The hot summers and rice in Japan

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The hot summers

In 2007, we had a very hot summer across Japan, and the maximum air temperature hit a new high of 40.9°C in August. In 2010, we experienced another record hot summer, and the mean air temperature across the three months from June to August was the highest on record since 1898. In northern Japan in particular, the 3-months mean air temperature was by more than 2°C higher than the normal. Similar anomaly was also observed in other part of the northern hemisphere (http://www.esrl.noaa.gov/psd/csi/events/2010/russianheatwave/prelim.html).

No matter what the causes of the heat anomalies are, we should learn how the agriculture have responded to the heat, and be better prepared for the future when the current anomalies become the norm. This issue of Journal of Agricultural Meteorology focuses on the impacts of high temperature on rice production in Japan. Most of the articles are based on or prompted by the findings in the hot summers of 2007 and 2010.

Rice in Japan

Rice plants are usually grown in flooded fields, which makes the micrometeorology of rice canopy unique. The free water surface serves as a major site of evaporation particularly before the canopy closure. The meristems of the rice plants are near the ground, and the young panicles are initiated submerged. The developed panicles are then pushed up by the elongating stems, and attain the flowering among the leaves at the canopy top. The temperature of the panicles is therefore determined by the energy budget of the water layer initially, and that of the top layer of the canopy later. The grain filling takes place at the canopy top while the water is being drained for the ease of heavy machineries to harvest grains. Increase in air temperature would affect the rice plants via the changes in the energy budget of the canopy (Fig. 1) and the panicles.

Rice is also unique in the way how it is consumed: it is mostly purchased as grains and cooked at home. The appearance and the cooking quality of the grains are therefore quite important for the consumers and, hence, the market as well as the growers. Imperfectly-filled grains with partial chalkiness would be priced much less than perfectly-looking grains. Some, if not all, of the appearance traits are indeed relevant to the cooking quality. The quality used to matter less when rice was the dominant source of food energy. In 1960, for example, 48% of total food energy supply came from rice, whereas in 2010 rice contributes to only 24% of the total energy supply. At the current satiety, people are concerned more with quality than quantity of rice.

Heat impacts on rice

The excessive heat reduces the quantity and quality of rice mostly in two ways. Temperature higher than 35°C damages the pollination, increase the number of sterile grains, and, hence, reduces the yield (Matsui et al., 2001). Prolonged heat during the grain filling period hinders the starch accumulation in grains, and thereby reduces the grain mass and/or grain appearance (Morita, 2008; Morita and Nakano, 2011), which lowers the grain price.

The findings

The frequency of hot summers increased in 1994, and since then damaging heat doses have often been observed in coastal plains of eastern, central and western Japan (Ishigooka et al., pp. 209–224 in this issue). In the summer of 2007, a field survey at 132 fields in eastern and central Japan confirmed that the heat wave caused spikelet sterility in the range from 2% to 23% (Hasegawa et al., pp. 225–232). The
extent of the heat damage was, however, less than that observed in chamber experiments (e.g., Nakagawa and Horie, 2000), which constituted the basis of the model prediction of the climate change impacts (e.g., Iizumi et al., 2011). The difference between the chamber and field observations could be due to the deviation of the panicle temperature in the field from the maximum air temperature (Yoshimoto et al., pp. 233–247). In chambers, the panicle temperature is usually well-coupled with the air temperature. The panicle temperature can be estimated within an agro-meteorology database for rice in Japan (Kuwagwa et al., pp. 297–306).

Hasegawa et al. (2011) field observations in 2007 also showed that the heat-induced sterility was ameliorated by increased nitrogen supply, which conforms to the finding in 2010 of less heat-induced sterility in the field under organic fertilizer management for 11 years (Tanaka et al., pp. 249–258). The possibility to ameliorate the heat damage by modifying the nutrient supply warrants further studies to understand the mechanisms.

In western Japan, the grain quality started the decline since mid-1980s (Fig. 6 of Ishigooka et al.), and, in 2010, only 23–25% of the harvested grains was perfectly filled (Shimoda, pp. 259–267). Choice of a heat-tolerant variety could ameliorate the quality decline due to high temperature (Morita and Nakano, 2010).

In northern Japan, on the other hand, the heat anomaly in 2010 allowed a variety from lower latitude to reach the flowering stage in time and attain a grain yield higher than the regional mean (Nemoto et al., pp. 269–274). The hot summer in 2010 also offered a chance to test an experimental methodology to estimate the effects of temperature rise by comparing crop growth at two sites of different latitude and, hence, temperature (Sameshima et al., pp. 307–312). With the day-length adjustment, the rice phenology under higher temperature in a field was closely simulated in another field at lower latitude (Nemoto et al., pp. 275–284). The phenological changes are worth further investigations, as a model of grain quality and yield showed that the temperature rise reduces the grain quality more via the phenological advancement than the direct impact (Okada et al., pp. 285–295). This implies a possibility of varietal choice for heat avoidance in addition to heat tolerance.

The hot summers have thus presented us with the chances to improve our capability to predict the performance of rice in the future and find options to cope with the challenges of temperature rise. Continuation of such efforts would make the rice production in Japan better prepared for the warmer world.

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References


