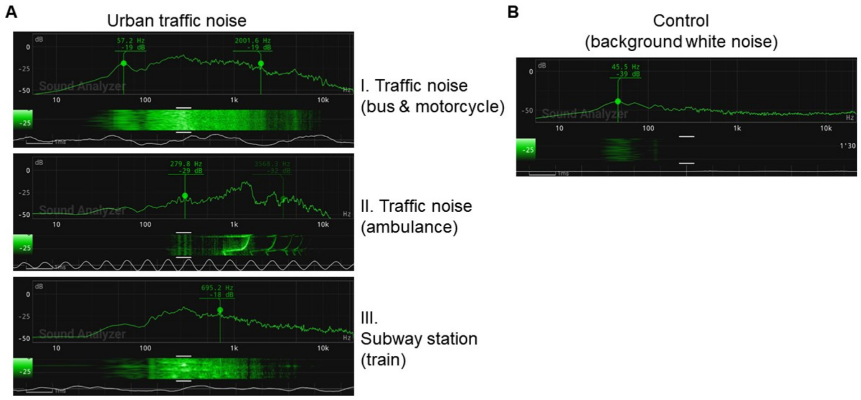

Figure 1. Urban traffic noise and control white noise waveforms. Waveforms of traffic noise (A) and background control noise (B) were analyzed using the Sound Analyzer software. X-axis indicates the range of sound frequency between 5 and 22 kHz. Y-axis represents the intensity of sound from 0 to 90 dB.

used in research on ecological and evolutionary contexts in natural environments (12).

Based on previous findings that noise exposure boosted *A. thaliana* immunity and improved drought tolerance, we hypothesized that traffic noise treatment would positively impact both seed germination and seedling growth (1, 2, 10). Although the seed germination events did not show a significant difference between the control and experimental groups, noise-treated seedlings were significantly longer than control plants. After 48 h of noise treatment, bulk RNA-sequencing (RNA-Seq) analysis was conducted to detect differences in the gene expression profiles of the whole seedlings. Intriguingly, we detected significant transcriptional changes responsible for stress response, auxin signaling pathway, as well as growth control, thus providing insights into the biological responses to noise pollution. Taken together, our findings demonstrate the stimulatory effects of traffic noise on the early growth of *A. thaliana.* Hence, our findings underscore the need for further investigation into the functional consequences of traffic noise on plant physiology and related ecological impacts.

RESULTS

To test whether environmental noise can stimulate seed germination and seedling growth, we first recorded traffic noise in several areas with high traffic density in Gangnam, Seoul. A total of 10 minutes of traffic noise contained at least three types of sources, such as buses & motorcycles, ambulances, and subway stations (**Figure 1A**). The treatment group of *A. thaliana* seeds was subjected to traffic noise at an average of 75 dB, with a minimum of 57 dB and a maximum of 90 dB, for 48 h. The control group was placed outside the sound-proof facility and exposed to background white noise at approximately 10 dB, ranging from a minimum of 5 dB to a maximum of 15 dB (**Figure 1B**).

After 48 h of continuous noise exposure, seed germination was determined (**Figure 2**). The criterion for germination was the presence of seed harboring protrusions of radicle, which is the first part of a seedling to emerge from the seed during the germination process. The percentage of germinated seeds was not significantly different between control (71.3% ± 12.22) and noise-treated (79.33% ± 3.05) seeds (p = 0.33, **Figure 3**). Thus, 48 h of traffic noise did not affect the germination of seeds.

Next, we assessed the effects of noise exposure on seedling growth by measuring the length of seedlings from the beginning of the hypocotyl to the tip of the roots. Seedlings in the traffic noise treatment group had significantly longer seedling lengths (10.95 ± 2.02 mm) than those in the control group (7.89 ± 1.99 mm), corresponding to noise-triggered growth stimulation of up to 39% ($p = 4.6 \times 10^{-14}$, **Figure 4**). These results thus indicate that 48 h of acute traffic noise treatment promoted early growth of *A. thaliana* seedlings.

To gain a deeper understanding of the molecular mechanisms occurring in the traffic noise-exposed seedlings, we performed RNA-seq of seedlings from traffic noise treatment and from control samples. A total of 690 differentially expressed genes (DEGs) (401 upregulated and 289 downregulated) were identified between the control and noise-exposed seedlings based on a fold change threshold of ≥ 1.5 for upregulation and ≤ −1.5 for downregulation (13) (**Figure 5**, **Table 1**).

To further clarify the biological pathways and functions in the *A. thaliana* seedlings affected by noise treatment, we classified DEGs based on biological processes (**Figure 6**, **Table 2**). Significantly enriched gene ontology categories were identified in the noise-exposed seedlings, including “stress response”, “auxin signaling pathway”, “growth regulation”, “protein transport”, “tricarboxylic acid cycle”, “autophagy”, and “hydrogen ion transport”. Taken together, genome-wide transcriptomic analysis strongly suggests pleiotropic effects of traffic noise stimuli on various physiological events in *A. thaliana* seedlings.

DISCUSSION

In the present study, we aimed to determine the effects of urban traffic noise on the seed germination and early growth of *A. thaliana* as a model for noise pollution-plant interaction. Seeds exposed to traffic noise did not exhibit altered germination compared to those grown in control conditions, indicating that traffic noise had no impact on seed germination. In seedling growth analysis, the results show that seedlings treated with traffic noise for 48 h exhibited a significant elongation of up to 39% compared to control,

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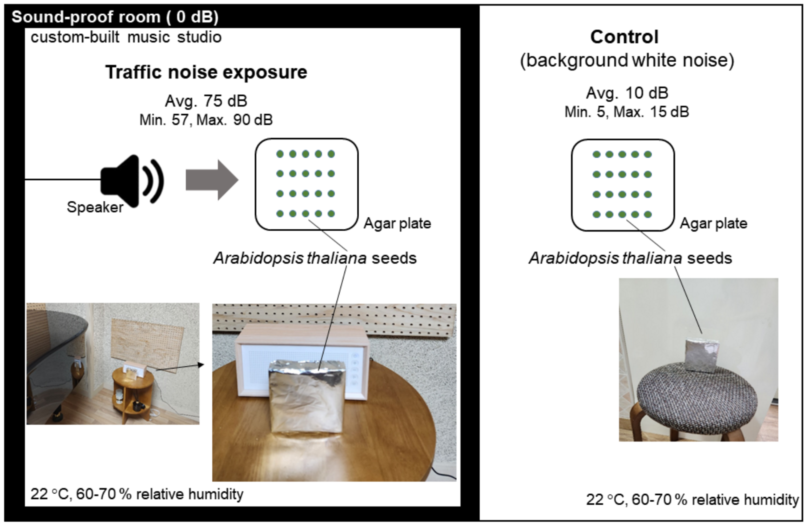

Figure 2. Schematic diagram of the experimental setup. To prevent external noise interference, the traffic noise treatments were performed in a sound-proof facility. Experimental groups were continuously treated with traffic noise at an average of 75 dB for 48 h. For the control group, the seeds were exposed to background white noise outside the sound-proof facility at an average of 10 dB. Both the sound-proof facility and the outside area were maintained at a constant temperature (22 °C) and humidity (60-70%).

suggesting a stimulatory effect of traffic noise on the early growth of seedlings. In transcriptomic RNA-seq analysis, we identified 690 DEGs in seedlings in response to noise exposure, which are related to stress response, auxin signaling pathway, growth regulation, autophagy, TCA cycle, protein transport, and hydrogen ion transport. Taken together, increased seedling length and altered gene expression profiles in traffic noise-treated *A. thaliana* with no sign of accelerated germination rate partially support the hypothesis that plants exposed to traffic noise pollution exhibit increased seed germination rate and enhanced early growth.

Further investigations will be needed to examine whether this phenotypic change represents a physiological response perturbed by artificial traffic noise or reflects the fitness response of *A. thaliana* to noise stress. To address this challenging question, we should first uncover fundamental principles of sound-sensing mechanisms in plants. Integrative analysis of the functional relationships between noise-evoked signaling networks and plant growth response pathways will ultimately allow us to understand the modes of noise-mediated signaling actions in the control of physiological alterations in plants.

Different types of sound (e.g., varying frequency) and treatment conditions (e.g., varying intensity or time) have various effects on different plants (14). In a previous study, traffic noise collected from high-density areas in Iran was used to treat two urban plant species, *Tagetes patula* and *Salvia splendens*, for 16 h per day for 15 days (9). Two-month-old plants subjected to this long-term treatment showed 27% and 17% reductions in fresh weight of *S. splendens* and *T. patula*, respectively, suggesting the negative impact of noise on the growth of those urban plants. In contrast, our data indicate that traffic noise led to significantly increased growth of *A. thaliana* seedlings, suggesting the stimulatory effects of traffic noise pollution on the early growth of *A. thaliana.* By testing the effects of long-term noise treatment on mature *A. thaliana* plants, we can further determine whether noise pollution differentially changes growth response depending on the developmental stage. In addition, the difference in length of noise exposure time compared to previous studies could have played a major part in the growth of *A. thaliana* in our study. It will also be critical to investigate whether anatomical and physiological traits in different plant species from *A. thaliana* could lead to contrasting responses to traffic noise.

The increased seedling growth rate observed in the present study is consistent with the earlier reported promoted growth in *A. thaliana* under defined frequency sound treatments. For example, the exposure to the sound treatment condition (200 Hz, 80 dB continuously for 2 weeks) increased the root growth of *A. thaliana* seedlings with positive phototropism (15). In another study, *A. thaliana* seeds showed significantly longer root growth than the control group under two experimental conditions (single 100 kHz or dual 100 + 9 kHz, 80 dB for 15 h per day for 3 days) (16). However, we should be cautious about generalizing these positive effects of sound on plant growth. A previous study with paddy rice showed positive effects on germination rate and growth of the sound treatment condition (400 Hz, 106 dB for 60 min per day for 2 days) (17). However, growth was severely inhibited by frequencies higher than 4 kHz and intensities greater than 111 dB (17). In addition, under the sound treatment condition (1 kHz, 100 dB for 60 min per day for 20 days), soluble protein content increased in *Actinidia chinensis*, but higher sound levels led to decreased content (18). Therefore, it is more likely that sound, including traffic noise pollution, elicits complex changes in plant growth depending on treatment conditions and species. Systematic investigations of additional experimental conditions (e.g., high loudness, different urban noise types, frequencies, noise exposure time) using *A. thaliana* will provide more comprehensive information that can be applied to interpret the physiological response of other plant species. More studies will be needed to examine whether *A. thaliana* and similar plants sharing the anatomical and ecological features

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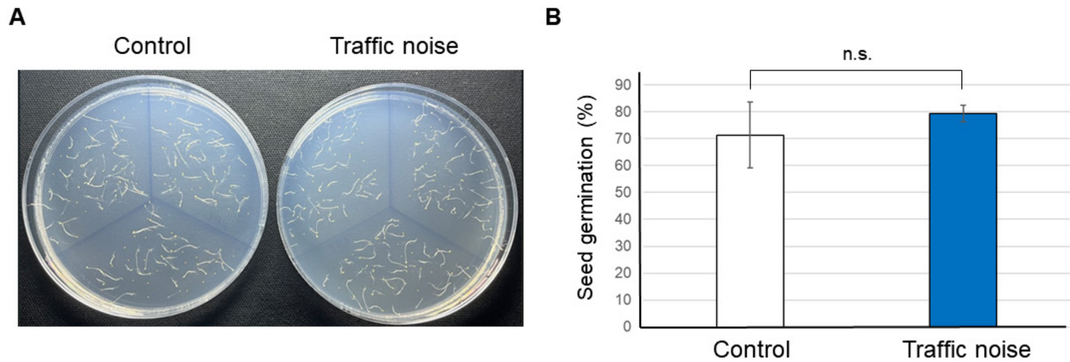

Figure 3: Effects of traffic noise exposure on the seed germination of *Arabidopsis thaliana.* (A) Seeds were exposed to either traffic noise or control white noise for 48 h. (B) Seed germination percentages (%) are presented as mean ± standard deviation (n = 3). Student's t test, n.s., not significant. Seed germination assays were performed independently three times, and similar results were obtained. Data are from one representative experiment out of three independent experiments.

elicit the same biological reactions to noise stimuli.

Further studies are required to uncover the molecular mechanisms underlying the traffic noise-induced stimulation of seedling growth. Based on our pathway analysis of the differentially expressed genes, a major pathway that was strongly influenced by traffic noise exposure was the stress pathway. Top-ranked genes that were robustly induced include heat shock protein (HSP) genes such as *HSP17.6II*, *AT1G53540 (HSP17.6C),* and *HSP17.4*. Heat stress response factors (HSFs) and HSPs are central players in the heat stress pathway and related biological events such as growth promotion and thermotolerance (19). Therefore, our results suggest that mechanical energy from the traffic noise is absorbed by the seedling, thereby leading to local heat production and the corresponding protective heat stress response. Further experiments to measure local temperature changes in noise-exposed seedlings will be needed to test whether noise-induced heat stress response is a key event in driving stress response and plant growth. Since HSPs are induced as molecular chaperones by a variety of stresses, such as dehydration, salinity, reactive oxidative species, heavy metals, and high-intensity irradiations, we should also consider the possibility that noise-dependent HSP induction could be mediated by other types of stress independent of heat (20, 21).

Vibrational energy from sound can mechanically stimulate cells, as touch produces a physiological response. Thigmomorphogenetic responses that are triggered by physical touches also include stress resistance (22). Two major mechanosensitive genes are TOUCH genes (TCH) that mainly encode calmodulins or calmodulin-like proteins and xyloglucan endo-transglycosylase/hydrolase (XTH) (23, 24). In our study, TCH and XTH genes were also upregulated by traffic noise treatment, which strongly suggests that noise and touch induce similar mechanical force-dependent gene expression changes.

Traffic noise also significantly stimulated the auxin signaling pathway. In the growth regulation pathway, expression of many small auxin upregulated RNA (SAUR) genes was indeed markedly elevated after traffic noise exposure. Auxin is one of the most important plant hormones essential for promoting cellular growth and increasing the rate of cell division (25). The SAUR family is a group of auxin-responsive genes conserved in many higher plant species, highlighting the importance of these genes in the regulation of auxin-induced dynamic and adaptive growth in response to noise (26). Hence, enhanced seedling growth can partly be explained by the activation of auxin-dependent signaling events.

Our transcriptomic analysis revealed unique changes in other biological pathways. Some genes in the TCA cycle and proton transport were downregulated by noise exposure, which indicates metabolic changes in noise-stimulated seedlings. One of the most dramatic reductions in expression by traffic noise was observed in the MLS gene, which encodes malate synthase, a key enzyme for the glyoxylate cycle (27). In germinating seeds, the glyoxylate cycle uses acetate from lipid breakdown and converts it to four-carbon gluconeogenic substrates to support seedling growth (28). Malate synthase-null seedlings exhibited enhanced growth, probably owing to accumulated glyoxylate serving as a substrate for biosynthesis (e.g., serine and glycerate) (29). By measuring glyoxylates and other energy metabolites, we can further validate the contribution of altered glyoxylate and energy metabolism to seedling outgrowth in response to traffic noise treatment.

The growth-defense trade-off is critical for plant homeostasis. Therefore, enhanced seedling growth in our study may have resulted in reduced immune response. From an in-depth analysis of DEGs, we identified significantly reduced expression of the RPS2 gene, which encodes a protein representative of the nucleotide-binding site-leucine-rich repeat (NBS-LRR) class of plant resistance proteins (30). RPS2 specifically recognizes *Pseudomonas syringae* strains expressing the avrRpt2 gene and initiates defense responses to bacteria carrying avrRpt2 (31). In addition, noise treatment led to marked upregulation of the homolog of BEE2 interacting with IBH 1 (HBI1), which promotes growth but suppresses immunity (32). Furthermore, traffic noise-exposed seedlings showed elevated expression of constitutive expresser of pathogenesis-related genes-5 (CPR5). CPR5 is known as a master regulator of growth and immunity, as cpr5-null mutants showed compromised growth but increased resistance against pathogens (33). Taken all together, while seedling outgrowth was promoted, changes in gene expression (e.g., RPS2, HBI1, and CPR5) in traffic noise-exposed seedlings

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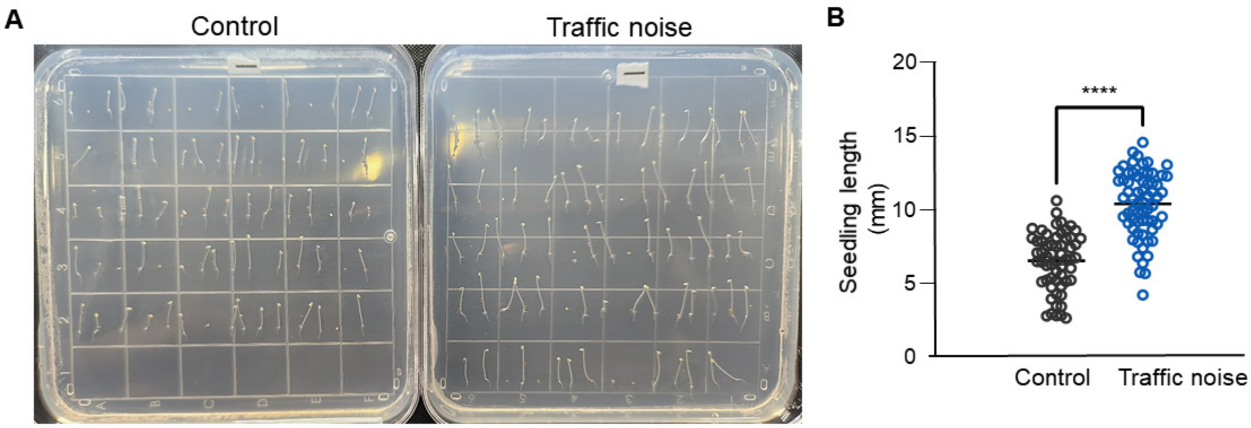

Figure 4. Effects of traffic noise exposure on the seedling growth of *A. thaliana*. (A) Seeds were vertically grown under the treatment of either traffic noise or control white noise for 48 h. (B) Length of seedlings from traffic noise (n = 66) or control white noise (n = 59) groups. Student's t test, ****$p < 0.001$. Seed length measurement assays were performed independently twice, and similar results were obtained. Data are from one representative experiment out of two independent experiments. Scale bar, 5 mm.

may elicit a reduced immune response. More experiments are needed to validate the possibility that traffic noise negatively impacts immune defense upon pathogen infection.

Our study has a limitation associated with the application of background noise to control group seeds. Due to limited technical resources, control seeds were placed outside the sound-proof facility that housed the seeds exposed to traffic noise. Notwithstanding, the main observations drawn from this study are likely biologically relevant, as plants in nature have no chance to grow in a completely soundless condition, and the experimental groups and control groups were protected from light and grown under the same conditions (e.g., temperature, humidity). Further analysis of A. thaliana seeds in the same sound-proof facility in response to background noise or no sound treatment will be helpful to validate and strengthen our findings and related implications.

The results of this study demonstrate the stimulatory role of urban traffic noise on *A. thaliana* seedling growth, which partially supports our initial hypothesis that traffic noise could stimulate both seed germination and seedling growth. Accompanying changes in gene expression suggest that traffic noise reprograms various cellular processes related to stress, auxin signaling, metabolism, and immunity. More biological information using single-cell transcriptomics and other omics technology (e.g., proteomics, metabolomics) will be needed to better understand the integrative, complex actions of traffic noise on various plants. It will also be important to systematically investigate the biological effects of different frequencies or variable sound intensities on diverse plants. As noise pollution emerges as a serious environmental factor, its direct effects on plant growth and life cycle can make considerable ecological changes by indirectly affecting plant-animal (e.g., insects) relationships. Ultimately, further research on the biological impacts of noise on plants can make significant contributions to developing technologies to protect ecological health from the detrimental effects of environmental noise pollution.

MATERIALS AND METHODS

Plant Material and Growth Condition

Wild-type seeds of *A. thaliana* obtained from the KAIST (Korea Advanced Institute of Science & Technology) plant biology laboratory were seeded on half-strength Murashige and Skoog (MS)-agar plates (MS 2.2 g, 2-morpholinoethanesulfonic acid 0.5 g, phytoAgar 8 g, distilled water 1L, pH 5.7) (Duchefa #M0222.0050, #M1503.0250, #P1003.1000). Seeds on the plates were irradiated with a pulse of far-red light (724 nm, 5 µmol m^{-2} s^{-1}) for 5 min, followed by a pulse of red light (656 nm, 25 µmol m^{-2} s^{-1}) for 5 min. After that, plates were sealed with 3M micropore tape to prevent dehydration and wrapped in aluminum foil to block light. No further light treatment was applied for both noise exposure and germination assays.

Exposure of Seeds to Urban Traffic Noise

To collect urban traffic noise, sound recording was performed in Gangnam, Seoul area with high traffic density by using iPhone 13 (Apple, Inc). Patterns of noise frequency and waveforms from three different source types (bus & motorcycle, ambulance, subway train) were analyzed by the Sound Analyzer 1.12.2 application (**Figure 1**). A total of 10 min recording of traffic noise was structured in the sequence of buses and motorcycles, succeeded by ambulances, and concluding with subway stations (**Figure 1A**). Sound analysis was also performed on the background white noise collected outside the sound-proof facility for control groups (**Figure 1B**). For the experimental groups, the traffic noise treatments were performed in a sound-proof facility by using the inote BT-V3 speaker system (Fusionfnc, Inc). Experimental groups were continuously treated with traffic noise at an average of 75 dB with a range of 57 to 90 dB for 48 h. Noise volume was measured using the Sound Meter application (Splend Apps, Inc). A sound-proof facility was custom-made to block external noise interference using polyester fiber acoustic panels and wood wool acoustic boards composed of wood fiber and inorganic cement binders (Rachmaninov Co. Korea). The facility measures 4 m in length, 3 m in width, and 2 m in height. As for the untreated control groups, the seeds were placed outside

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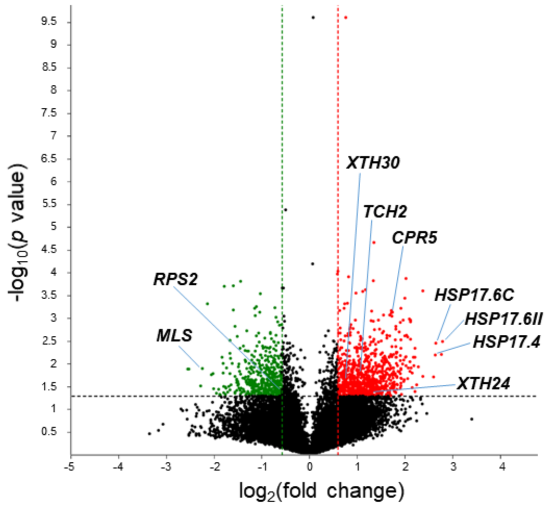

Figure 5. Volcano plot of the differentially expressed genes (DEGs) due to 48 h of noise exposure. The green dots indicate genes that reduced 1.5-fold below, and the red dots indicate genes that increased 1.5-fold above the control. The dotted black line shows the significance threshold (p = 0.05) with points above the line having $p < 0.05$ and points below the line having $p > 0.05$. Among significantly altered genes, several genes of top ranked and interesting pathways are indicated.

the sound-proof facility and exposed to background white noise at an average of 10 dB with a range of 5 to 15 dB. Both the sound-proof facility and the outside area were maintained at a constant temperature (22 °C) and humidity (60-70%).

Germination Assay

The experimental group of *A. thaliana* seeds was subjected to traffic noise at an average of 75 dB. *A. thaliana* seeds were placed in a sound-proof facility to prevent the transfer of vibrations between samples during the sound wave treatments. After 48 h of traffic noise exposure, the sound was turned off, and the seed germination was determined by counting all seeds harboring at least one radicle protrusion. The control group was exposed to a background noise of approximately 10 dB on average. Germination assays were independently performed three times.

Seedling Length Measurement

For seedling growth assays, seeds were stratified by immersion in water and incubation under dark conditions at 4°C for 3 days, followed by red pulses (10 min, 25 µmol m^{-2} s^{-1}). The light irradiation chamber was maintained at 22 °C. Seeds were vertically grown and exposed to traffic noise or control white noise for 48 h. Seedling growth was assessed by using ImageJ software. The length of seedlings was measured from the beginning of the hypocotyl to the tip of the roots. Seedling length measurement assays were independently performed twice.

RNA-seq Analysis & Gene Ontology (GO) Analysis

Three sets of seedling samples (8-10 seedlings per set) from 48 h noise exposure and control groups were collected and processed for RNA-Seq analysis. Total RNA was isolated using Trizol reagent (Invitrogen, Waltham, MA, USA). RNA quality was assessed with an Agilent 2100 bioanalyzer using the RNA 6000 Nano Chip (Agilent Technologies, Santa Clara, CA, USA). RNA quantification was performed using an ND-2000 Spectrophotometer (Thermo Fisher Scientific, Inc., Waltham, MA, USA). QuantSeq 3′ mRNA-Seq was performed by Ebiogen (Ebiogen, Inc., Seoul, South Korea). The libraries for control and traffic nose-treated seedlings (n = 3 each) were constructed using the QuantSeq 3′ mRNA-Seq Library Prep Kit (Lexogen GmbH, Vienna, Austria) according to the manufacturer's instructions. High-throughput sequencing was performed as single-end 75 bp sequencing using NextSeq 500 (Illumina, Inc., San Diego, CA, USA). Sequenced reads were trimmed for adaptor sequence, masked for low-complexity or low-quality sequence, and then mapped to TAIR10.1 (NCBI) whole genome using Bowtie2. Differentially expressed genes were identified through counts derived from unique and multiple alignments, utilizing Bedtools coverage. The read count data underwent processing via the quantile normalization method using EdgeR within R (R Development Core Team, 2016) through Bioconductor.

Classification of DEGs based on biological processes was conducted using the Database for Annotation Visualization and Integrated Discovery (DAVID) software (34). Data mining and

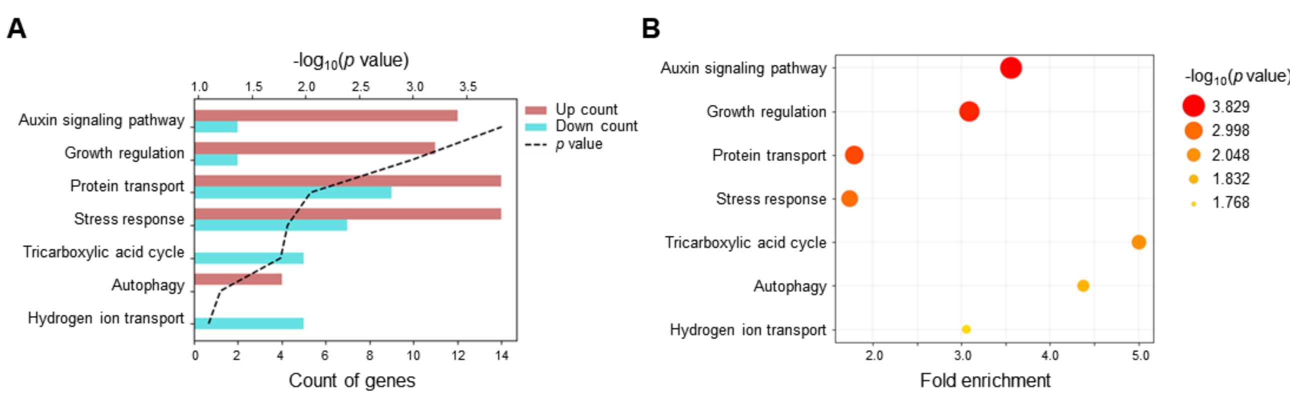

Figure 6. Gene Ontology (GO) enrichment analysis of DEGs between the noise-treated and control groups. (A) Gene classification was based on searches conducted by the DAVID software tool (34). Count of upregulated (red bars) and downregulated (blue bars) genes are represented. The black dotted line of the graphs represents the $-\log_{10}(p \text{ value})$. (B) The x-axis represents the fold enrichment of the GO terms. The color intensity and the size of the bubbles increase with the $-\log_{10}(p \text{ value})$.

graphic visualization were performed using ExDEGA (Ebiogen Inc., Seoul, South Korea). Sequencing data were deposited in the NCBI GEO (accession number GSE240794).

Statistical Analysis

Differences between averages of germinated seed numbers and measured seedling length in control and noise exposure groups were analyzed using a two-tailed Student's *t*-test. Statistical significance was set at $p < 0.05$. Statistical calculations were performed in Microsoft Excel (**Figure 3**) and GraphPad Prism 7 software (**Figure 4**).

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REFERENCES

1. Lopez-Ribera, Ignacio and Vicient, Carlos M. "Drought tolerance induced by sound in Arabidopsis plants." *Plant Signaling and Behavior*, vol. 12, no. 10, Oct. 2017, pp. e1368938. https://doi.org/10.1080/15592324.2017.1368938
2. Choi, Bosung, *et al*. "Positive regulatory role of sound vibration treatment in *Arabidopsis thaliana* against *Botrytis cinerea* infection." *Scientific Reports*, vol. 7, no. 1, May. 2017, pp. 2527. https://doi.org/10.1038/s41598-017-02556-9
3. Barber, Jesse R., *et al*. "The costs of chronic noise exposure for terrestrial organisms." *Trends in Ecology & Evolution*, vol. 25, no. 3, Mar. 2010, pp. 180–189. https://doi.org/10.1016/j.tree.2009.08.002
4. Kleist, Nathan J., *et al*. "Chronic anthropogenic noise disrupts glucocorticoid signaling and has multiple effects on fitness in an avian community." *Proceedings of the National Academy of Sciences of the United States of America*, vol. 115, no. 4, Jan. 2018, pp. E648–E657. https://doi.org/10.1073/pnas.1709200115
5. Francis, Clinton D., *et al*. "Noise pollution alters ecological services: enhanced pollination and disrupted seed dispersal." *Proceedings of the Royal Society B: Biological Sciences*, vol. 279, no. 1739, Jul. 2012, pp. 2727–2735. https://doi.org/10.1098/rspb.2012.0230
6. Mishra, Ratnesh C., *et al*. "Plant acoustics: in the search of a sound mechanism for sound signaling in plants." *Journal of Experimental Botany*, vol. 67, no. 15, Aug. 2016, pp. 4483–4494. https://doi.org/10.1093/jxb/erw235
7. National Research Council (US) Committee on Disability Determination for Individuals with Hearing Impairments. "Basics of sound, the ear, and hearing." *Hearing Loss: Determining Eligibility for Social Security Benefits*, edited by Robert A Dobie and Susan Van Hemel, National Academies Press (US), 2004, pp. 42–68. https://doi.org/10.17226/11099
8. "Environmental noise guidelines for the European region." *WHO Regional Office for Europe*. www.who.int/europe/publications/i/item/9789289053563. Accessed 20 Nov. 2023
9. Kafash, Zohreh H., *et al*. "Traffic noise induces oxidative stress and phytohormone imbalance in two urban plant species." *Basic and Applied Ecology*, vol. 60, May. 2022, pp. 1–12. https://doi.org/10.1016/j.baae.2022.01.010
10. Appel, Heidi M. and Cocroft, Reginald B. "Plants respond to leaf vibrations caused by insect herbivore chewing." *Oecologia*, vol. 175, no. 4, Aug. 2014, pp. 1257–1266. https://doi.org/10.1007/s00442-014-2995-6
11. Koornneef, Maarten and Meinke, David. "The development of Arabidopsis as a model plant." *The Plant Journal*, vol. 61, no. 6, Mar. 2010, pp. 909–921. https://doi.org/10.1111/j.1365-313X.2009.04086.x
12. Bergelson, Joy and Roux, Fabrice. "Towards identifying genes underlying ecologically relevant traits in *Arabidopsis thaliana*." *Nature Reviews Genetics*, vol. 11, no. 12, Dec. 2010, pp. 867–879. https://doi.org/10.1038/nrg2896
13. Zhao, Bi, *et al*. "How many differentially expressed genes: a perspective from the comparison of genotypic and phenotypic distances." *Genomics*, vol. 110, no. 1, Jan. 2018, pp. 67–73. https://doi.org/10.1016/j.ygeno.2017.08.007
14. Bhandawat, Abhishek and Jayaswall, Kuldip. "Biological relevance of sound in plants." *Environmental and Experimental Botany*, vol. 200, Aug. 2022, pp. 104919. https://doi.org/10.1016/j.envexpbot.2022.104919
15. Rodrigo-Moreno, Ana, *et al*. "Root phonotropism: early signalling events following sound perception in Arabidopsis roots." *Plant Science*, vol. 264, Nov. 2017, pp. 9–15.https://doi.org/10.1016/j.plantsci.2017.08.001
16. Kim, Joo Yeol, *et al*. "Sound waves promote *Arabidopsis thaliana* root growth by regulating root phytohormone content." *International Journal of Molecular Sciences*, vol. 22, no. 11, May. 2021, pp. 5739. https://doi.org/10.3390/ijms22115739
17. Wang, Bochu, *et al*. "Biological effect of sound field stimulation on paddy rice seeds." *Colloids and Surfaces B: Biointerfaces*, vol. 32, no. 1, Oct. 2003, pp. 29–34. https://doi.org/10.1016/S0927-7765(03)00128-0
18. Yang, Xiaocheng, *et al*. "Effects of sound stimulation on energy metabolism of *Actinidia chinensis* callus." *Colloids and Surfaces B: Biointerfaces*, vol. 30, no. 1-2, Jul. 2003, pp. 67–72. https://doi.org/10.1016/S0927-7765(03)00027-4
19. Wang, Wangxia, *et al*. "Role of plant heat-shock proteins and molecular chaperones in the abiotic stress response." *Trends in Plant Science*, vol. 9, no. 5, May. 2004, pp. 244–252. https://doi.org/10.1016/j.tplants.2004.03.006
20. Swindell, William R., *et al*. "Transcriptional profiling of Arabidopsis heat shock proteins and transcription factors reveals extensive overlap between heat and non-heat stress response pathways." *BMC Genomics*, vol. 8, May. 2007, pp. 125. https://doi.org/10.1186/1471-2164-8-125
21. Ul Haq, Saeed, *et al*. "Heat shock proteins: dynamic biomolecules to counter plant biotic and abiotic stresses." *International Journal of Molecular Sciences*, vol. 20, no.21, Oct. 2019, pp. 5321. https://doi.org/10.3390/ijms20215321
22. Monshausen, Gabriele B. and Haswell, Elizabeth S. "A force of nature: molecular mechanisms of mechanoperception in plants." *Journal of Experimental Botany*, vol. 64, no. 15, Nov. 2013, pp. 4663–4680. https://doi.org/10.1093/jxb/ert204
23. Braam, Janet, *et al*. "Plant responses to environmental stress: regulation and functions of the Arabidopsis TCH genes." *Planta*, vol. 203, no. Suppl 1, Aug. 1997, pp. S35–S41. https://doi.org/10.1007/pl00008113
24. Lee, Dennis, *et al*. "Genome-wide identification of touch- and darkness-regulated Arabidopsis genes: a focus on calmodulin-like and XTH genes." *New Phytologist*, vol. 165, no. 2, Feb. 2005, pp. 429–444. https://doi.org/10.1111/j.1469-8137.2004.01238.x

25. Teale, William D., *et al*. "Auxin in action: signalling, transport and the control of plant growth and development." *Nature Reviews Molecular Cell Biology*, vol. 7, no. 11, Nov. 2006, pp. 847–859. https://doi.org/10.1038/nrm2020
26. Stortenbeker, Niek and Bemer, Marian. "The SAUR gene family: the plant's toolbox for adaptation of growth and development." *Journal of Experimental Botany*, vol. 70, no. 1, Jan. 2019, pp. 17–27. https://doi.org/10.1093/jxb/ery332
27. Kornberg, Hans L. and Krebs, Hans. A. "Synthesis of cell constituents from C2-units by a modified tricarboxylic acid cycle." *Nature*, vol. 179, no. 4568, May 1957, pp. 988–991. https://doi.org/10.1038/179988a0
28. Eastmond, Petet J. and Graham, Ian A. "Re-examining the role of the glyoxylate cycle in oilseeds." Trends in Plant Science, vol. 6, no. 2, Feb. 2001, pp. 72–78. https://doi.org/10.1016/s1360-1385(00)01835-5
29. Cornah, Johanna E., *et al*. "Lipid utilization, gluconeogenesis, and seedling growth in Arabidopsis mutants lacking the glyoxylate cycle enzyme malate synthase." Journal of Biological Chemistry, vol. 279, no. 41, Oct. 2004, pp. 42916–42923. https://doi.org/10.1074/jbc.M407380200
30. Mindrinos, Michael, *et al*. "The A. thaliana disease resistance gene RPS2 encodes a protein containing a nucleotide-binding site and leucine-rich repeats." *Cell*, vol. 78, no. 6, Sep. 1994, pp. 1089–1099. https://doi.org/10.1016/0092-8674(94)90282-8
31. Kunkel, Barbara N., *et al*. "RPS2, an Arabidopsis disease resistance locus specifying recognition of *Pseudomonas syringae* strains expressing the avirulence gene avrRpt2." *Plant Cell*, vol. 5, no. 8, Aug. 1993, pp. 865–875. https://doi.org/10.1126/science.8091210
32. Malinovsky, Frederikke G., *et al*. "Antagonistic regulation of growth and immunity by the Arabidopsis basic helix-loop-helix transcription factor homolog of brassinosteroid enhanced expression2 interacting with increased leaf inclination1 binding bHLH1." *Plant Physiology*, vol. 164, no. 3, Mar. 2014, pp. 1443–1455. https://doi.org/10.1104/pp.113.234625
33. Bowling, Scott A., *et al*. "The cpr5 mutant of Arabidopsis expresses both NPR1-dependent and NPR1-independent resistance." *Plant Cell*, vol. 9, no. 9, Sep. 1997, pp. 1573–1584. https://doi.org/10.1105/tpc.9.9.1573
34. Huang, Da W., *et al*. "Systematic and integrative analysis of large gene lists using DAVID bioinformatics resources." *Nature Protocols*, vol. 4, no. 1, Jan. 2009, pp. 44–57. https://doi.org/10.1038/nprot.2008.211

APPENDIX

Table 1. List of DEGs in *Arabidopsis thaliana* seedlings exposed to traffic noise

	Fold change	*p* value	Average of normalized Data (log2)			
Gene symbol	**sound /control**	**sound /control**	**control**	**sound**	**Locus tag**	**Entrez ID**
HSP17.6II	6.868	0.003	1.363	4.143	AT5G12020	831075
AT1G02305	1.625	0.041	6.217	6.918	AT1G02305	839538
CLPP5	0.611	0.009	5.256	4.546	AT1G02560	839433
emb2386	0.647	0.045	8.597	7.968	AT1G02780	839407
AT1G53540	6.273	0.004	2.282	4.931	AT1G53540	841789
HSP17.4	6.181	0.006	1.388	4.015	AT3G46230	823768
SPI	1.613	0.031	4.356	5.045	AT1G03060	839323
MCCA	1.810	0.022	4.948	5.805	AT1G03090	838362
AT1G03590	0.665	0.035	4.591	4.002	AT1G03590	839447
PRP39	0.554	0.039	6.002	5.150	AT1G04080	839314
AT1G04230	1.880	0.033	6.106	7.017	AT1G04230	839575
SHY2	1.887	0.032	6.068	6.984	AT1G04240	839570
AT1G29460	4.501	0.007	1.912	4.082	AT1G29460	839822
AT5G07580	4.332	0.001	2.331	4.446	AT5G07580	830651
AT1G07020	1.788	0.002	3.221	4.060	AT1G07020	837212
AT1G04537	1.799	0.002	3.213	4.060	AT1G04537	28716140
AT2G37130	4.300	0.015	7.439	9.543	AT2G37130	818289
AT1G07930	0.660	0.012	8.786	8.186	AT1G07930	837308
AT2G29500	4.285	0.009	2.430	4.529	AT2G29500	817499
VSR7	4.058	0.011	2.399	4.419	AT4G20110	827757
AT1G08340	0.247	0.035	4.032	2.017	AT1G08340	837354
SDH6	0.608	0.024	6.226	5.508	AT1G08480	837369
HGO	3.908	0.008	3.175	5.142	AT5G54080	835494
CRT1b	0.663	0.043	5.550	4.957	AT1G09210	837441
PIF3	1.642	0.031	3.687	4.403	AT1G09530	837479
NFXL1	1.551	0.033	4.286	4.919	AT1G10170	837555
DET3	0.647	0.001	7.980	7.351	AT1G12840	837840
GSTF4	3.904	0.001	3.739	5.704	AT1G02950	838240
ORP1D	0.458	0.022	4.885	3.758	AT1G13170	837875
AT1G76220	3.777	0.021	2.590	4.508	AT1G76220	843955

AOC4	0.607	0.020	7.534	6.814	AT1G13280	837888
ML2	3.775	0.013	2.917	4.833	AT2G42890	818890
AT1G15140	0.330	0.001	4.105	2.505	AT1G15140	838079
AT1G15270	0.637	0.010	7.156	6.505	AT1G15270	838094
AT1G05163	0.445	0.012	5.028	3.860	AT1G05163	28716259
AT1G15405	0.445	0.012	5.028	3.860	AT1G15405	5007697
AT1G15670	1.905	0.044	6.568	7.498	AT1G15670	838136
AT1G15760	0.463	0.039	5.125	4.012	AT1G15760	838145
AT1G15810	0.592	0.045	5.414	4.658	AT1G15810	838150
AT1G15930	0.621	0.032	7.730	7.042	AT1G15930	838163
PAB1	0.605	0.030	5.062	4.337	AT1G16470	838217
AT1G16700	0.454	0.001	5.245	4.106	AT1G16700	838239
MYA1	1.630	0.014	3.489	4.194	AT1G17580	838333
AT1G17860	1.535	0.036	5.305	5.923	AT1G17860	838365
AT1G05347	1.545	0.037	5.305	5.932	AT1G05347	28716296
ATARCA	0.640	0.043	8.878	8.235	AT1G18080	838388
SNRK2.3	3.771	0.004	2.475	4.390	AT5G66880	836822
AT1G18540	0.573	0.007	6.483	5.679	AT1G18540	838435
IQD30	0.541	0.026	5.486	4.600	AT1G18840	838465
AT1G19530	3.736	0.007	6.853	8.755	AT1G19530	838540
RRA3	0.661	0.009	4.528	3.930	AT1G19360	838519
AT5G67130	3.680	0.015	2.215	4.095	AT5G67130	836848
AT5G18640	3.464	0.042	2.534	4.326	AT5G18640	831982
rpl32	3.422	0.032	7.388	9.163	ArthCp072	844704
CNGC8	1.853	0.017	5.675	6.564	AT1G19780	838566
XCP2	0.550	0.009	4.789	3.927	AT1G20850	838677
NAC3	3.387	0.035	3.374	5.134	AT3G15500	820789
AT3G51400	3.344	0.012	3.088	4.830	AT3G51400	824303
ATS2	3.341	0.001	2.948	4.689	AT4G30580	829181
LYM1	0.645	0.023	5.224	4.591	AT1G21880	838790
AT1G22060	0.606	0.019	4.265	3.543	AT1G22060	838811
CPR5	3.282	0.001	3.818	5.533	AT5G64930	836617
AT1G22790	1.806	0.039	4.083	4.936	AT1G22790	838885
TPS9	1.540	0.039	6.755	7.377	AT1G23870	838998
AT1G24510	0.616	0.031	7.315	6.616	AT1G24510	839066
AT1G24822	1.751	0.040	5.473	6.281	AT1G24822	839086

LpxC2	1.690	0.039	5.706	6.463	AT1G24880	839088
AT1G24996	1.823	0.040	5.336	6.203	AT1G24996	839092
AT1G25175	1.682	0.032	5.751	6.501	AT1G25175	6240724
PDS1	3.235	0.011	3.267	4.960	AT1G06570	837168
AT1G05993	0.411	0.019	4.117	2.835	AT1G05993	28716413
AT1G26880	0.547	0.042	7.442	6.572	AT1G26880	838331
RPL10B	0.551	0.039	4.556	3.695	AT1G26910	837036
HK3	1.946	0.001	5.395	6.355	AT1G27320	839621
APT1	0.529	0.005	7.683	6.764	AT1G27450	839636
AT1G27670	1.518	0.002	6.745	7.347	AT1G27670	839659
AT1G52710	3.189	0.047	3.319	4.992	AT1G52710	841704
AT3G51390	3.174	0.010	2.924	4.591	AT3G51390	824302
SNOR105	0.536	0.011	5.680	4.781	AT1G29071	5007736
AT1G06227	0.548	0.020	5.682	4.816	AT1G06227	28716454
ATPMEPCRD	3.154	0.021	8.214	9.871	AT2G43050	818907
AT1G29470	0.615	0.044	7.311	6.609	AT1G29470	839823
ERF4	3.095	0.009	2.628	4.258	AT3G15210	820752
RWA4	0.472	0.017	4.785	3.703	AT1G29890	839867
CAB1	1.913	0.023	9.342	10.278	AT1G29930	839871
AT1G29500	3.066	0.030	3.879	5.496	AT1G29500	839827
AT1G30630	0.632	0.019	5.656	4.994	AT1G30630	839943
AT1G30720	1.759	0.005	4.192	5.006	AT1G30720	839952
AT1G80440	3.050	0.008	6.026	7.635	AT1G80440	844383
XTH30	1.706	0.018	9.649	10.419	AT1G32170	840109
ESP3	0.456	0.028	4.679	3.548	AT1G32490	840143
AT1G32530	0.479	0.010	4.280	3.217	AT1G32530	840147
PRPL11	0.446	0.036	6.099	4.933	AT1G32990	840194
AT1G33120	0.440	0.026	7.051	5.868	AT1G33120	840208
PGY2	0.624	0.045	8.259	7.577	AT1G33140	840211
AT1G34630	0.514	0.025	4.553	3.592	AT1G34630	840367
RPL21C	0.659	0.022	6.464	5.863	AT1G35680	840472
SBP1	1.666	0.024	5.350	6.087	AT1G45976	841106
AT2G40270	3.016	0.009	2.706	4.298	AT2G40270	818619
AT1G47410	0.568	0.030	5.997	5.181	AT1G47410	841146
RBP47C'	0.491	0.013	5.073	4.047	AT1G47500	841159
SERPIN1	1.501	0.026	3.822	4.408	AT1G47710	841182

EMB3105	0.472	0.049	7.361	6.276	AT1G48350	841255
AT3G11280	2.995	0.019	2.719	4.301	AT3G11280	820299
AT1G51200	1.647	0.011	8.612	9.332	AT1G51200	841543
AT1G51980	0.616	0.002	5.647	4.949	AT1G51980	841627
CYP71B34	2.969	0.007	3.976	5.546	AT3G26300	822234
AT1G52750	1.974	0.014	4.361	5.342	AT1G52750	841708
TCP3	0.661	0.022	4.650	4.053	AT1G53230	841756
AT1G30090	2.945	0.010	3.201	4.760	AT1G30090	839888
AT1G53560	1.503	0.035	6.420	7.007	AT1G53560	841791
AT5G18140	2.905	0.022	3.201	4.740	AT5G18140	831932
AXR4	1.990	0.006	4.274	5.266	AT1G54990	841941
AT1G55340	0.570	0.020	6.057	5.245	AT1G55340	841980
EDA40	2.871	0.012	3.562	5.083	AT4G37890	829945
AT1G57610	0.539	0.004	4.528	3.636	AT1G57610	842137
ATP-PRT1	0.593	0.003	5.683	4.928	AT1G58080	842175
AT1G58235	1.694	0.023	4.849	5.609	AT1G58235	842192
AT1G58684	0.661	0.012	6.565	5.968	AT1G58684	842222
AT3G26580	2.860	0.009	3.898	5.414	AT3G26580	822266
AT3G52460	2.828	0.020	4.476	5.976	AT3G52460	824411
KTI1	2.828	0.035	6.977	8.477	AT1G73260	843660
AT1G60070	0.655	0.007	6.939	6.330	AT1G60070	842301
TPS10	1.540	0.001	5.596	6.219	AT1G60140	842309
AT2G21180	2.825	0.020	4.125	5.623	AT2G21180	816653
AT4G05150	2.807	0.026	4.939	6.428	AT4G05150	825863
AT1G61667	1.984	0.040	3.428	4.416	AT1G61667	842463
SNAP33	2.802	0.006	3.299	4.785	AT5G61210	836242
AT1G63640	0.586	0.026	4.011	3.240	AT1G63640	842668
ATG8B	2.795	0.015	3.103	4.586	AT4G04620	825794
AT1G08643	0.316	0.007	7.416	5.752	AT1G08643	28716875
AT1G64650	0.494	0.006	6.553	5.534	AT1G64650	842773
CYP89A9	2.791	0.035	3.216	4.696	AT3G03470	821250
AT1G65820	1.659	0.034	6.217	6.947	AT1G65820	842893
ERD1	2.787	0.043	3.525	5.004	AT5G51070	835180
AT4G33890	2.760	0.039	3.730	5.194	AT4G33890	829532
AT1G66180	1.674	0.039	6.650	7.394	AT1G66180	842933
CLPP3	0.605	0.007	5.038	4.313	AT1G66670	842985

AT1G47395	2.758	0.002	2.652	4.116	AT1G47395	841143
TRM22	0.398	0.025	5.670	4.339	AT1G67040	843024
AT1G67430	0.526	0.042	8.092	7.164	AT1G67430	843063
emb1688	0.451	0.044	4.136	2.989	AT1G67440	843064
AT1G68300	1.697	0.030	5.834	6.598	AT1G68300	843159
RAV2	1.767	0.000	5.776	6.597	AT1G68840	843216
AT5G01740	2.748	0.025	2.571	4.029	AT5G01740	831686
AT1G69980	1.845	0.046	3.926	4.810	AT1G69980	843335
TPS8	1.763	0.026	3.556	4.374	AT1G70290	843365
AT2G43535	2.744	0.033	8.014	9.470	AT2G43535	818955
GDPD4	1.629	0.035	5.339	6.043	AT1G71340	843475
AT1G72020	0.657	0.015	7.858	7.253	AT1G72020	843533
SLK1	2.737	0.015	2.586	4.039	AT4G25520	828657
LPA3	0.463	0.002	5.211	4.100	AT1G73060	843637
ACR9	2.664	0.035	6.526	7.940	AT2G39570	818542
DR4	0.556	0.020	6.052	5.206	AT1G73330	843668
SS2	1.528	0.040	4.137	4.748	AT1G74020	843740
HVA22A	1.796	0.043	4.533	5.378	AT1G74520	843793
HBI1	2.664	0.012	2.910	4.324	AT2G18300	816346
AT1G74680	1.672	0.011	3.496	4.237	AT1G74680	843807
AT1G22520	2.601	0.033	2.932	4.311	AT1G22520	838858
AT1G75770	0.577	0.035	4.378	3.585	AT1G75770	843910
TUB1	0.566	0.002	8.439	7.618	AT1G75780	843911
AT1G75785	0.565	0.002	8.438	7.615	AT1G75785	28717428
AT1G75800	1.558	0.002	6.336	6.976	AT1G75800	843913
XTH24	2.598	0.040	7.250	8.628	AT4G30270	829150
AT1G76460	1.583	0.040	5.657	6.320	AT1G76460	843979
SKIP	1.519	0.032	6.005	6.609	AT1G77180	844055
AT1G77940	0.434	0.008	6.846	5.641	AT1G77940	844129
AT5G16110	2.574	0.021	7.362	8.726	AT5G16110	831468
AT1G80180	1.682	0.002	5.412	6.162	AT1G80180	844358
GLY3	2.573	0.026	4.914	6.278	AT1G53580	841793
PLPB	2.560	0.002	5.085	6.441	AT2G02710	814800
AT4G14740	2.560	0.048	3.473	4.829	AT4G14740	827127
J8	1.918	0.022	6.528	7.468	AT1G80920	844432
AT2G01010	0.431	0.027	12.800	11.587	AT2G01010	3767991

AT2G01020	0.502	0.007	6.743	5.750	AT2G01020	3767992
AT2G03875	0.348	0.039	10.400	8.877	AT2G03875	28717528
PDE331	1.535	0.008	6.585	7.203	AT2G01190	814647
AT2G01250	0.481	0.033	8.298	7.243	AT2G01250	814652
PAHX	1.621	0.029	5.018	5.716	AT2G01490	814677
LRS1	2.533	0.000	3.533	4.873	AT3G05090	819671
AT1G19110	2.530	0.029	5.027	6.366	AT1G19110	838494
SPP	0.545	0.041	4.905	4.028	AT2G03120	814841
AT2G03350	1.887	0.020	3.473	4.390	AT2G03350	814864
AT2G04690	1.992	0.005	4.515	5.509	AT2G04690	815012
ZAP1	0.601	0.023	4.068	3.333	AT2G04880	815035
ACO3	0.553	0.045	7.967	7.112	AT2G05710	815120
ELF8	0.552	0.018	4.648	3.790	AT2G06210	815177
AT2G05195	0.448	0.042	4.408	3.249	AT2G05195	28717631
AT2G12462	0.555	0.017	4.829	3.979	AT2G12462	3768692
AT2G14880	0.501	0.032	6.490	5.493	AT2G14880	815977
AT2G15695	1.523	0.041	3.461	4.068	AT2G15695	816063
AT1G07135	2.526	0.024	5.184	6.521	AT1G07135	837224
RSH2	2.526	0.032	3.827	5.163	AT3G14050	820619
AT4G02370	2.525	0.006	4.623	5.960	AT4G02370	828057
AT2G18400	0.550	0.037	4.476	3.614	AT2G18400	816355
AT2G19680	0.586	0.021	4.130	3.358	AT2G19680	816487
AT2G20450	0.441	0.039	5.145	3.964	AT2G20450	816564
DGK5	0.536	0.046	5.332	4.431	AT2G20900	816624
pEARLI4	1.810	0.002	4.913	5.769	AT2G20960	816630
AT1G25550	2.515	0.036	4.475	5.806	AT1G25550	839142
AT4G21740	2.512	0.020	4.436	5.765	AT4G21740	828262
PAB4	0.604	0.026	6.753	6.025	AT2G23350	816867
AT2G24060	0.617	0.028	4.685	3.988	AT2G24060	816940
PRPL35	0.525	0.050	6.758	5.828	AT2G24090	816943
NF-YB11	0.467	0.031	4.252	3.154	AT2G27470	817292
AT2G27680	0.622	0.024	4.707	4.021	AT2G27680	817314
AT2G27720	0.573	0.037	9.427	8.624	AT2G27720	817318
AT2G28671	1.547	0.008	8.278	8.908	AT2G28671	6241140
ESB1	1.547	0.008	8.277	8.907	AT2G28670	817416
TOPP1	0.616	0.031	5.938	5.239	AT2G29400	817489

GSTU7	1.558	0.030	6.260	6.900	AT2G29420	817491
GLYI7	2.512	0.039	3.531	4.860	AT1G80160	844356
UGT71C2	1.931	0.038	3.841	4.791	AT2G29740	817524
BPC6	2.510	0.032	3.043	4.370	AT5G42520	834259
AT2G31585	1.916	0.019	5.359	6.298	AT2G31585	5007916
SAD2	1.535	0.021	5.254	5.873	AT2G31660	817722
AT2G31810	1.752	0.039	4.493	5.302	AT2G31810	817738
RAP	0.556	0.023	4.626	3.779	AT2G31890	817747
XIF	0.590	0.018	4.349	3.588	AT2G31900	817748
AT2G31902	0.596	0.018	4.272	3.525	AT2G31902	10723053
AT2G32150	1.767	0.012	9.001	9.822	AT2G32150	817774
GH9B8	0.620	0.038	6.113	5.423	AT2G32990	817861
AT2G33180	0.620	0.040	4.548	3.859	AT2G33180	817879
AT2G33400	0.506	0.049	4.489	3.505	AT2G33400	817904
AT2G33830	1.559	0.039	10.548	11.188	AT2G33830	817950
AT2G34480	0.659	0.023	9.395	8.793	AT2G34480	818011
NSL1	2.496	0.018	3.593	4.912	AT1G28380	839735
NPSN11	0.588	0.019	4.862	4.096	AT2G35190	818086
AT2G35382	0.402	0.013	4.586	3.272	AT2G35382	3768581
AT2G35680	1.758	0.037	6.000	6.814	AT2G35680	818137
AT5G60580	2.481	0.045	3.207	4.518	AT5G60580	836179
DOT1	1.663	0.015	10.146	10.879	AT2G36120	3768574
AT1G66130	2.479	0.027	2.860	4.170	AT1G66130	842927
RTFL17	2.478	0.026	5.687	6.996	AT1G13245	837884
RPL24A	0.505	0.021	7.941	6.956	AT2G36620	818234
AT3G47210	2.467	0.026	3.216	4.519	AT3G47210	823874
AT2G36950	1.829	0.026	5.651	6.522	AT2G36950	818269
AT2G37120	0.652	0.048	6.048	5.431	AT2G37120	818288
CKA1	2.443	0.030	4.547	5.836	AT5G67380	836873
AT2G37470	0.561	0.005	6.743	5.909	AT2G37470	818324
PSRP4	0.605	0.008	7.034	6.310	AT2G38140	818392
PECT1	0.453	0.010	4.499	3.357	AT2G38670	818449
NSP4	2.443	0.008	4.342	5.631	AT3G16410	820888
CYP71B29	2.430	0.036	3.628	4.909	AT1G13100	837867
AT2G39805	1.500	0.000	4.812	5.398	AT2G39805	818567
HOS1	1.696	0.032	3.321	4.083	AT2G39810	818568

AT2G40070	0.425	0.016	4.241	3.007	AT2G40070	818595
AT4G22750	2.423	0.014	4.501	5.778	AT4G22750	828372
FER4	1.604	0.009	4.379	5.061	AT2G40300	818622
AT2G40420	1.571	0.008	3.379	4.031	AT2G40420	818635
PRA1.E	2.423	0.042	3.886	5.163	AT1G08770	837399
ERD15	1.584	0.010	9.108	9.771	AT2G41430	818741
AT2G42670	1.868	0.026	3.687	4.588	AT2G42670	818867
MBF1A	1.504	0.042	4.894	5.483	AT2G42680	818868
MPK20	1.654	0.015	4.370	5.097	AT2G42880	818888
AT5G38200	2.420	0.047	3.723	4.998	AT5G38200	833802
AT1G72175	2.417	0.046	2.852	4.125	AT1G72175	843549
AT2G43460	0.657	0.018	7.761	7.156	AT2G43460	818947
AT2G41160	2.408	0.045	2.875	4.143	AT2G41160	818715
AT1G21050	2.405	0.046	4.240	5.506	AT1G21050	838699
MEKK1	2.401	0.004	3.581	4.845	AT4G08500	826409
NQR	2.397	0.037	4.102	5.363	AT3G27890	822411
AT2G44300	0.543	0.037	4.859	3.979	AT2G44300	819038
UMAMIT17	2.396	0.033	3.425	4.686	AT4G08300	826384
CHL-CPN10	0.600	0.013	6.431	5.694	AT2G44650	819073
AT4G13010	2.388	0.048	3.710	4.966	AT4G13010	826914
FLA8	0.634	0.003	9.581	8.922	AT2G45470	819155
ATI1	1.509	0.049	4.840	5.434	AT2G45980	819206
AT2G46220	1.741	0.002	5.248	6.048	AT2G46220	819229
SDH4	0.581	0.046	6.887	6.103	AT2G46505	819261
AT2G46690	1.645	0.047	5.466	6.183	AT2G46690	819281
ARF1A1C	0.605	0.040	7.794	7.068	AT2G47170	819330
DIM1A	0.590	0.040	4.628	3.867	AT2G47420	819355
FUM1	0.535	0.026	4.948	4.044	AT2G47510	819364
AT2G48100	0.654	0.019	5.248	4.635	AT2G48100	819422
HB20	0.641	0.008	4.453	3.811	AT3G01220	821232
AT3G01520	1.806	0.036	6.698	7.551	AT3G01520	821122
AT3G01930	0.635	0.049	5.539	4.884	AT3G01930	821218
AT1G14890	2.383	0.021	5.314	6.566	AT1G14890	838054
BPM4	1.827	0.018	3.436	4.305	AT3G03740	821170
PRA1.F4	2.375	0.010	3.927	5.175	AT3G13710	820580
emb2171	0.555	0.019	9.362	8.513	AT3G04400	819595

ZDS	1.810	0.020	3.721	4.577	AT3G04870	819647
AT3G13700	2.375	0.010	3.927	5.175	AT3G13700	820579
DRT102	2.374	0.019	4.068	5.316	AT3G04880	819648
AT1G60420	2.374	0.011	4.743	5.991	AT1G60420	842337
AT1G21680	2.362	0.018	4.387	5.627	AT1G21680	838770
AT3G05560	0.629	0.024	7.227	6.558	AT3G05560	819722
RPL18	0.552	0.028	9.342	8.485	AT3G05590	819725
AT3G05670	1.937	0.020	4.055	5.009	AT3G05670	819734
SYP43	1.524	0.020	3.456	4.063	AT3G05710	819740
AT3G05760	0.591	0.016	5.464	4.705	AT3G05760	819745
PRXIIF	0.526	0.030	5.761	4.834	AT3G06050	819778
AT3G06125	1.618	0.029	6.955	7.649	AT3G06125	5007986
GALK	0.666	0.018	4.854	4.268	AT3G06580	819837
AT3G06700	0.633	0.030	7.218	6.558	AT3G06700	819855
TRX z	0.538	0.041	4.983	4.089	AT3G06730	819858
AT2G43630	2.360	0.049	2.792	4.030	AT2G43630	818965
AT1G08315	2.354	0.009	3.774	5.009	AT1G08315	837352
PEX13	1.638	0.018	6.878	7.591	AT3G07560	819945
AT5G07890	2.350	0.027	2.988	4.221	AT5G07890	830682
AT3G07870	1.889	0.008	3.593	4.510	AT3G07870	819978
AT3G09760	2.345	0.007	4.022	5.252	AT3G09760	820134
AT3G09200	0.571	0.025	9.653	8.844	AT3G09200	820076
AT3G09470	1.836	0.013	3.989	4.866	AT3G09470	820104
ATL6	2.343	0.013	4.170	5.399	AT3G05200	819684
RABE1e	0.495	0.049	4.655	3.641	AT3G09900	820148
SAUR28	2.340	0.015	3.411	4.638	AT3G03830	821123
LYC	1.710	0.010	4.064	4.838	AT3G10230	820185
ASD1	1.506	0.050	4.675	5.265	AT3G10740	820243
AT3G11230	0.630	0.023	4.070	3.403	AT3G11230	820293
AT5G10770	2.340	0.027	4.509	5.736	AT5G10770	830944
AT3G11810	1.617	0.031	5.334	6.027	AT3G11810	820354
RPS5A	0.578	0.019	9.571	8.779	AT3G11940	820367
ELC	1.778	0.044	4.821	5.652	AT3G12400	820419
RALF1	2.340	0.023	4.602	5.829	AT1G02900	839389
SDRB	2.340	0.028	4.018	5.244	AT3G12800	820462
FHA2	2.335	0.040	3.681	4.905	AT3G07220	819910

NF-YA4	2.332	0.018	2.847	4.069	AT2G34720	818037
RAP2.2	1.683	0.028	5.540	6.291	AT3G14230	820643
WAG2	1.695	0.023	3.925	4.686	AT3G14370	820658
PRPS20	0.466	0.004	7.950	6.848	AT3G15190	820750
AT3G15200	0.355	0.029	7.202	5.708	AT3G15200	820751
AT1G04647	2.326	0.012	3.769	4.987	AT1G04647	28716157
AT3G15356	1.872	0.049	7.312	8.217	AT3G15356	820768
UBC5	2.324	0.005	5.664	6.880	AT1G63800	842683
AT3G15450	1.577	0.017	10.479	11.136	AT3G15450	820784
AT3G18280	2.322	0.023	4.367	5.583	AT3G18280	821356
AT3G45730	2.320	0.041	3.362	4.576	AT3G45730	823715
APG8H	1.640	0.020	5.332	6.046	AT3G15580	820798
AT3G16080	0.611	0.026	5.724	5.013	AT3G16080	820853
AT1G59970	2.318	0.007	3.536	4.749	AT1G59970	842291
AAE7	1.929	0.043	3.301	4.249	AT3G16910	820946
NAC2	2.315	0.026	3.572	4.783	AT3G15510	820790
CIPK1	1.804	0.034	4.243	5.094	AT3G17510	821016
RBL14	0.403	0.026	4.026	2.714	AT3G17611	821028
RLK902	0.534	0.012	5.480	4.576	AT3G17840	821053
AT3G17850	0.651	0.037	4.766	4.147	AT3G17850	821054
AT3G17900	0.503	0.007	4.575	3.583	AT3G17900	821058
CPUORF7	2.314	0.026	2.931	4.141	AT2G31280	817685
HDA15	0.643	0.047	4.171	3.534	AT3G18520	821382
TCP-1	0.621	0.016	6.464	5.776	AT3G20050	821544
UCNL	1.668	0.012	4.009	4.747	AT3G20830	821631
PGR7	0.606	0.039	4.031	3.307	AT3G21200	821673
AT3G21805	0.407	0.022	5.825	4.529	AT3G21805	3768883
AT3G04165	0.627	0.007	5.821	5.149	AT3G04165	28718728
IAA2	1.546	0.012	7.704	8.333	AT3G23030	821877
AT3G23310	1.672	0.021	4.500	5.242	AT3G23310	821911
AT3G24190	1.996	0.048	3.316	4.313	AT3G24190	822005
AT3G24715	1.859	0.010	3.248	4.142	AT3G24715	822069
ADS1	2.302	0.031	3.711	4.914	AT1G06080	837117
RIN4	1.726	0.025	4.150	4.937	AT3G25070	822098
FRD3	2.295	0.012	3.270	4.468	AT3G08040	819995
AT4G35750	2.291	0.007	8.309	9.505	AT4G35750	829728

PRXQ	0.439	0.025	6.818	5.629	AT3G26060	822203
AT2G44140	2.290	0.037	6.771	7.967	AT2G44140	819020
AT2G15960	2.285	0.009	6.415	7.607	AT2G15960	816091
NF-YC4	2.284	0.007	3.567	4.758	AT5G63470	836466
GHS1	0.627	0.044	7.044	6.370	AT3G27160	822335
AT5G07770	2.284	0.016	3.023	4.215	AT5G07770	830670
AT3G29075	0.599	0.039	5.288	4.549	AT3G29075	822552
AT3G41768	0.432	0.025	12.797	11.586	AT3G41768	3769408
AT3G06355	0.442	0.024	10.041	8.863	AT3G06355	28718910
AT3G41979	0.500	0.021	6.626	5.626	AT3G41979	3769409
AT3G06365	0.314	0.006	14.041	12.370	AT3G06365	28718911
WRKY70	2.280	0.018	3.858	5.047	AT3G56400	824807
HDA3	0.339	0.045	4.017	2.455	AT3G44750	823605
AT3G44820	1.665	0.028	4.561	5.297	AT3G44820	823616
AT3G05165	2.274	0.030	4.351	5.536	AT3G05165	819680
AT1G60000	2.273	0.027	3.878	5.062	AT1G60000	842294
RPS15AD	0.591	0.016	7.317	6.559	AT3G46040	823747
SHL1	2.270	0.017	4.971	6.154	AT4G39100	830065
AT3G46320	0.625	0.026	7.379	6.700	AT3G46320	823777
AT3G46430	0.562	0.015	5.552	4.721	AT3G46430	823793
AT3G47160	1.778	0.020	4.979	5.809	AT3G47160	823869
BZO2H3	2.268	0.021	3.605	4.786	AT5G28770	832990
AT3G47370	0.516	0.015	7.176	6.221	AT3G47370	823891
AT3G47490	0.268	0.036	4.490	2.589	AT3G47490	823903
AT2G44130	2.265	0.047	6.696	7.875	AT2G44130	819019
AT3G47965	1.919	0.024	3.483	4.423	AT3G47965	2745951
RR5	1.685	0.020	3.969	4.722	AT3G48100	823965
CXE5	2.248	0.039	5.055	6.224	AT1G49660	841390
AT3G48760	1.962	0.020	4.463	5.435	AT3G48760	824037
EMB1080	0.573	0.010	8.442	7.638	AT3G48930	824054
AT3G48970	1.771	0.047	6.182	7.007	AT3G48970	824058
AT3G49080	0.526	0.007	4.787	3.861	AT3G49080	824070
AT3G49350	1.661	0.014	4.766	5.498	AT3G49350	824097
NACA2	0.613	0.026	5.802	5.096	AT3G49470	824109
UBP26	0.568	0.049	4.643	3.827	AT3G49600	824122
IDD2	1.876	0.013	3.382	4.290	AT3G50700	824234

AT3G51010	0.538	0.041	6.421	5.528	AT3G51010	824265
AT3G51270	1.863	0.015	3.708	4.606	AT3G51270	824290
AT1G28390	2.248	0.004	3.276	4.445	AT1G28390	839736
AT1G66760	2.244	0.015	3.386	4.552	AT1G66760	842994
CAX3	1.578	0.016	4.004	4.662	AT3G51860	824349
AT3G51990	1.890	0.009	3.470	4.389	AT3G51990	824362
AT3G52040	0.352	0.024	4.659	3.152	AT3G52040	824367
AT3G52060	1.998	0.014	7.579	8.577	AT3G52060	824369
ATPQ	0.625	0.046	7.186	6.507	AT3G52300	824395
AT2G15880	2.239	0.030	4.911	6.074	AT2G15880	816084
AT3G52480	1.898	0.029	4.593	5.517	AT3G52480	824413
AT4G38290	2.238	0.027	2.855	4.017	AT4G38290	829986
UBQ1	0.629	0.033	8.124	7.454	AT3G52590	824425
AT3G52660	0.648	0.015	4.640	4.014	AT3G52660	824432
AT3G53430	0.630	0.001	8.208	7.541	AT3G53430	824511
AT3G53870	0.632	0.029	7.443	6.782	AT3G53870	824554
AT3G53890	0.608	0.019	7.229	6.510	AT3G53890	824556
AT3G54470	0.576	0.003	6.222	5.428	AT3G54470	824612
HTA11	0.480	0.008	6.112	5.052	AT3G54560	824621
PDE329	0.475	0.016	4.612	3.537	AT3G55250	824691
AT3G55485	0.432	0.034	4.431	3.220	AT3G55485	10723055
AT3G08485	0.421	0.026	4.420	3.171	AT3G08485	28719133
EPC1	1.862	0.029	4.726	5.622	AT3G55830	824749
AT3G55840	1.619	0.025	5.004	5.699	AT3G55840	824750
AT3G55940	1.878	0.011	4.128	5.038	AT3G55940	824760
ROC2	0.454	0.005	4.266	3.126	AT3G56070	824773
AT3G56360	1.719	0.013	5.629	6.411	AT3G56360	824803
AT3G56370	0.624	0.011	6.426	5.745	AT3G56370	824804
AT5G59895	2.234	0.004	3.290	4.449	AT5G59895	28721279
AT3G56720	0.533	0.017	4.142	3.233	AT3G56720	824839
AT3G57880	1.805	0.021	3.951	4.802	AT3G57880	824957
AT3G58610	0.655	0.039	8.444	7.832	AT3G58610	825030
AT3G59068	0.586	0.029	4.131	3.360	AT3G59068	28719415
AT3G59070	0.586	0.028	4.130	3.358	AT3G59070	825076
AT3G59350	1.966	0.020	7.979	8.955	AT3G59350	825104
AT3G59370	0.402	0.002	6.373	5.059	AT3G59370	825106

AT3G59540	0.593	0.005	7.479	6.725	AT3G59540	825123
AT3G59650	0.606	0.013	4.002	3.279	AT3G59650	825134
AT3G59940	1.645	0.001	7.963	8.681	AT3G59940	825164
AT3G09275	1.660	0.000	7.883	8.614	AT3G09275	28719203
WAVH1	2.230	0.004	3.473	4.630	AT2G22680	816799
AT3G60770	0.489	0.011	7.479	6.447	AT3G60770	825248
AT5G03230	2.221	0.037	4.372	5.523	AT5G03230	831900
PEX11E	1.665	0.022	6.251	6.987	AT3G61070	825279
AT3G61200	1.507	0.031	5.636	6.227	AT3G61200	825292
AT3G61260	1.577	0.003	7.891	8.549	AT3G61260	825298
AT3G61870	0.487	0.000	5.004	3.968	AT3G61870	825360
ROC4	0.463	0.001	7.089	5.977	AT3G62030	825376
LCD	1.590	0.019	3.854	4.523	AT3G62130	825386
AT3G62530	0.459	0.031	7.001	5.876	AT3G62530	825427
ATERDJ3B	0.643	0.048	5.346	4.710	AT3G62600	825434
OEP6	0.379	0.020	5.095	3.695	AT3G63160	825491
RPS13A	0.607	0.029	8.501	7.780	AT4G00100	828167
AT4G00585	0.644	0.029	5.524	4.890	AT4G00585	828026
AT4G00810	0.504	0.047	8.305	7.317	AT4G00810	828004
iqd17	0.531	0.035	4.663	3.750	AT4G00820	828002
AT4G26990	2.221	0.028	3.276	4.427	AT4G26990	828807
AT4G02450	0.620	0.049	7.572	6.883	AT4G02450	828006
GSTF2	1.645	0.027	6.505	7.224	AT4G02520	827931
AT4G04205	0.329	0.000	5.362	3.759	AT4G04205	28719545
AT4G02940	0.526	0.004	5.326	4.399	AT4G02940	828132
EMB2770	0.610	0.036	5.092	4.378	AT4G03430	827925
AT1G21400	2.218	0.047	3.848	4.998	AT1G21400	838739
AT5G42530	2.217	0.004	3.608	4.757	AT5G42530	834260
RFNR1	0.525	0.032	4.437	3.507	AT4G05390	825887
EXL4	2.215	0.009	10.605	11.752	AT5G09440	830803
UMAMIT20	1.613	0.036	3.405	4.094	AT4G08290	826383
GAPA	2.213	0.050	8.220	9.366	AT3G26650	822277
PP2-A13	2.200	0.013	5.455	6.593	AT3G61060	825278
AT4G08520	0.604	0.001	6.193	5.465	AT4G08520	826411
UBP9	1.793	0.017	3.825	4.668	AT4G10570	826649
AT4G11190	1.508	0.007	7.609	8.201	AT4G11190	826721

AT4G11380	0.513	0.022	5.012	4.049	AT4G11380	826741
PLDGAMMA1	1.957	0.028	3.877	4.846	AT4G11850	826791
HEXO3	2.194	0.005	3.759	4.892	AT1G65590	842871
AT4G12980	0.626	0.029	4.820	4.145	AT4G12980	826910
AT2G08780	2.193	0.034	5.654	6.787	AT2G08780	28718024
AT4G13180	0.622	0.034	7.266	6.581	AT4G13180	826932
AL3	2.191	0.004	3.763	4.895	AT3G42790	823316
AT4G13790	1.536	0.041	3.435	4.054	AT4G13790	827013
AT4G14270	1.934	0.038	5.457	6.409	AT4G14270	827068
AT4G14358	0.491	0.036	4.080	3.053	AT4G14358	6240839
IBR10	1.883	0.043	5.778	6.691	AT4G14430	827088
SAUR36	2.180	0.024	4.647	5.771	AT2G45210	819129
AT4G06235	0.538	0.021	4.099	3.205	AT4G06235	28719756
AT4G15000	0.604	0.037	9.575	8.849	AT4G15000	827159
AT2G36220	2.179	0.034	5.674	6.797	AT2G36220	818194
HSBP	0.614	0.005	5.814	5.110	AT4G15802	827261
ATG8F	1.618	0.021	6.441	7.136	AT4G16520	827351
AT4G16720	0.596	0.049	7.824	7.077	AT4G16720	827375
AT4G17390	0.635	0.034	8.108	7.454	AT4G17390	827451
IVD	2.177	0.033	5.399	6.521	AT3G45300	823668
AT4G17940	1.598	0.033	4.592	5.269	AT4G17940	827519
AT4G18380	1.654	0.037	4.294	5.020	AT4G18380	827567
AT4G06795	1.802	0.025	4.206	5.056	AT4G06795	28719815
AT4G06800	1.799	0.025	4.206	5.053	AT4G06800	28719816
MYB98	0.569	0.007	4.374	3.561	AT4G18770	827611
IRX1	0.581	0.025	4.500	3.717	AT4G18780	827612
RTFL16	2.167	0.011	5.961	7.076	AT3G25717	822160
AT4G20820	1.794	0.040	4.318	5.161	AT4G20820	827830
AT4G21105	0.533	0.027	7.296	6.388	AT4G21105	827858
AT4G13530	2.164	0.000	5.767	6.881	AT4G13530	826985
AT4G22240	1.574	0.004	4.218	4.873	AT4G22240	828319
ABCA2	2.161	0.043	3.380	4.492	AT3G47730	823927
ARF9	1.622	0.027	3.528	4.226	AT4G23980	828498
AT4G24026	1.687	0.015	4.263	5.018	AT4G24026	6240360
AT4G24330	0.559	0.030	5.957	5.117	AT4G24330	828536
AT4G24440	1.876	0.039	3.958	4.866	AT4G24440	828546

AT4G07275	0.499	0.022	4.985	3.982	AT4G07275	28719906
AT4G24750	0.436	0.031	6.146	4.948	AT4G24750	828577
AT4G24840	0.586	0.015	4.540	3.769	AT4G24840	828587
AT5G61530	2.156	0.038	4.363	5.472	AT5G61530	836274
AT4G25620	1.873	0.029	4.292	5.197	AT4G25620	828667
AT4G25710	1.612	0.006	5.682	6.371	AT4G25710	828676
CIL	0.489	0.015	4.777	3.746	AT4G25990	828705
RPS2	0.641	0.035	4.008	3.366	AT4G26090	828715
AT5G60760	2.142	0.043	3.437	4.536	AT5G60760	836197
AT4G27090	0.600	0.018	8.892	8.155	AT4G27090	828817
AT4G27450	1.776	0.003	7.026	7.855	AT4G27450	828854
LLG3	0.527	0.032	4.610	3.686	AT4G28280	828943
AT4G28290	0.527	0.032	4.610	3.686	AT4G28290	828944
emb2726	0.594	0.033	7.822	7.070	AT4G29060	829027
AT4G29270	0.645	0.026	6.336	5.703	AT4G29270	829048
AT4G29410	0.520	0.003	5.623	4.680	AT4G29410	829062
ATR2	1.622	0.041	4.828	5.526	AT4G30210	829144
MEMB11	2.138	0.013	3.950	5.047	AT2G36900	818264
BHLH32	2.126	0.035	4.337	5.425	AT3G25710	822159
RPS6	0.494	0.043	8.128	7.111	AT4G31700	829298
MEF8S	0.501	0.030	5.435	4.439	AT4G32450	829380
LUG	0.628	0.019	4.184	3.514	AT4G32551	829390
AT4G32910	1.931	0.047	3.607	4.556	AT4G32910	829427
AT4G33120	0.561	0.014	5.550	4.717	AT4G33120	829449
AT4G33180	0.439	0.028	4.233	3.045	AT4G33180	829455
AT4G33865	0.638	0.035	7.900	7.250	AT4G33865	829529
TPX2	2.116	0.041	8.262	9.344	AT1G65970	842909
BT2	2.110	0.004	6.043	7.120	AT3G48360	823994
ROC5	0.656	0.050	9.917	9.308	AT4G34870	829639
AT4G35080	0.656	0.019	4.011	3.402	AT4G35080	829660
AT4G35720	1.864	0.035	6.536	7.434	AT4G35720	829724
PUP14	2.109	0.021	5.934	7.011	AT1G19770	838565
GB2	1.627	0.017	4.555	5.257	AT4G35860	829740
ROT3	1.985	0.013	4.063	5.052	AT4G36380	829790
AT5G09565	2.107	0.040	4.187	5.262	AT5G09565	28721111
CEN2	1.796	0.010	4.836	5.681	AT4G37010	829855

AT4G37510	0.516	0.040	4.530	3.576	AT4G37510	829906
AT2G44360	2.100	0.003	3.928	4.998	AT2G44360	819043
TCH2	2.095	0.014	6.753	7.820	AT5G37770	833755
MYB88	2.091	0.008	3.993	5.058	AT2G02820	814812
AT4G39200	0.531	0.038	9.410	8.496	AT4G39200	830075
AT4G39838	1.660	0.013	5.304	6.036	AT4G39838	10723025
AT4G39840	1.660	0.013	5.304	6.036	AT4G39840	830143
AT4G40050	1.650	0.033	4.259	4.982	AT4G40050	830168
AT5G01590	0.366	0.046	5.867	4.418	AT5G01590	830369
AT1G09845	2.089	0.013	3.003	4.065	AT1G09845	28717185
AT5G02740	0.604	0.034	4.559	3.831	AT5G02740	831811
CDL1	1.738	0.007	4.894	5.691	AT5G02800	831285
LCL1	1.842	0.015	5.623	6.505	AT5G02840	831766
AT1G55530	2.087	0.012	4.995	6.056	AT1G55530	842000
UBQ3	1.788	0.009	10.385	11.224	AT5G03240	831899
ATXRCC1	2.085	0.002	2.978	4.039	AT1G80420	844382
MLS	0.210	0.013	8.920	6.666	AT5G03860	831690
AT5G04760	1.868	0.037	4.882	5.784	AT5G04760	830354
NHL3	1.624	0.040	4.005	4.705	AT5G06320	830520
UBP12	1.592	0.010	6.856	7.527	AT5G06600	830548
AT5G06970	0.528	0.008	4.992	4.070	AT5G06970	830588
MIF1	2.083	0.009	4.635	5.694	AT1G74660	843805
AT2G35859	2.080	0.005	4.246	5.302	AT2G35859	10723041
AT1G60010	2.079	0.029	3.680	4.736	AT1G60010	842295
AT5G08180	0.479	0.003	5.372	4.312	AT5G08180	830714
AT5G08300	0.577	0.012	6.787	5.994	AT5G08300	830726
BGLU16	2.075	0.017	6.016	7.069	AT3G60130	825183
AT5G10390	0.519	0.012	6.168	5.222	AT5G10390	830903
AT5G10400	0.453	0.010	7.216	6.076	AT5G10400	830904
AT4G06676	2.075	0.044	3.024	4.077	AT4G06676	826112
AT5G10830	0.537	0.038	5.619	4.722	AT5G10830	830950
AT5G11480	0.479	0.034	5.469	4.408	AT5G11480	831019
AT5G11900	0.543	0.028	6.561	5.679	AT5G11900	831063
RHA1	2.067	0.046	5.170	6.217	AT5G45130	834549
AT5G13430	0.643	0.024	5.924	5.287	AT5G13430	831184
PHT3;1	0.615	0.004	7.588	6.888	AT5G14040	831252

PDF1B	0.475	0.002	4.286	3.212	AT5G14660	831318
FDH	1.580	0.036	6.560	7.221	AT5G14780	831330
P5CR	0.584	0.049	6.733	5.959	AT5G14800	831332
bZIP3	1.741	0.009	4.217	5.017	AT5G15830	831440
KIN2	0.437	0.034	5.688	4.494	AT5G15970	831454
AT4G17900	2.066	0.004	4.830	5.877	AT4G17900	827514
AT5G16130	0.576	0.015	7.478	6.681	AT5G16130	831470
AAE5	1.703	0.013	6.547	7.316	AT5G16370	831498
AT5G02565	0.498	0.013	6.141	5.136	AT5G02565	28720480
AT5G16680	1.644	0.016	3.329	4.046	AT5G16680	831529
AT5G16880	1.708	0.009	5.827	6.599	AT5G16880	831551
AT5G17410	0.500	0.028	4.200	3.199	AT5G17410	831607
AT5G17610	1.503	0.030	3.464	4.052	AT5G17610	831627
AT5G18030	2.065	0.011	4.836	5.883	AT5G18030	831670
SAUR24	1.531	0.024	4.781	5.395	AT5G18080	28721172
AT5G18130	1.575	0.011	3.757	4.413	AT5G18130	831931
AT1G61590	2.064	0.010	5.557	6.603	AT1G61590	842455
AT5G18420	1.525	0.047	3.622	4.231	AT5G18420	831960
UBC32	2.063	0.011	4.462	5.506	AT3G17000	820956
AT5G18800	0.617	0.039	6.420	5.724	AT5G18800	831998
MSL9	0.409	0.040	5.548	4.257	AT5G19520	832072
AT5G19860	1.622	0.039	6.453	7.151	AT5G19860	832107
AT5G20090	1.654	0.006	5.358	6.085	AT5G20090	832131
AT5G20610	1.681	0.008	5.388	6.138	AT5G20610	832183
COPT5	1.516	0.032	7.583	8.183	AT5G20650	832188
AT5G22440	0.416	0.025	5.546	4.282	AT5G22440	832305
AT5G23610	1.680	0.011	4.155	4.904	AT5G23610	832427
DMR6	1.733	0.000	4.698	5.491	AT5G24530	832524
AT5G24735	1.859	0.012	6.620	7.515	AT5G24735	5008225
CIPK25	1.719	0.017	4.418	5.200	AT5G25110	832582
CYP71B13	1.843	0.034	3.582	4.463	AT5G25140	832585
AT5G25280	1.544	0.010	7.650	8.276	AT5G25280	832600
AT5G26850	0.550	0.018	4.936	4.073	AT5G26850	832743
AT1G19660	2.060	0.038	4.677	5.720	AT1G19660	838553
AT5G28900	0.543	0.023	4.240	3.359	AT5G28900	833013
RPS1	0.557	0.015	6.292	5.448	AT5G30510	833138

AT5G35525	1.749	0.002	7.858	8.665	AT5G35525	833517
AT4G15475	2.052	0.040	3.484	4.521	AT4G15475	827219
ARF8	0.593	0.012	4.623	3.870	AT5G37020	833672
BPS1	2.051	0.009	5.812	6.849	AT1G01550	839536
AT3G52535	2.049	0.036	3.025	4.060	AT3G52535	5008081
AT5G38640	0.466	0.038	4.733	3.630	AT5G38640	833854
SNOR108	0.436	0.028	6.550	5.352	AT5G41471	3771391
RPS10B	0.642	0.037	8.847	8.207	AT5G41520	834154
UBC8	1.752	0.034	6.674	7.484	AT5G41700	834173
BXL1	2.042	0.040	7.340	8.370	AT5G49360	834996
AT5G56100	2.037	0.008	5.717	6.744	AT5G56100	835709
AOS	1.744	0.039	4.741	5.544	AT5G42650	834273
AT5G42740	0.550	0.012	4.319	3.456	AT5G42740	834283
ACO2	2.034	0.031	9.890	10.914	AT1G62380	842536
APS4	1.847	0.044	6.205	7.091	AT5G43780	834400
CML43	0.533	0.045	4.708	3.800	AT5G44460	834473
AT5G44580	1.793	0.007	3.660	4.502	AT5G44580	834486
AT5G43260	2.032	0.033	3.803	4.826	AT5G43260	834344
AT5G45950	0.658	0.030	5.549	4.946	AT5G45950	834635
LARP6a	1.785	0.004	5.924	6.760	AT5G46250	834667
SSP4	1.597	0.017	3.592	4.268	AT5G46410	834684
MYC3	1.619	0.047	4.113	4.808	AT5G46760	834719
NSP5	1.577	0.032	9.334	9.991	AT5G48180	834871
AT5G07145	0.482	0.047	4.347	3.293	AT5G07145	28720867
sks3	0.485	0.047	4.347	3.302	AT5G48450	834900
RAP2.10	2.028	0.007	4.565	5.585	AT4G36900	829843
AT5G49530	0.588	0.009	4.409	3.644	AT5G49530	835014
EXO70F1	1.740	0.032	4.418	5.217	AT5G50380	835106
AT3G07580	2.027	0.018	3.202	4.221	AT3G07580	819949
AT5G51970	1.713	0.014	5.081	5.857	AT5G51970	835272
AT5G52430	0.493	0.018	4.902	3.881	AT5G52430	835319
HB52	1.957	0.040	5.785	6.754	AT5G53980	835481
AT1G18470	2.022	0.039	4.918	5.934	AT1G18470	838427
AT5G54630	1.702	0.006	3.810	4.578	AT5G54630	835552
GASA1	2.022	0.028	11.015	12.031	AT1G75750	843908
AT5G56710	0.550	0.007	7.868	7.004	AT5G56710	835772

MT1B	1.838	0.043	3.207	4.085	AT5G56795	3771524
MYB36	1.708	0.025	3.815	4.587	AT5G57620	835866
SKIP1	1.595	0.004	4.560	5.234	AT5G57900	835901
UXS3	0.660	0.019	8.496	7.898	AT5G59290	836047
AT5G59613	0.588	0.044	7.715	6.950	AT5G59613	836081
AT5G59690	0.557	0.034	10.063	9.218	AT5G59690	836090
AT5G59850	0.663	0.027	7.089	6.497	AT5G59850	836107
AT3G15430	2.019	0.010	4.000	5.014	AT3G15430	820782
ALP	1.702	0.031	6.950	7.718	AT5G60360	836158
AT4G12340	2.019	0.046	3.247	4.260	AT4G12340	826843
AT3G07350	2.018	0.002	3.419	4.431	AT3G07350	819923
AT3G24730	2.016	0.024	3.186	4.197	AT3G24730	822071
ANK6	1.543	0.005	5.883	6.509	AT5G61230	836244
JAL22	2.016	0.014	10.176	11.187	AT2G39310	818516
CNX1	0.614	0.001	7.159	6.456	AT5G61790	836301
AT5G62350	1.842	0.046	6.107	6.988	AT5G62350	836356
AT5G62910	1.664	0.045	3.579	4.314	AT5G62910	836411
MLP28	2.015	0.022	8.059	9.070	AT1G70830	843420
MUM2	1.954	0.039	4.741	5.708	AT5G63800	836500
ERS	0.548	0.021	4.552	3.685	AT5G64050	836526
AT5G64572	1.890	0.046	7.586	8.505	AT5G64572	5008331
AT5G35690	2.015	0.017	3.340	4.350	AT5G35690	833542
AT5G65360	0.533	0.013	7.620	6.711	AT5G65360	836661
AT5G65480	1.651	0.020	7.643	8.366	AT5G65480	836673
AT5G65925	1.884	0.032	5.143	6.057	AT5G65925	836722
ZWI	0.584	0.024	4.960	4.185	AT5G65930	836723
AT5G66052	1.632	0.034	8.995	9.702	AT5G66052	836736
AT1G31130	2.014	0.036	5.229	6.239	AT1G31130	839998
AT5G66053	1.687	0.040	8.352	9.107	AT5G66053	6240214
CPK28	1.548	0.046	4.510	5.140	AT5G66210	836753
DGL1	0.626	0.011	5.841	5.165	AT5G66680	836801
AT5G03380	2.012	0.011	7.180	8.188	AT5G03380	831854
AT3G10020	2.011	0.025	8.518	9.527	AT3G10020	820163
AT4G34180	2.005	0.026	4.250	5.254	AT4G34180	829566
rpl16	0.405	0.005	5.259	3.956	DA397_mgp39	36335645
rrn5	0.394	0.019	6.927	5.584	DA397_mgr03	36335687

	0.398	0.024	6.860	5.530	.	38088289
matK	0.549	0.031	10.166	9.301	ArthCp003	844797
trnR	0.431	0.047	4.102	2.888	ArthCt093	1466268
rpoC2	0.507	0.011	8.637	7.656	ArthCp012	844785
rpoC1	0.439	0.033	7.851	6.662	ArthCp013	844784
trnG	0.284	0.016	4.843	3.026	ArthCt116	4042809
trnI	0.170	0.013	7.588	5.029	ArthCt107	146626
trnA	0.346	0.023	7.008	5.476	ArthCt108	1466258
DGR1	2.000	0.014	5.811	6.811	AT1G80240	844364
ccsA	0.626	0.043	8.830	8.154	ArthCp073	844769
ArthCr091	0.358	0.034	6.493	5.010	ArthCr091	4042818
trnA	0.352	0.030	7.015	5.510	ArthCt114	4042813
trnI	0.173	0.013	7.570	5.041	ArthCt124	5563231

Table 2. GO enrichment analysis

The threshold of minimum gene counts belonging to an annotation term is expressed as count (%). The false discovery rate (FDR) is the ratio of the number of false positive classifications to the total number of positive classifications.

	Count	Genes	Count (%)	*p* value	FDR
Auxin signaling pathway	14	AT5G18030, ARF1A1C, SHY2, AT1G29460, IAA2, SAUR28, SAUR36, AT1G29500, SAUR24, ARF9, GSTF2, AT2G46690, ARF8, WAG2	0.57	1.482×10^{-4}	0.0127
Growth regulation	13	AT5G18030, HBI1, AT1G29460, SAUR28, SAUR36, CPK28, AT1G29500, SAUR24, AT3G17850, AT2G46690, WAG2, AT4G13790, HDA15	0.53	1.005×10^{-3}	0.0432
Protein transport	23	RHA1, ARF1A1C, AT4G24840, ATI1, RABE1E, SNAP33, AT4G32910, AT5G16880, AT4G08520, VSR7, EXO70F1, AT1G30630, AT1G60070, APG8H, AT2G44140, SYP43, NPSN11, GB2, AT5G01590, ATG8F, SAD2, ELC, AT4G11380 211	0.93	8.964×10^{-3}	0.2570
Stress response	22	PRXIIF, RHA1, KIN2, ATI1, NAC2, LCD, ATERDJ3B, RSH2, MYB88, HSP17.4, DGK5, AT1G53540, AT5G59613, AT3G46430, LYC, HSBP, HVA22A, SAD2, GSTF2, AT2G29500, HSP17.6II	0.89	1.471×10^{-2}	0.2936
Tricarboxylic acid	5	MLS, AT5G08300, ACO3, SDH6, SDH4	0.20	1.707×10^{-2}	0.2936
Autophagy	4	APG8H, AT2G44140, ATI1, ATG8F	0.16	6.209×10^{-2}	0.8899
Hydrogen ion transport	5	AT2G19680, AT5G59613, AT3G46430, ATPQ, DET3	0.20	7.998×10^{-2}	0.9826