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Effectiveness of cold plasma for rice cultivation at various growth stages

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Due to rapid changes in climate and social conditions, the application of cold plasma to agriculture has recently had much attentions to develop a novel technology. In Japan, rice cultivation consists of various steps for ~5 months, such as germination, raising seedlings, transplanting in a paddy, and harvest. In our group, the effects of plasma treatment on their growth and yield have been investigated at each step.[1] In this study, we will report our examinations using representative brewer's rice cultivar in Japan, Yamadanishiki, at various stages of cultivation. First, we treated the seedlings in vegetative growth stage after transplanting in a paddy, such as the direct plasma irradiation and the indirect treatment by plasma-activated Ringer's lactate solution (PAL).[2,3] Second, we focused on the process of the formation and ripening of grains, each caryopsis after flowering was treated with direct plasma irradiation.[4] Yamadanishiki has characteristics to form the chalk at the center of endosperm frequently, termed "white core"(Fig. 1a), which is important structure for producing Japanese rice wine (sake) to proceed the water absorption and fermentation with *Aspergillus* sp. We evaluated the quality of the harvested brown rice, and verified the efficacies of cold plasma treatment to the rice cultivation.

After transplanting of young seedlings of Yamadanishiki, in the University test paddy at Togo town, Aichi, on Jun 20, the seedlings were treated with plasma by the direct plasma irradiation of the shoot apical meristem (SAM) and the indirect treatment to immerse PAL solution, until the end of Jul, in which the young panicles start to be formed. After harvest on Oct 20, we evaluated the degree of plant growth and the grain quality. Figure 1b shows the ratio of white-core grains to total number of grains under a variety of treatment conditions. In each control plant by non-treatment and immersion with distilled water (DW), the ratios were 32.5% and 29.6%, respectively. In direct irradiation, the ratios were increased to 39.7% in plants irradiated for 30 s, and decreased according to the increase of irradiation time, such as 3 and 5 min. In the case of PAL treatment, the ratios were increased dilution-dependently to 35.8% at 25-fold dilution. These results indicated that plasma treatment under optimal condition in the field was effective for improvement of crop quality.

On the other hand, to investigate the effects of plasma treatment on the grain ripening, 20 seedlings of Yamadanishiki planted in a paddy were transplanted into Wagner's pots on Aug 3 and then grown in a greenhouse. After heading and start of flowering on Aug 31, the flowering days were checked on 767 caryopses and each was irradiated with He plasma jet at 1, 5, 10 or 15 days after flowering (DAF). Then, each grain were individually harvested, and the ratios of white-core grains to total number of grains under each treatment condition were calculated as shown in Fig. 2. In control grain, it was 30.9%, and they were increased in the grains treated at 10 and 15 DAFs. The results indicated that plasma treatment in grain ripening process was effective for the improvement of quality. In addition, we constructed growth chambers installed a variety of sensor and those data management system, "Smart Agriculture System". Using these systems, same test was conducted with a simulation of climate changes in University test field at Togo town, and showed similar tendencies regarding the formation of white-core grain. The results demonstrated that the system is effective for the test with a reproduction of various environments, and for creation of cultivation recipe on the basis of collected data.

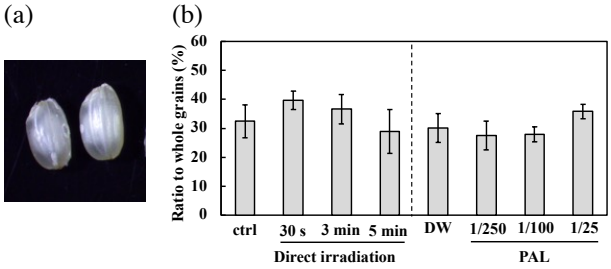

Fig. 1 (a) White-core grain and (b) ratio of white-core grains to total number of grains with plasma treatment in a paddy.

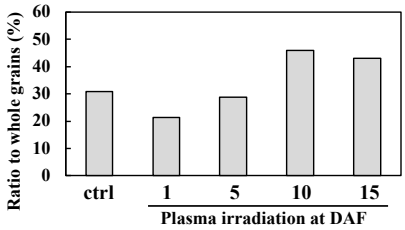

Fig. 2 Ratio of white-core grains to total number of grains with plasma treatment of caryopses.

Acknowledgments

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