Japan Academy Prize to:

Takeshi HORIE
Professor Emeritus, Kyoto University

for "Agricultural Systems Studies on the Effect of Global Warming on Rice Production in Asia"

Outline of the work:

Global warming in association with the increase in the concentration of greenhouse gases is anticipated to give a large impact on the production of rice, which is the staple food of most Asian people. In order to clarify these impacts on rice production in Asia and develop countermeasures, Dr. Takeshi Horie conducted network field experiments across Asia using a diversity of rice genotypes and that in a temperature gradient chambers (TGC) with an enriched carbon dioxide (CO_2) concentration. In this way, basic data on genotype-by-environment (GxE) interactions in rice growth and yield formation processes were obtained. Data were analyzed using a systems analytical method, and he successfully developed a dynamic process model to simulate the growth and yield of major rice genotypes grown under diverse atmospheric environmental conditions. Using this model and global warming climates presented by general circulation models, he clarified the potential effects of global warming on rice production in different rice-producing areas in Asia. He then explored plant traits and the genetic resources necessary for the development of rice genotypes that are adaptable to global warming climate given the increasing food demands in the near future. Through these pioneering studies, he made significant contributions to the research of global climate change and food production as well as for the development of agricultural systems analysis.

1. Development of a dynamic process model for the prediction of rice growth and yield

Dr. Horie conducted network field experiments to assess rice growth and yield across Japan and Asia, which covered major rice-producing climates to develop a GxE interaction database on the growth and yield formation processes. He also constructed a daily climate database that covered the major rice-producing areas in Asia. Using these databases and the Simplex method for optimizing non-linear functions, he developed two dynamic process models that consisted of simultaneous differential equations for simulating rice growth and yield based on the environment. The first model, named SIMRIW, which predicts climatically potential growth and yields of various rice genotypes grown at different locations, well simulated the year-to-year and spatial variations in rice yield recorded in Japan and USA based on climate. The second model, named GEMRICE, modeled more basic physiological and physical processes of photosynthesis, nitrogen uptake and assimilation than SIMRIW, and successfully explained rice growth and yield observed in the Asian network experiments based on climate and soil conditions.

2. Prediction of the potential effects of global warming on rice production in Asia

Dr. Horie developed a CO_2-enriched TGC, cultivated various rice genotypes under different CO_2 temperature regimes in the TGC, and showed that doubling CO_2 under the current climate conditions increased rice yield by a maximum of approximately 30%. He reported that there is a large genotypic difference in the effect of CO_2 on rice yield and that the positive effect of CO_2 decreases with increasing temperature and becomes negative above a certain temperature. By parametrizing these data and incorporating them into SIMRIW, he predicted rice yields for the major rice-producing areas in Asia under doubled CO_2 climates that are presented by GFDL, GISS, and UKMO general circulation models. The results indicated that although the effect of a future climate on rice yield would be different depending on the general circulation model employed, a doubled CO_2 climate will generally positively affect rice yield in the northern and near-equatorial regions in Asia, but will negatively affect rice yield in the inner regions of China and India and some southeast Asian regions; therefore, climate change will have an enormous influence on rice production in Asia.

3. Plant traits governing rice adaptability to global warming and genetic resources

Based on model analyses and experiments, Dr. Horie indicated that rice genotypes with a higher adaptability to anticipated global warming are those that have a higher tolerance to high temperature-induced spikelet sterility and have a higher productivity under increased atmospheric CO_2. He found that a rice genotype having superiority in the former ability has a larger cavity for anther dehiscence at the anther septum and that genotypes having superiority in the latter ability exhibit traits of higher stomatal CO_2 conductance and higher nitrogen use efficiency in spikelet production which is associated with a morphological trait of a larger number of spikelets per secondary rachis branch of the panicle. He explored superior genotypes that exhibit these traits among the rice diversity research set of germplasm developed by the National Institute of Agrobiological Science. He identified a local variety from Bangladesh and one from China that have a higher stomatal conductance and aus type indica varieties that have a higher spikelet production efficiency. These are the genetic resources that can be used to breed adaptable rice genotypes for future climates.

As described above, Dr. Horie has pioneered systems analytical studies on the effect of global warming on rice production in Asia and produced some outstanding work. His results contributed to forming a consensus on the prevention of global warming through many reports, including that of the Intergovernmental Panel on Climate Change, and have also been widely utilized in research on global climate change and food production. Additionally, he made significant contributions to international agricultural research organizations as a member of the Board of Trustees for the Africa Rice Center and the Independent Science Panel for the International Research Program: Climate Change, Agriculture, and Food Security. Due to these significant contributions, he was awarded the Prize of the Society of Agricultural Meteorology of Japan, the Japan Prize of Agriculture Science, and the Nippon Agricultural Research Institute Prize.

List of Main Publications

I. Books

1) Horie, T. (1994) Crop ontogeny and development. In: Boote, K.J., Bennett, J.M., Sinclair, T.R. and Paulsen, G.M. (Eds.) *Physiology and Determination of Crop Yield*. Amer. Soc. Agronomy. Madison, WI, USA, pp. 153–180.
2) Horie, T., Nakagawa, H., Centeno, H.G.S. and Kropff, M.J. (1995) The rice crop simulation model SIMRIW and its testing. In: Matthews, R.B., Kropff, M.J., Bachelet, D. and van Laar, H.H. (Eds.) *Modeling the Impact of Climate Change on Rice Production in Asia*. CAB International, Oxon, UK, pp. 51–66.

3) Matthews, R.B., Horie, T., Kropff, M.J., Bachelet, D., Centeno, H.G., Shin, J.C., Mohandass, S., Singh, S., Zhu, D. and Lee, M.H. (1995) A regional evaluation of the effect of future climate change on rice production in Asia. *Ibid.*, pp. 95–139.
4) Horie, T., Nakagawa, H., Ohnishi, M. and Nakano, J. (1995) Rice production in Japan under current and future climates. *Ibid.*, pp. 143–164.
5) Horie, T., Homma, K. and Yoshida, H. (2007) Physiological and morphological traits associated with high yield potential in rice. In: Aggarwal, P.K., Ladha, J.K., Singh, R.K., Devakumar, C. and Hardy, B. (Eds.) *Science, Technology, and Trade for Peace and Prosperity*. International Rice Research Institute (IRRI), Indian Council of Agricultural Research, and National Academy of Agricultural Sciences, New Delhi, India, pp. 149–159.
6) Horie, T. and Yoshida, H. (2010) Prediction of the effects of global warming on rice production. In: Ogawa, T., Oikawa, T. and Minami, K. (Eds.) *Leading the Frontiers of Climate Change Research: Humanity and the Changing Global Environment*. Shimizukoubundou-shobou, Tokyo, Japan, pp. 319–334 (in Japanese).
7) Horie, T. (Ed.) (2015) *Rice Cultures in Asia and Africa: The Diverse Production Ecologies and Ways to Sustainable Development*. Nousangyoson bunkakyokai (Rural Culture Association Japan), Tokyo, Japan, 276 pp. (in Japanese).

II. Papers

1) Horie, T. (1978) Studies on photosynthesis and primary production of rice plants in relation to meteorological environments. I. Gaseous diffusive resistances, photosynthesis and transpiration in the leaves as influenced by radiation intensity and wind speed. J. Agric. Meteor. 34: 125–136.
2) Horie, T. (1979) Studies on photosynthesis and primary production of rice plants in relation to meteorological environments. II. Gaseous diffusive resistances, photosynthesis and transpiration in the leaves as influenced by atmospheric humidity, and air and soil temperatures. J. Agric. Meteor. 35: 1–12.
3) Horie, T. (1980) Studies on photosynthesis and primary production of rice plants in relation to meteorological environments. III. A model for the simulation of net photosynthesis, transpiration and temperature of a leaf and a test of its validity. J. Agric. Meteor. 35: 201–213.
4) Horie, T. (1981) System ecological studies on crop-weather relationships in photosynthesis, transpiration and growth. Bull. Natl. Inst. Agric. Sci. Ser. A. 28: 1–181 (in Japanese with English summary).
5) Horie, T. and Sakuratani, T. (1985) Studies on crop-weather relationship model in rice. (1) Relation between absorbed solar radiation by the crop and the dry matter production. J. Agric. Meteor. 40: 331–342 (in Japanese with English summary).
6) Horie, T. (1987) A model for evaluating climatic productivity and water balance of irrigated rice and its application to Southeast Asia. Southeast Asian Stud. 25: 62–74.
7) Sinclair, T.R. and Horie, T. (1989) Leaf nitrogen, photosynthesis, and crop radiation use efficiency: A review. Crop Sci. 29: 90–98.
8) Horie, T. and Nakagawa, H. (1990) Modelling and prediction of developmental process in rice. I. Structure and method of parameter estimation of a model for simulating developmental process toward heading. Japan. Jour. Crop Sci. 59: 687–695 (in Japanese with English summary).
9) Horie, T., Yajima, M. and Nakagawa, H. (1992) Yield forecasting. Agric. Syst. 40: 211–236.
10) Horie, T. (1993) Predicting the effects of climatic variation and elevated CO_2 on rice yield in Japan. J. Agric. Meteor. 48: 567–574.
11) Horie, T., Nakagawa, H., Nakano, J., Hamotani, K. and Kim, H.Y. (1995) Temperature gradient chambers for research on global environment change. III. A system designed for rice in Kyoto, Japan. Plant, Cell Environ. 18: 1064–1069.

12) Kim, H.Y., Horie, T., Nakagawa, H. and Wada, K. (1996) Effects of elevated CO_2 concentration and high temperature on growth and yield of rice. II. The effect on yield and its components of Akihikari rice. Japan. Jour. Crop Sci. 65: 644–651 (in Japanese with English summary).
13) Hasegawa, T. and Horie, T. (1996) Leaf nitrogen, plant age and crop dry matter production in rice. Field Crops Res. 47: 107–116.
14) Matsui, T., Namuco, O.S., Ziska, L.H. and Horie, T. (1997) Effects of high temperature and CO_2 concentration on spikelet sterility in indica rice. Field Crops Res. 51: 213–219; Erratum (1998) Field Crops Res. 55: 189.
15) Matthews, R.B., Kropff, M.J., Horie, T. and Bachelet, D. (1997) Simulating the impact of climate change on rice production in Asia and evaluating options for adaptation. Agric. Syst. 54: 399–425.
16) Horie T., Ohnishi, M., Angus, J.F., Lewin, L.G., Tsukaguchi, T. and Matano, T. (1997) Physiological characteristics of high-yielding rice inferred from cross-location experiments. Field Crops Res. 52: 55–67.
17) Matsui, T., Omasa, K. and Horie, T. (1999) Mechanism of anther dehiscence in rice (*Oryza sativa* L.). Ann. Bot. 84: 501–506.
18) Nakagawa, H. and Horie, T. (2000) Rice responses to elevated CO_2 and temperature. Global Environ. Res. 3: 101–113.
19) Matsui, T., Omasa K. and Horie, T. (2001) Comparison between anthers of two rice (*Oryza sativa* L.) cultivars with tolerance to high temperatures at flowering or susceptibility. Plant Prod. Sci. 4: 36–40.
20) Horie, T. (2004) Determination of the yield potential and associated traits in rice. Gamma Field Symp. 43: 1–13.
21) Yoshida, H., Horie, T. and Shiraiwa, T. (2006) A model explaining genotypic and environmental variation of rice spikelet number per unit area measured by cross-locational experiments in Asia. Field Crops Res. 97: 337–343.
22) Horie, T., Matsuura, S., Takai, T., Kuwasaki, K., Ohsumi, A. and Shiraiwa, T. (2006) Genotypic difference in canopy diffusive conductance measured by a new remote-sensing method and its association with the difference in rice yield potential. Plant, Cell Environ. 29: 653–660.
23) Kanemura, T., Homma, K., Ohsumi, A., Shiraiwa, T. and Horie, T. (2007) Evaluation of genotypic variation in leaf photosynthetic rate and its associated factors by using rice diversity research set of germplasm. Photosynth. Res. 94: 23–30.
24) Ohsumi, A., Hamasaki, A., Nakagawa, H., Yoshida, H., Shiraiwa, T. and Horie, T. (2007) A model explaining genotypic and ontogenetic variation of leaf photosynthetic rate in rice (*Oryza sativa*) based on leaf nitrogen content and stomatal conductance. Ann. Bot. 99: 265–273.
25) Yoshida, H. and Horie, T. (2009) A process model for explaining genotypic and environmental variation in growth and yield of rice based on measured plant N accumulation. Field Crops Res. 113: 227–237.
26) Yoshida, H. and Horie, T. (2010) A model for simulating plant N accumulation, growth and yield of diverse rice genotypes grown under different soil and climatic conditions. Field Crops Res. 117: 122–130.
27) Yoshida, H., Horie, T., Nakazono, K., Ohno, H. and Nakagawa, H. (2011) Simulation of the effects of genotype and N availability on rice growth and yield response to an elevated atmospheric CO_2 concentration. Field Crops Res. 124: 433–440.

Other 74 books and 142 papers