【別紙２】

論文名：Morpho-physiological and molecular mechanism for tolerances to individual or combined heat and salt stresses of rice
(イネにおける熱および塩の単独または複合ストレス耐性の形態生理および分子機構)
（要約）

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（以下要約を記入する）

Global salinity and temperature stresses have been accelerating due to the emergent of anthropological activities such as irrational farming practices, excessive lifting of groundwater, food and textiles commodities production and excessive emission of carbon dioxide gas from different manufacturing factories. It has been projected that ~50% of cultivable land would be salt affected and the global temperature may accelerate to the critical +1.5 °C (2.8 °F) by 2050 which may affect the growth and yield formation of crops. An extrapolation by Food and Agricultural Organization, the world's population is expected to be reached about 9.8 billion; an increase of 119% in edible crop production will be necessary if agricultural practices do not alter dramatically. Sorry to say, crops face adverse climatic conditions concurrently and/or sequentially through or short episodes of its life cycle that create abiotic stresses such as extreme temperature, drought, flood, salinity, and heavy metals that hamper the crop productivity and quality.

Rice (*Oryza sativa* L.) is an important staple food for half of the world's population. Over 20% of worldwide rice cultivated land is estimated to be saline by the end of the century due to the earthquake- and tsunami-induced soil salinity, and sea level increases. Rice is one of the salt-sensitive cereal crops, especially the seedling stage is most critical. Modern cultivated rice genotypes showed evident yield reductions when the salinity value exceeded a threshold of 3 dS m^{-1} (30 mM NaCl) and survival of salt-sensitive genotypes compromised at 70 mM NaCl. The expected climate change includes the rise in the global average surface air temperature. The increase in surface air temperature will probably be around +1.5 °C, at the end of this century but most of the modern rice is currently cultivated in regions where temperatures are above the optimal for growth (28/22°C). Any further increase in mean temperature or episodes of high temperatures during sensitive stages may reduce rice yields drastically.

Two of the most harmful ecological stress factors on rice growth and productivity in worldwide are excessive salinity and high warmth. To date, most studies on plant stress response have focused on a single stress condition. However, in the field, these stresses commonly coexist, resulting in huge crop output losses. Therefore, it is necessary to elucidate the mechanisms of plant response to various multiple abiotic stresses in order to increase crop yields.

In this study, we aimed to examine the effects of salinity (SS, 75 mM NaCl), heat stress (HT, 30/26°C), and combined (SS+HT) stress, on seedling, vegetative and reproductive stages of the rice, and to check the impact of multiple stresses on rice yield parameters. Salt susceptible elite cultivar (WT; 'Yukinkomai'), salt tolerant genotype (YNU; 'YNU31-2-4') and the sister lines (YNU-SLs) without *hst1* gene were used for various evaluation.

At the seedling stage, morpho-physiological, biochemical, and transcriptional responses were assessed to determine the genotypes' capacity to withstand stress. This study suggested a significant role of Na^+ and K^+ uptake and transport, water restriction, osmoprotectant accumulation and the expression of transcripts and ROS-scavenging enzyme accumulation seen under stress combination, which cannot be inferred from the independent response of plants to each of the single stresses. The morpho-physiological, biochemical and molecular assessment results show that under SS+HT, YNU retained higher dry matter production, relative water content and photosynthetic pigments concentration, reduced malondialdehyde and Na+ levels, and also showed higher antioxidant system (osmo-protective compounds; proline and enzymes: CAT, SOD, APX) under both stress and recovery. Ion transporter genes *OsSOSs*, *OsHKT* and heat sock gene *OsHSP18* significantly play a vital role in protecting YNU under heat and/or salinity stresses.

At the vegetative and reproductive stages, single salt, heat and SS+HT stress at short episodes or throughout the vegetative to the reproductive stage of rice genotypes showed dissimilar responses. In general, YNU genotypes showed a lower Na^+, higher K^+ and lower Na^+/K^+ ratio than Yukinkomai and YNU-SLs experiencing salt stress followed by heat stress at a short episode or throughout during vegetative to reproductive stage, indicating the accumulation of higher ROS scavenging enzyme. From the vegetative to reproductive stage, SLs were more affected by prolonged salt stress experienced from vegetative to the reproductive stage than the Yukinkomai and YNU genotypes due to a significant decrease of morpho-physiological, photosynthetic rates and pigments except only in the heat treatments. The YNU genotypes showed

more tolerances under salt stress up to the reproductive stage than Yukinkomai and YNU-SLs. Under SS+HT stresses, three genotypes were affected more than the single stress, but the YNU genotype showed comparatively more tolerant than others.

Finally, it becomes much clearer that different stresses could interact to minimize the negative impact on plant health and performance by coordinating the allocation of assimilates between plant growth and defence responses, even if the effect of each stress applied individually is strongly negative. In nature, variation in temperature and salinity are frequent environmental constraints restricting plant performance, and in the field, they can occur simultaneously or independently. Studying and identifying the strategies used by rice subjected to combined stresses could elucidate the ways of importing the genes/pathways used by this plant into other cultivars or species to develop climate-resilient crops.