Main Research Results

1. A chemical soil-washing method for remediating paddy fields contaminated with cadmium

Japanese paddy fields have often suffered from soil contamination by cadmium (Cd) derived from old mines and refining plants. Excessive intake of Cd is harmful to a person's health, as has been shown in the case of itai-itai disease. To ensure the safety of foods, the concentration of Cd in staple crops, and especially in rice, should be below a standard value, because half of the Cd intake by Japanese people is derived from rice.

Current Japanese regulatory laws have designated those paddy fields that produce rice grains containing more than 1 ppm of Cd as "contaminated paddy fields". There have been efforts to remediate these paddy fields by soil dressing, but this process is becoming increasingly difficult as a result of its high cost and the difficulty in obtaining uncontaminated soil. As a result, we have developed a chemical soil-washing method for the restoration of Cd-contaminated paddy fields.

First, we tested the efficiency of a variety of chemicals in extracting Cd from a paddy soil sampled from Nagano Prefecture. We selected ferric chloride ($FeCl_3$) as a promising wash chemical because it is inexpensive and highly effective in extracting Cd, and because it imposes a low environmental burden. The mechanism of extraction of Cd was attributed to a significant pH reduction in the soil when $FeCl_3$ was applied. The reduction was caused by the release of protons during the generation of iron hydroxide with a small solubility product (Ksp = 3.16×10^{-38}) from $FeCl_3$, as indicated in the formula below. The usual amount of $FeCl_3$ applied ranged from 1 to 7 t ha^{-1}.

$$(FeCl_3 \rightarrow Fe^{3+} + 3Cl^- ,\ Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+)$$

Next, for the on-site washing experiment, a plot (109 m^2) was set up in a farmer's paddy field in Nagano Prefecture. It was surrounded by thick plastic sheets to prevent the water from leaking out. After the plot had been submerged, we applied $FeCl_3$ to the water, mixed the soil with the water to extract Cd from the soil, and then drained the contaminated wastewater. A standard puddling machine was sufficient for the mixing process. The paddy field was then rinsed several times with agricultural water to eliminate any remaining Cd and chlorine. After the wastewater had been introduced into a stationary-type wastewater-treatment machine and a chelating agent in the machine had selectively removed the Cd from the wastewater, the purified water was drained (Fig. 1).

The amount of soil-Cd in the washed plot was reduced to approximately 55% of that in the unwashed plot, as determined by extraction with hydrochloric acid at 0.1 mol L^{-1}. The effect of the washing treatment lasted until at least the end of the growing period.

Moreover, application of the washing method had no negative effects on the growth and yield of paddy rice (variety: Akitakomachi), and the Cd content in rice straw and brown rice was markedly decreased (Fig. 2). The washing method developed in this study shows promise for remediating Cd-contaminated paddy fields. (T. Makino, Y. Maejima, Y. Sakurai, and T. Otani)

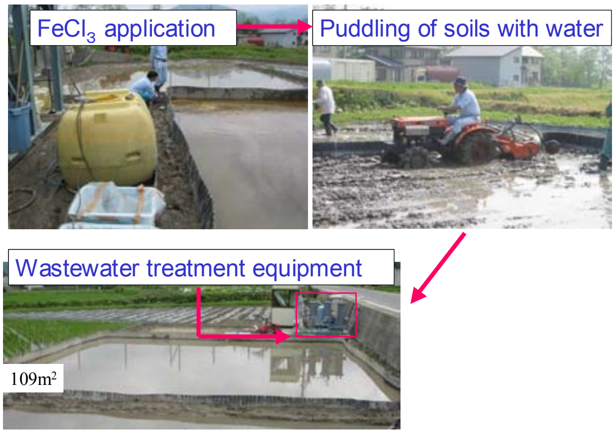

Fig. 1 On-site soil washing in a Nagano paddy field

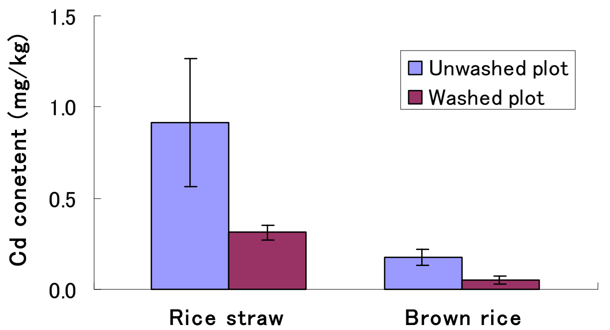

Fig. 2 Changes in the Cd content of rice straw and brown rice with soil washing treatment

2. System for simulating nitrogen turnover in upland soils in Japan

Nitrogen (N) is one of the essential elements for plant growth, but its inappropriate application to agricultural soils can cause environmental pollution, such as nitrate contamination of groundwater. Therefore, various agricultural practices have been developed and applied to reduce N leaching from agricultural fields by improving the recovery rate of N by the crop. However, such practices are not always as effective as expected because of fluctuations in N dynamics in the soil (e.g. by mineralization, immobilization, and denitrification) and in field conditions (e.g. weather, soil characteristics, and method of field management). The purpose of this study was to develop a simulation system that could be used easily to manage the quantitative evaluation of N dynamics in the soil under field conditions.

The simulation system is based on the N turnover model developed at Rothamsted Experimental station in the UK (Bradbury et al., 1993). The model assumes that part of the inorganic N mineralized through the decomposition of applied organic materials, crop residues, and soil organic matter is immobilized in either the soil microbe fraction or the soil humus which has a longer half-life than the former fraction. It also assumes that the decomposition of organic materials that have a carbon to N ratio (C/N ratio) above a certain level requires sufficient amounts of inorganic N in the soil solution and continues only while sufficient amounts exists.

The system that we developed enables the user to input data such as the weather conditions and the type, dosage, depth, and application dates of fertilizers and/or manure (Fig. 1). The decomposition rate of organic N was modified for volcanic ash soils by reference to the phosphate absorption coefficient (PAC). This is because these soils, which are characterized by particularly high PACs, are predominant in upland fields in Japan, and because the decomposition rates of N in the soil organic matter (SOMN) in these soils are known to be slower than in other soils because of the high PAC.

The system displays weekly amounts of variables, such as N uptake by the crop, N loss through denitrification and bypass flow, N leaching below 1.5 m depth, SOMN associated with the turnover of N, the undecomposed N fraction in applied organic materials, ammonium N retained in the soil profile (0- to 1.5-m depth), nitrate N remaining in the soil layers, and carbon dioxide emission from the soil profile (Fig. 2).

Implementation of the system will help users to evaluate the effectiveness of the standard application rate of fertilizer on crop production as well as of newly developed technologies on the growth of the target crop under conditions of ongoing management at the site. It will also help in the quantitative evaluation of whether the applications of these standards and technologies are

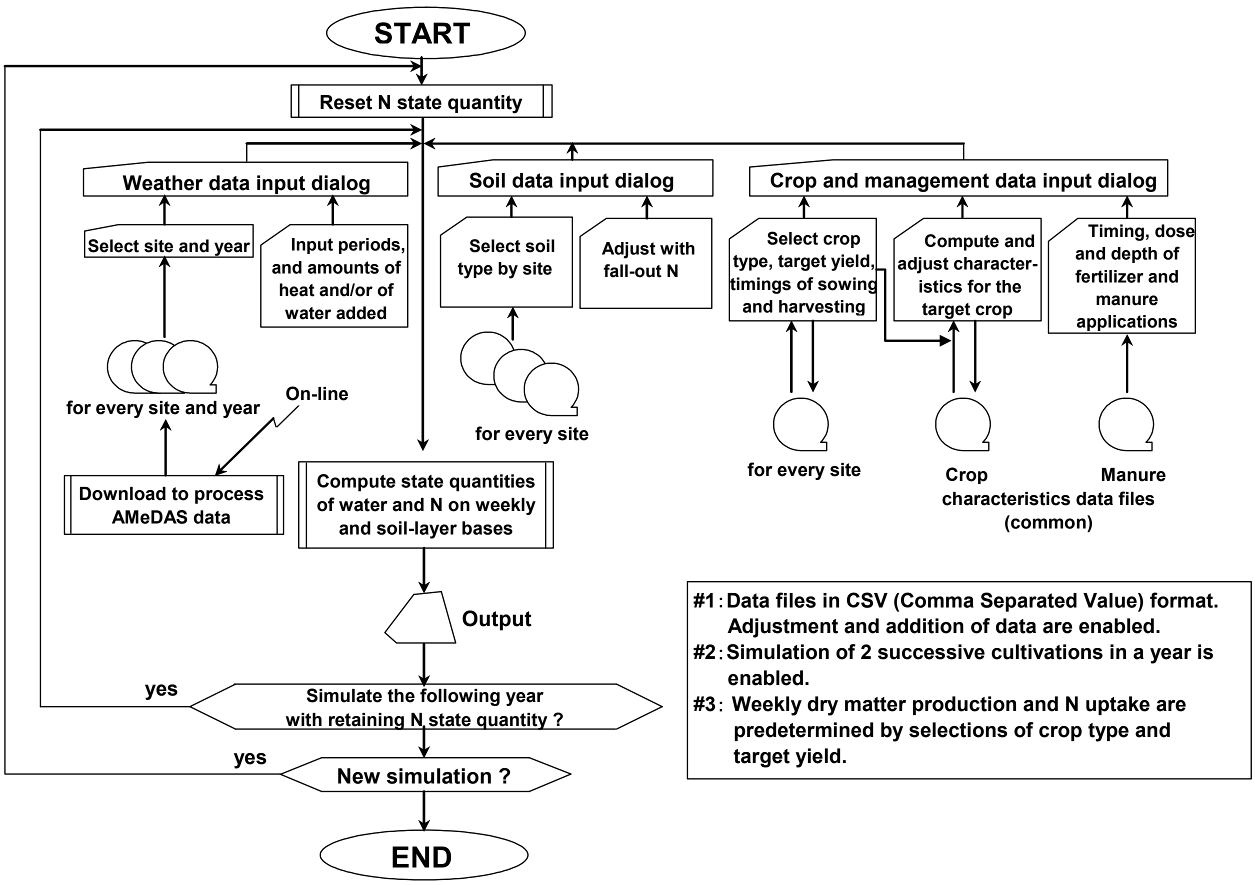

Fig. 1 Flowchart of system used to simulate N turnover in upland soils.

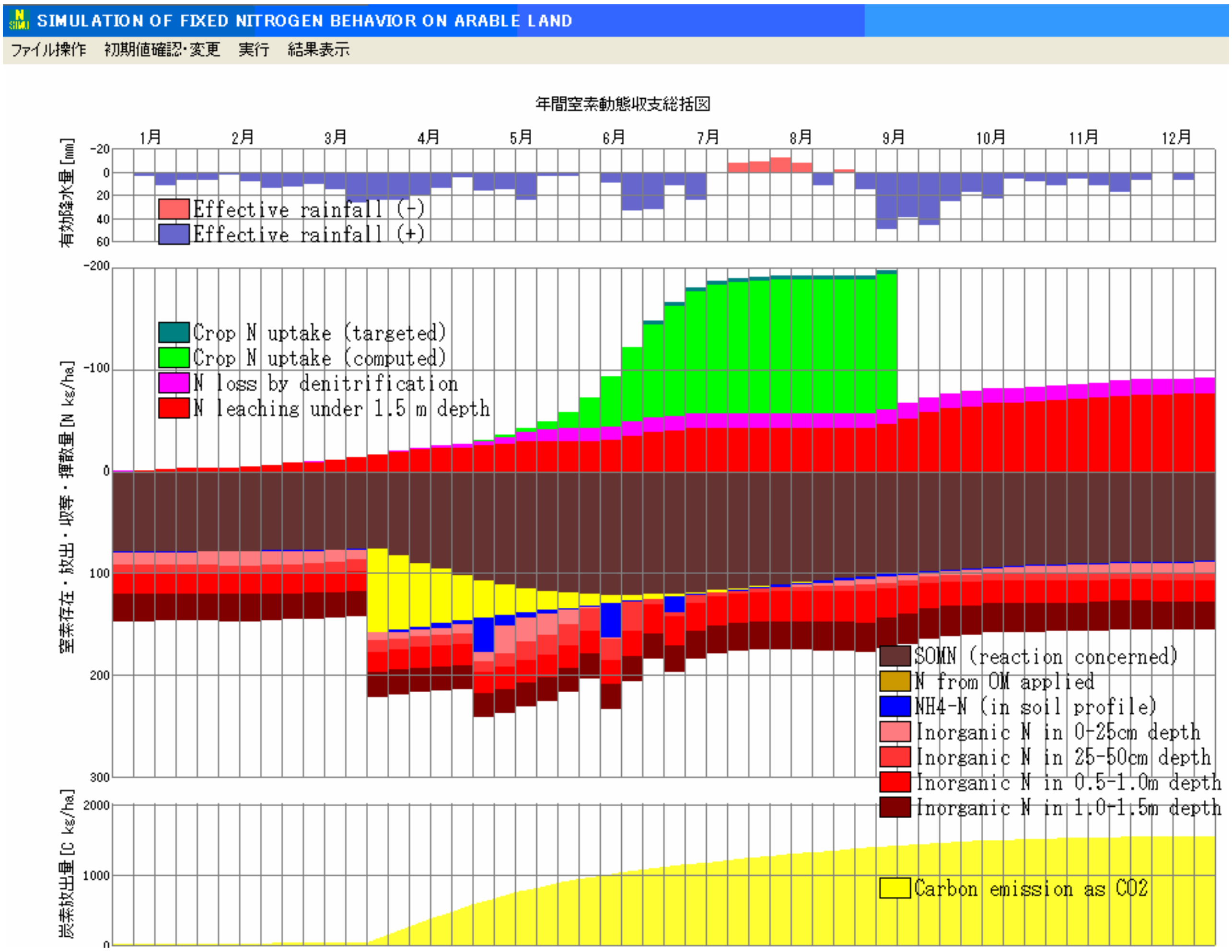

Fig. 2 Example of an output of the simulation system.
Simulation conditions: 1) weather data—from Okazaki in Aichi Prefecture (average over 33 years); 2) soil type—fine textured yellow soil, Tadenuma series; 3) crop cultivation—wheat, sown on 3 May and harvested on 14 September; 4) target yield—4.4 t ha^{-1}; 5) manure application—dose of 20 t ha^{-1} applied into 0- to 25-cm depth on 25 March; 6) fertilizer application—total dose of 60 kg ha^{-1} applied into 0- to 25-cm depth on 3 May, 15 June, and 3 July.
Note: N uptake, denitrification, leaching, and CO_2 emission are shown as cumulative amounts, and the other variables are shown as abundances in the soil profile.

likely to be environmentally safe. (S. Itahashi, K. Hayashi, M. Takeuchi)

Reference

Bradbury, N. J., A. P. Whitmore, P. B. S. Hart and D. S. Jenkinson (1993) Modelling the fate of nitrogen in crop and soil in the years following application of ^{15}N-labelled fertilizer to winter wheat. Journal of Agricultural Science, Cambridge, 121: 363–379

3. The Asian-Pacific Alien Species Database (APASD) system: development and placement on the Internet

In 2003 an International Seminar was held in Tsukuba to disseminate knowledge on biological invasions upon the countries in the Asia Pacific region by alien species and to develop a database for accumulating and sharing data on these species. Our Institute took on the task of developing the database system, and it was completed and made available on the Internet in November 2004. At a workshop held in Taiwan in 2004, several researchers and specialists lectured on the alien species that had invaded into their countries, and these data were input into the database. This database system was named the Asian-Pacific Alien Species Database (APASD), and it is a relational database with web application. Users of

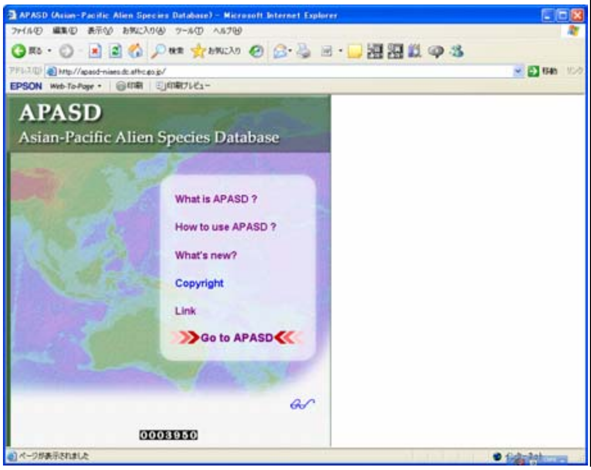

Fig. 1 Accessing the Asian-Pacific Alien Species Database.

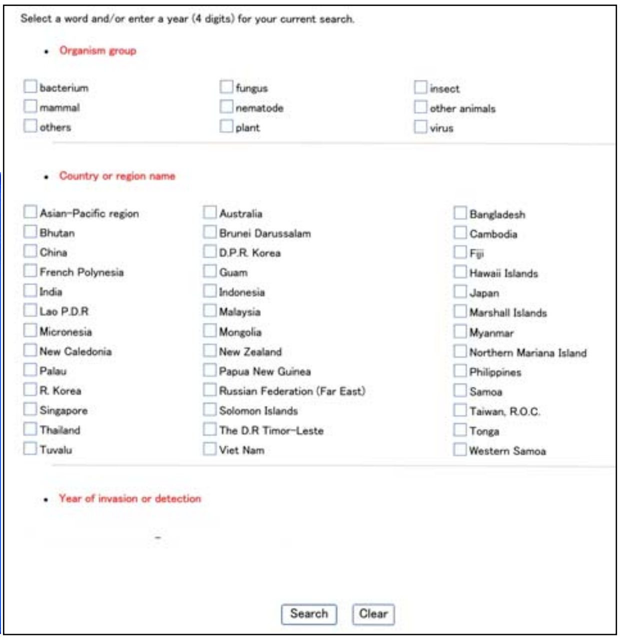

Fig 2 Searching for a target species. The user starts by selecting the organism group, and/or country name, and /or inputting the year of invasion.

the system can easily input, search, and read large amounts of data (Figs. 1 and 2).

The APASD has three functions. The first is for common users, who may freely read APASD data on the Internet. The second is for contributors, who may input various items of data on species, including photos and references, into the APASD through the Internet. The third is for administrators, who may manipulate items in the master tables such as organism name, country or region name, categories of invasion and establishment, and habitat. They transfer the data written by contributors from the temporary system to the regular system after they have been checked.

The target species to be accumulated in this database comprise those alien organisms, such as plants, mammals, insects, nematodes, the other animals and microbes (bacteria, fungi, viruses), that inhabit the agro-ecosystems of the Asia-Pacific region. Our intention is to accumulate data mainly from Japan and other Asian countries.

Data such as taxonomic name, situation of establishment, expansion of distribution area, ecological and economic damages, characteristics of reproduction and growth, countermeasures, references, and photographs can be accumulated and read. Contributors in a number of countries can input data on the same species at the same time, and users can compare those data on the same page. By using the APASD, we can not only share and exchange data from many countries, but also develop an international network of alien species by using the system as a tool for the many people in these countries who are interested in alien species.

The APASD can be accessed in English through a link to “DATABASE AND DATA MAP” on the NIAES homepage, or directly at the following URL (http://apasd-niaes.dc.affrc.go.jp/). (M. Matsui)

References

Matsui, M. et al. (2004) Development of the Asian-Pacific Alien Species Database (APASD). Proceedings of an International Workshop on the Development of a Database for Biological Invasion in the Asian and Pacific Region, Taichung, Taiwan, 2004, sponsored by FFTC, ARI, BAPHIQ of Taiwan, and NIAES, pp. 44–55.

Yamanaka, T. and M. Matsui (2003) Development and utilization of APASD (Asian-Pacific Alien Species Database). Proceedings of an International Seminar on Biological Invasions. Environmental Impacts and the Development of a Database for Asian-Pacific Region, Tsukuba, Japan, 2003, sponsored by NIAES and FFTC, pp. 155–176.

4. Effect of change in land use from paddy rice to upland crop cultivation on methane and nitrous oxide emissions

Since the rice production adjustment policy was implemented in 1975, temporary cultivation of upland crops for a few or several years in drained paddy fields has been recommended to farmers in Japan. The area of drained paddy fields used for upland crop cultivation is now 740 000 ha—about 30% of the total upland crop cultivation area in Japan. Despite the fact that the dynamics of greenhouse gas emissions may be changed significantly by this drainage of paddy soils for upland crop cultivation, owing to changes in soil physicochemical and biological properties, studies on greenhouse gas emissions from drained paddy soils are limited. We therefore measured methane (CH_4) and nitrous oxide (N_2O) emissions from both paddy fields under irrigated rice cultivation and drained fields under upland crop cultivation.

Three kinds of cropping system, single cropping of paddy rice (PR), single cropping of upland rice (UR), and double cropping of soybean and wheat (SW), were used for 2 years (2002–03) in the experimental fields of NIAES. CH_4 and N_2O fluxes from the PR, UR, and SW plots were measured continuously and simultaneously with automated flux monitoring systems. CH_4 emission from the PR plots in 2003 was 5.8 times higher than that in 2002, mainly because of a prolonged period of continuous submergence in 2003. In contrast, slight absorption of CH_4 was observed in the UR and SW plots throughout the year (Fig. 1). In the UR and SW plots, significantly higher N_2O emissions were observed in the summer season (from July to August). In the SW plots, a significant increase in N_2O emission was also observed in the spring of 2003, during the flowering to ripening stages of the winter crop (wheat). Other temporal increases in N_2O fluxes were occasionally found in the UR and SW plots after heavy rainfall or crop harvesting. In contrast, N_2O emissions from the PR plots were low during the paddy rice cultivation periods (Fig. 2).

In summary, the effect of land-use change from paddy rice to upland crop cultivation on greenhouse gas emissions was characterized mainly by the absence of CH_4 emission and an increase in N_2O emission. Compared with the results of other studies in Japan, the cumulative CH_4 emission in our PR plots was significantly lower than the average value (19.0 ± 12.5 g CH_4 m^{-2}), whereas our cumulative N_2O emissions in the UR and SW plots were comparatively high. The combined net global warming potentials (net GWP) as a result of the CH_4 and N_2O emissions were 100 to 442, 102 to 110, and 79 to 146 g CO_2 m^{-2} in the PR, UR, and SW plots, respectively. Net GWP in the PR plots in 2003 was extremely high compared with the other values, owing to the high levels of CH_4 emission, thus illustrating the par-

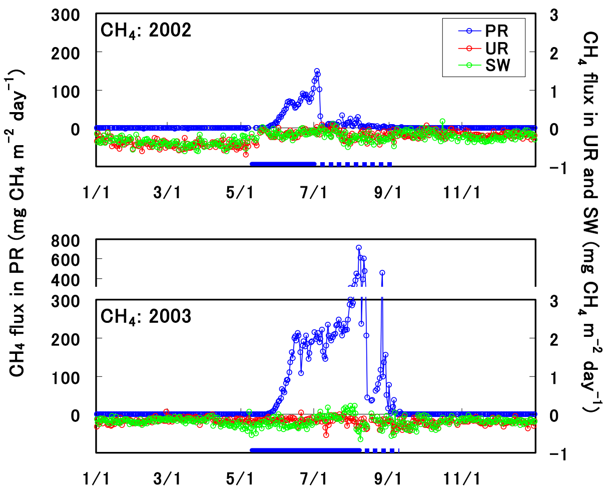

Fig. 1 Seasonal courses of CH_4 fluxes in fields under single cropping of paddy rice (PR), single cropping of upland rice (UR), and double cropping of soybean and wheat (SW). Horizontal bars at bottoms of the figures show periods of submergence of PR plots.

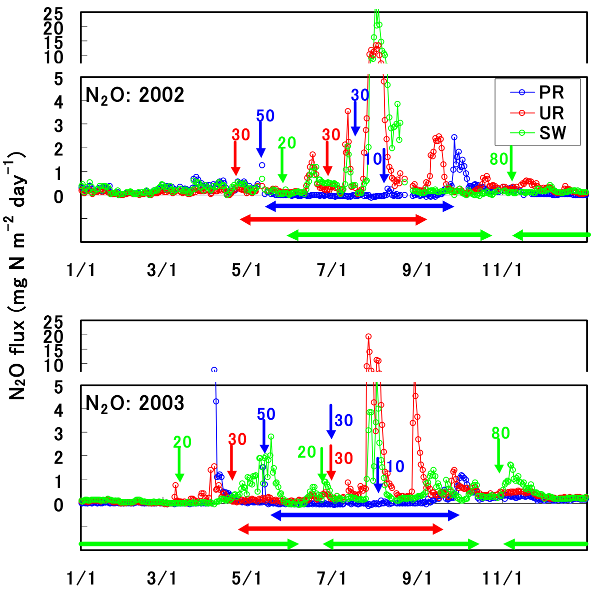

Fig. 2 Seasonal courses of N_2O fluxes in fields under single cropping of paddy rice (PR), single cropping of upland rice (UR), and double cropping of soybean and wheat (SW). Vertical and horizontal arrows in different colors show rates of N fertilizer application (kg N ha^{-1}) and periods of the crop cultivation, respectively, for the corresponding cropping systems.

ticular importance of water management during the paddy rice cultivation period in relation to CH_4 emission. This also suggests that drainage of paddy soils for upland crop cultivation is effective for reducing net GWP in paddy fields with high potential for CH_4 emission, such as those that are poorly drained or have low soil iron content. Our results can also be utilized in Japan's National Greenhouse Gases Inventory. To further improve the inventory, greenhouse gas emissions from drained paddy fields in various locations and with various kinds of crop cultivation will need to be measured. In particular, N_2O emissions from fields with high levels of N fertilizer application, such as those used for vegetable cultivation, must be carefully taken into account. (S. Nishimura)

5. Invasion and occurrence of the banana moth, *Opogona sacchari* (Bojer) (Insecta, Lepidoptera), over a wide area of Japan

A total of nearly 450 species of insects and their kin, including plant-parasitic mites, spiders, and nematodes, were introduced into Japan between 1868 (the Meiji Era) and 2002 (Ecological Society of Japan, 2002)—an average of 3 species a year. Recently, the number of invasive insects has increased because of the rapidly increasing importation of agricultural products and other material, even though Japanese plant quarantine has been reinforced. Artificial conditions such as those found in greenhouses or fostered by global warming may set the stage for the successful establishment of invasive insects in Japan.

The banana moth, *Opogona sacchari* (Bojer) (Photo 1), is a large species of the family Tineidae. The moth's wingspan is almost 20 mm in males and 23 mm in females, and the mature larva (Photo 2) is 30 mm long. This species is known as a pest of many tropical crops, fruits, and ornamental plants in places such as Africa, Europe, the West Indies, Brazil, and the southern United States. It has rarely been recorded in Asia. It was first detected in Japan in 1986 at the Moji Plant Protection Station, where larvae were found feeding on the stem of *Dracaena* sp. (Agavaceae) imported from Madagascar. The other recorded occurrence in Japan was in Chichijima, Ogasawara, in 1999.

However, through identifications that we performed in cooperation with Osaka Prefecture University, we have other records of this moth from many localities in Japan (Table 1). Most of the records are based on identification requests from Agricultural Experimental Stations in Japanese prefectures.

Table 1 shows that this pest species has a wide host range in Japan, as is the case in other countries. It also damages other plants such as potato, eggplant, and corn, although damage to these plants has not yet been recorded in Japan. It is known as an important pest of stored products.

Photo 1 Adult *Opogona sacchari* (Bojer).

Photo 2 Mature larva of *Opogona sacchari* (Bojer) (blue arrow) and the damage caused to the graft union of a *Ficus benjamina* (Moraceae) by this insect pest.

In Japan, *O. sacchari* appears to occur in the warm regions of Honshu, Shikoku, Kyushu, and the Ryukyu Islands. However, even in cool regions such as Hokkaido and Tohoku, we have pointed out to farmers its presence in greenhouses. (S. Yoshimatsu and K. Yasuda)

Reference

Yoshimatsu, S., Y. Miyamoto, T. Hirowatari and K. Yasuda (2004) Occurrence of *Opogona sacchari* (Bojer) in Japan (Lepidoptera, Tineidae). Japanese Journal of Applied Entomology and Zoology, 48: 135–139. (in Japanese with English summary)

Table 1 Records of *Opogona sacchari* (Bojer) in Japan

Date	Locality	Host plant (Family name): substrate or damaged portion
July 1986[a]	Kanmon Port, Fukuoka Pref.	*Dracaena* sp. (Agavaceae): stem
1988	Kimitsu City, Chiba Pref.	*Pachira glabra* (Bombacaceae): apical portion of current shoot
July 1992	Onna-son, Okinawa Pref.	*Ficus benjamina* (Moraceae): graft union
October 1993	Kaidu-cho, Gifu Pref.	Bromelia (Bromeliaceae): leaf bud, stem near ground, and core
January 1993	Itako-machi, Ibaraki Pref.	*Yucca* sp. (Agavaceae): xylem
September 1994– February 1995	Imaichi-cho, Nara City, Nara Pref.	Potted *Cymbidium* sp. (Orchidaceae): compost
March 1995	Imai-cho, Nara City, Nara Pref.	Potted *Cymbidium* sp. (Orchidaceae): compost
April 1997	Mashiki-machi, Kumamoto Pref.	*Dracaena concinna* (Agavaceae): branch and underground parts *Philodendron bipinnatifidum* (Araceae): tuberous roots *Tulipa* sp. and *Lilium* sp.(Liliaceae): bulb
April 1997	Tamagusuku-son, Okinawa Pref.	*Dracaena* sp. (Agavaceae): branch
August 1998	Tamatsukuri-machi, Ibaraki Pref.	*Pachira glabra* (Bombacaceae): epidermal cell and pith
October 1998	Kamisu-machi, Ibaraki Pref.	*Pachira glabra* (Bombacaceae): nursery stock
April 1999	Tosa City, Kochi Pref.	*Dendrobium* sp. (Orchidaceae): roots, bulb and around compost
September–October 1999[b]	Chichi-jima, Ogasawara, Tokyo	Concentrated chicken feed
2000–	Kitakanbara-gun, Niigata Pref.	*Begonia* sp. (Begoniaceae): bulb *Aloe arborescens* (Liliaceae), *Musa* sp. (Musaceae), *Passiflora edulis* (Passifloraceae)
September 2001	Hachijo-jima, Tokyo	*Dracaena* sp. (Agavaceae), *Strelitzia augusta* (Musaceae) and *Chamaedorea seifrizii* (Palmae)

[a] Detected at the Moji Plant Protection Station and reported by Baba (1990).

[b] Reported by Takahashi et al. (2000).