AN EARLY-WARNING SYSTEM AGAINST COOL-WEATHER DAMAGE IN RICE PRODUCTION

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ABSTRACT

This presentation describes an early warning system based on meteorological observations and weather forecasts that has been designed to warn farmers about cool weather that can damage rice crops.

Tohoku District is located in northern Japan, in northern Honshu, south of Hokkaido. It has a cool-temperate rainy climate, and in winter there is a lot of snow. Tohoku District has abundant water resources, and its major industry is agriculture; 26% of Japan's rice production comes from Tohoku District.

Figure 1 shows historical trends in grain yield in Tohoku region. Yields have increased progressively from 1.5 t ha^{-1} in 1881 to more than 5 t ha^{-1} in the 1970s. Although yields have remained relatively constant since the 1970s, low-temperature stress and disease are constraints on stable production. Considerable fluctuations in yield are experienced in Tohoku region. The most severe yield losses have been caused by cool weather, which occurs roughly every 4 years. Damage from cool weather is the most serious climatic damage to rice production in Japan. This damage is particularly serious in northern Japan because of the variability of its summer climate.

Rice blast is the most serious crop disease in Japan; it becomes serious in cool summers, and often decreases rice yield. Suitable conditions for rice blast are five days mean temperatures from 20 to 25°C, cloudy skies accompanied by fog or drizzle, and high relative humidity.

Cool summers are brought by the Yamase, a cold northeasterly wind that is characteristic of northern Japan. This important summer phenomenon causes considerable decreases in rice yields. To mitigate damage from cool weather, breeding programs have been conducted to improve the cold tolerance of rice and to improve cultivation techniques, such as deep-water management. Unusually severe cool weather damage occurred in 1993, when the average rice yield in the region decreased by 44% compared with the normal yield. This cost the region ¥469×10^9. Therefore, to reduce the agricultural damage caused by cool weather, the National Agricultural Research Center for Tohoku Region developed the Early Warning System for Rice (**Figure 2**) in 1996 (Torigoe 2001). This system provides crop and weather information through the Internet to help farmers reduce yield losses. The system is primarily based on a combination of meteorological observations with information on rice growing stages, the impacts of low temperatures, and the impacts of diseases such as rice blast.

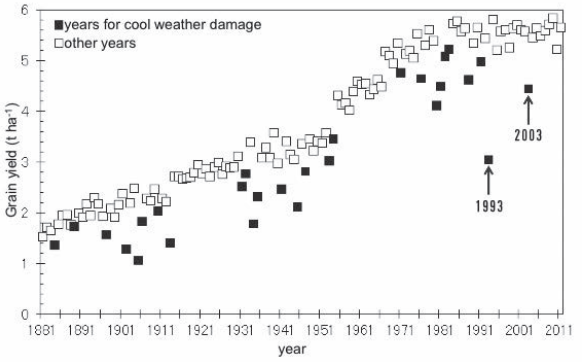

Figure 1: Changes in grain yield of brown rice in Tohoku Region.

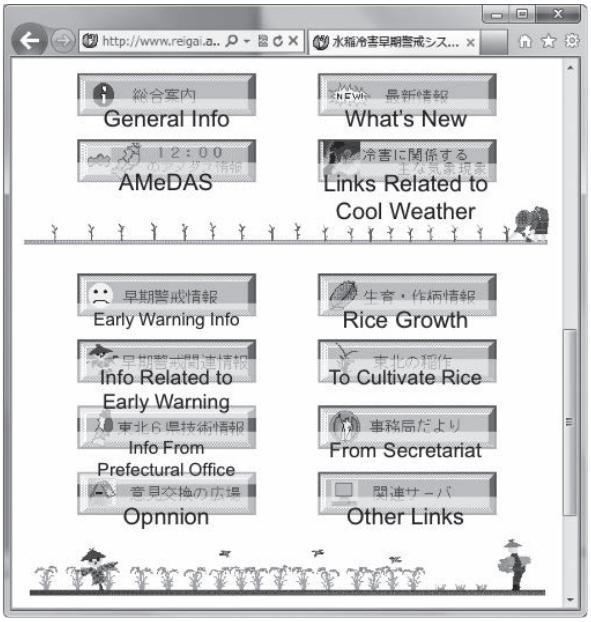

Figure 2: Menu of the "Early Warning System for Rice". Available at <http://www.reigai.affrc.go.jp> with translation.

Severe cool weather damage also occurred in 2003, when the average rice yield in the region decreased by 20% compared with the normal yield. However, rice yields for users of the system decreased by less than 10% because farmers were able to implement deep-water management (which uses the high thermal capacity of water to mitigate temperature decreases) and timely spraying of agricultural chemicals to

control rice blast.

Following the cool weather damage in 2003, the Early Warning System was improved in 2006. This new system uses meteorological forecasts based on the Japan Meteorological Agency's Global Spectral Model to predict the weather several days in advance. The current experimental version of the early-warning system provides 2-week temperature forecasts so farmers have more time to respond. When the system predicts abnormal weather, it can send an alert to a user's computer or mobile phone (**Figure 3**). In previous versions, only historical data were used, but the current system uses numerical simulations to extend the rice blast forecast several days into the future. Agricultural chemicals can effectively control rice blast if they are applied at the right time. The model forecasts conditions conducive to rice blast growth using meteorological data and recommends the best timing for chemical spraying (**Figure 4**). Because rice cultivation was recently damaged severely by hot weather, the new system also provides warnings of the risk of high temperature damage, which can affect ripening of rice grains and the incidence of sheath blight disease.

Decreased rice yields caused by cool weather have also been reported in Australia, the United States, Taiwan, Bangladesh, India, Nepal, and other countries. Similar information systems would benefit these regions. In recent years, rice production has increased in Heilongjiang, in northeastern China, where the growing period for rice is short and temperatures are low and severe yield losses are caused by cool weather roughly every 4-5 years. For example, rice yield was unusually low (33% below normal in the Jamusi area) in 2002 as a result of cool summer temperatures. The temperature was roughly 19°C during the meiosis stage, and was below 17°C at heading, causing spikelet sterility and incomplete ripening. We are therefore constructing an early warning system for use in Heilongjiang to provide weather and crop information.

Meteorological records for northern Asia suggest that temperature fluctuations are growing in magnitude and frequency, so it is becoming increasingly important to protect crops against poor weather by using weather and crop information provided by an early warning system.

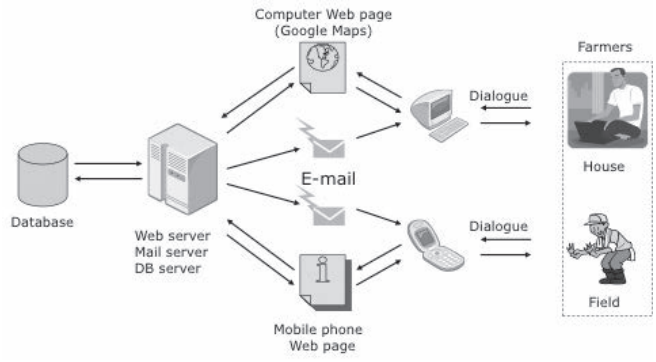

Figure 3: A web-based agricultural information system. Alert mail will send automatically to users when a dangerous situation will occur at their fields.

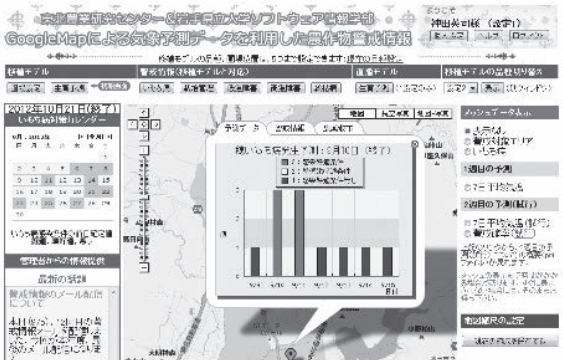

Figure 4: Rice blast outbreak information. Users can see the time series of danger levels from the past to the future.

KEYWORDS

Paddy rice, Cool Weather Damage, Rice blast, Early Warning System, Tohoku, Japan

REFERENCES

Torigoe, Y., 2001: Journal of Agricultural Science, 56, 193-196.

National Agriculture and Food Research Organization

Early-warning system against cool weather damages in rice production

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Food and Agriculture for the Future

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Outline

1. Geography
   —Agricultural district
2. Agricultural Weather in Tohoku
   —Moderately cool weather produces high quality rice, but cold weather damages rice
   —Large yearly variations in recent 30 years
3. Early Warning System
   —Reduces crop damage due to cool weather
   3-1. 1st System
   3-1a. Early Warning System for Heilongjiang
   3-2. 2nd System
   3-3. future System

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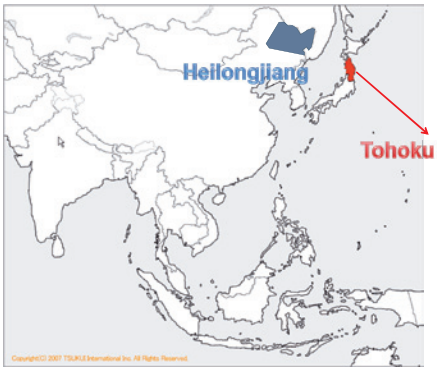
1.Geography Location of the study area



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Geographical features

- Cool climate
- Abundant water resources
- River valleys and plains for farming
- High quality rice

- Tohoku produces 26% of Japan's rice harvest
- Heilongjian produces 27% of Chinease japonica type rice harvest

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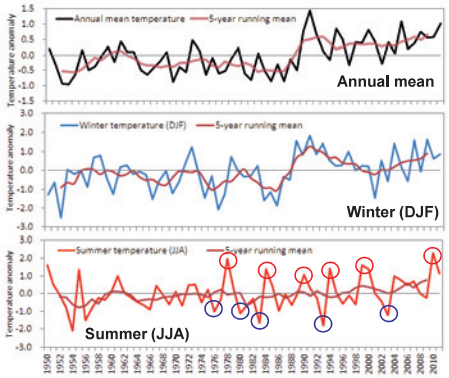
2. Agricultural Weather in Tohoku Time series of temperature anomalies



Time series of temperature anomalies in Northern Japan from 1950 to 2011

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Time series in grain yield in Tohoku

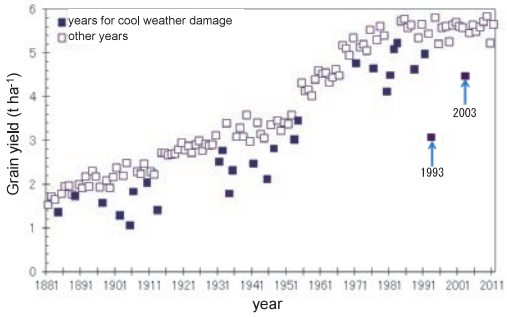

Fig. Changes in grain yield of brown rice in Tohoku region.
Data were obtained from the Crop Statistic of the Ministry of Agriculture, Forest and Fisheries of Japan.

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Cool weather damage in 1993

Losses: 469 billion yen

Rice production index: 56

The total damage rate: 54.2%

By *Yamase* wind : 48.7%

By rice blast disease: 4.9%

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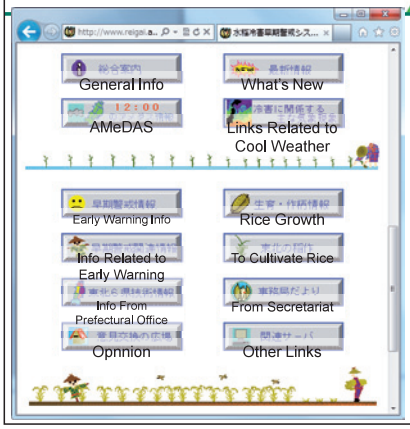
3. Early Warning System for Rice



1st system based on current meteorological observations with information on rice growing stages

Fig. Menu of the "Early Warning System for Rice". Available at <http://www.reigai.affrc.go.jp> with translation.

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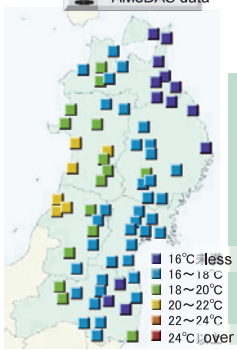
Real-time meteorological observation

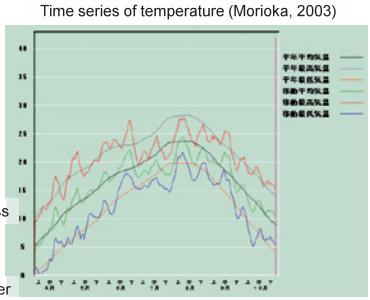
Real-time AMeDAS data

Time series of meteorological data



daily mean temperature July 26, 2003

Time series of temperature (Morioka, 2003)



2003年の気温経過（盛岡アメダス）

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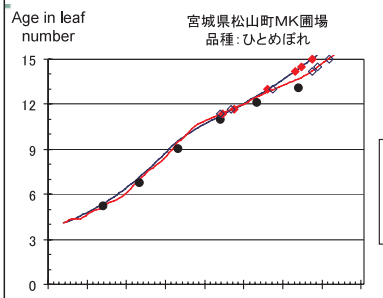
Estimate rice growing stage by model



Estimate by temperature in normal year

Estimate by temp. in 2003

Observed age in leaf number

	Age in leaf number (9-Aug)	Panicle neck node differentiation	Panicle formation	Meiosis
Normal Year	15.8	2-Jul	18-Jul	30-Jul
This Year(2003)	15	1-Jul	20-Jul	5-Aug

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3-1a. Early Warning System for Heilongjiang

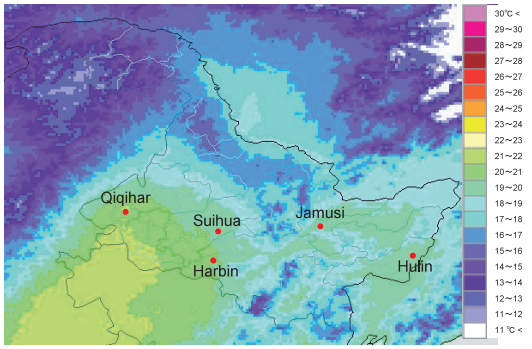

Fig. Mesh data on air temperature in Heilongjiang in August 2002.
Mesh data calculated at 5 * 5 km grid-point with World Meteorological Organization (WMO) data.

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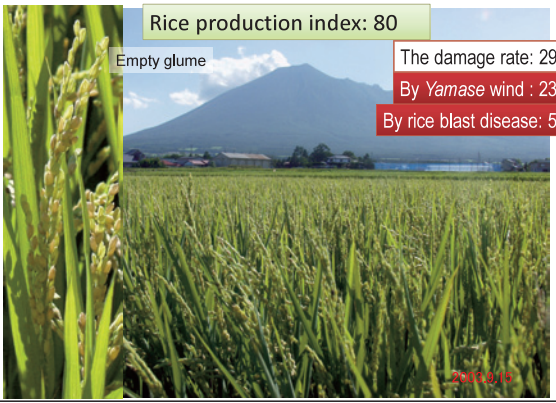
Cool weather damage in 2003 in Tohoku District

Rice production index: 80



The damage rate: 29.4%

By *Yamase* wind : 23.3%

By rice blast disease: 5.3%

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1st system estimation in 2003

Pref	Cities and Towns	Famers	Difference of sterility percentage farmer's sterility - average sterility	Yield farmer's yield / average yield 2004		Cultivar
Miyagi	Matsuyama	Monitor A	-20.4	103.7	129.4	Hitomebore
Miyagi	Matsuyama	Monitor B	-17.2	93.2	144.5	Hitomebore
Miyagi	Matsuyama	Monitor C	-22.2	98.3	128.1	Hitomebore
Miyagi	Iwadeyama	Monitor D	-5.4	98.1	147.1	Hitomebore
Miyagi	Kogota	Monitor E	-14.3	94.2	118.2	Hitomebore
Miyagi	Kogota	Monitor E	-13.3		116.5	Manamusume
Miyagi	Ishinomaki	Monitor F	-4.7	121.5	132.0	Sasaroman
Miyagi	Ishinomaki	Monitor G	-14.9		130.2	Takitate
Yamagata	Mogami	Monitor H	6.9	111.6	137.2	Akitakomachi
Yamagata	Mogami	Monitor H	2.1	92.3	123.0	Sasanishiki

Average data were obtained from the Crop Statistic of the Ministry of Agriculture, Forest and Fisheries of Japan.

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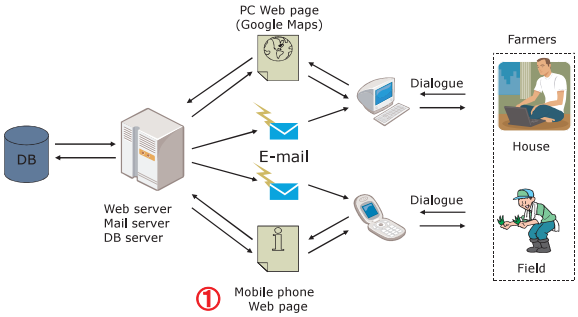
3–2 2nd system
Agricultural web information system



An e-mail alert will be sent out automatically to users when dangerous conditions arise for their fields.

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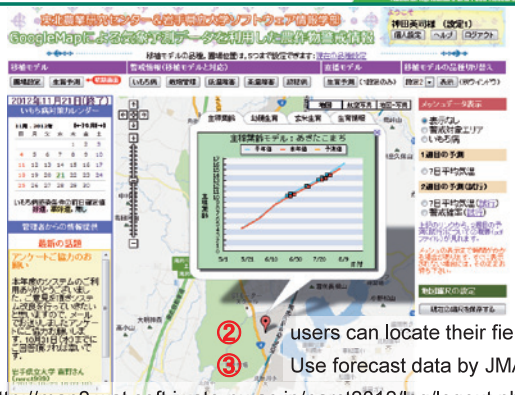
Forecast of the booting stage of rice



② users can locate their fields

③ Use forecast data by JMA

<http://map2.wat.soft.iwate-pu.ac.jp/narct2012/log/logout.php>

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Forecast of the low temperature damage caused by the *Yamase* wind

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Two-week temperature prediction web page

An e-mail alert for low temperature

****** 2週目の予測：低温確率（試行） ******

低温に注意して下さい．7月31日から1週間程度，7日平均気温が22℃を下回る可能性が高く，20℃以下となる確率は46.2%となっています．

Title: Two-week low temperature prediction and probability (Trial)

Please be on the alert for low temperatures. During the week from July 31st, there is a 46.2% high probability that the temperature will be lower than 22 degrees.

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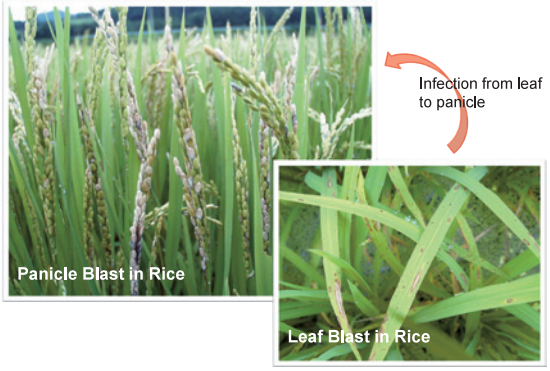
Rice Blast



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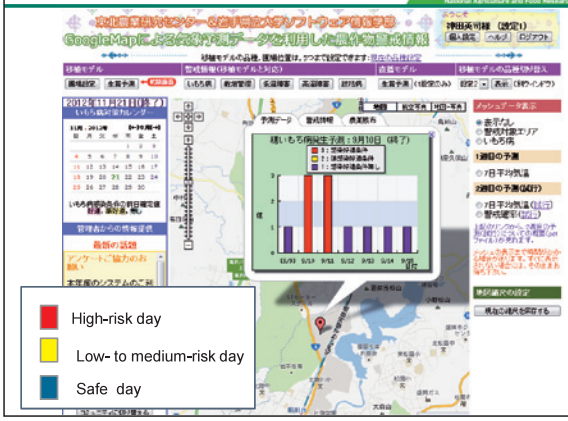
Rice blast outbreak information



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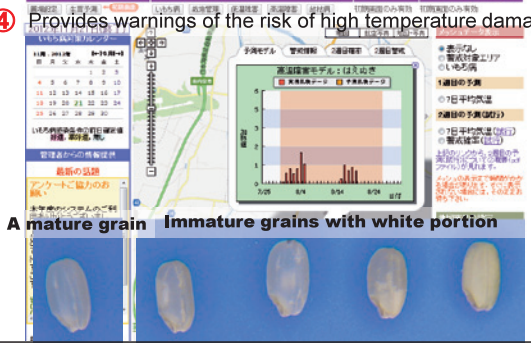
Forecast of the high temperature damage

④ Provides warnings of the risk of high temperature damage



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Incidense of sheath blight disease

④ Provides warnings of the risk of high temperature damage

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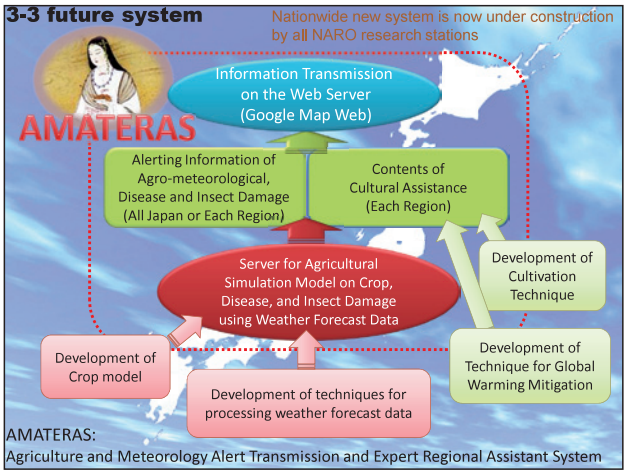
3-3 future system

Nationwide new system is now under construction by all NARO research stations



AMATERAS:
Agriculture and Meteorology Alert Transmission and Expert Regional Assistant System

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Summary

In the Tohoku District, the summer weather has shown large year to year variations in the past 30 years.

This early warning system is effective in reducing cool weather damage to rice.

The early warning system produces information posted on a web site that alert farmers to take appropriate steps to protect their crops.

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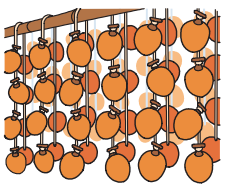
Thank you very much



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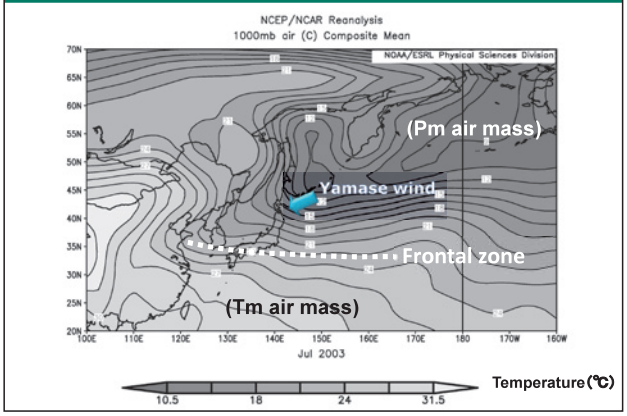
Cool summer and the *Yamase* wind



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Yamase wind blowing over a paddy field

Yamase wind produces low-temperature, low-sunshine duration, and high humidity.

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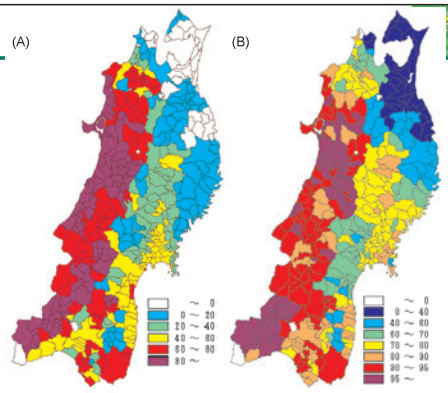

Fig. Comparison of crop situation index (A) in 1993 and (B) 2003
Crop situation index is ratio to the average yield of five years except the maximum and minimum yield in past seven years .

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Use Forecast Data (one week) for crop management of rice

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Chairman Dr. Kazunobu Toriyama: The last speaker of this session will not talk about insects; instead, he will address cold damage to rice. Allow me to introduce Dr. Kanda, who is from the NARO Tohoku Agricultural Research Center. His expertise is in the area of crop management, where he has worked for some 15 years. He recently received an award, and his presentation today will highlight some very interesting new tools. Please, Dr. Kanda, the floor is yours.

Dr. Eiji Kanda: Thank you very much for the introduction. Usually I am speaking in the Tohoku dialect in Japanese and a computer language; therefore please allow me to speak in Japanese rather than in English.

Now, even though I do not speak in English I am extremely pleased and delighted to have this opportunity to speak to you. Today I would like to talk about the current status of an early-warning system against cool-weather damage in rice production. I would like to talk about the history of what we have been researching and our aspirations going forward.

First of all I would like to talk about the history of the Tohoku region and the geography of the Tohoku region, and also the weather. Because of the cold weather, high-quality rice is being produced, but when there is cool weather damage, rice is also damaged. In the summertime, in the past 30 years we are seeing yearly variations in temperatures. That is the reason why we require the early warning system, to guard against the damages of cool weather as well as extreme weather. I would like to talk about the most up-to-date system. Also, what we have introduced in Heilongjiang in China. I would also like to talk about the second renewed system, and lastly talk about the future system that we are working on at the moment.

Please refer to this red area; this is the Tohoku district. It is located in the northern part of Honshu Island. It is monsoon weather; we have distinct seasons. Usually the summertime is hot and humid and in winter there is a lot of snow. It is about 46° latitude, similar to Beijing as well as New York. For your information, this is Heilongjiang located in the north east of China. This is 46° latitude; it is north compared to the Tohoku district.

Now, about geographical features. Tohoku has a cool climate and we are blessed with abundant water resources from river valleys, lakes and much rainfall. This is the reason why this region is able to produce high-quality rice. As a result, Tohoku produces 26% of Japan's rice harvest of top quality rice. Heilongjiang is also a region which has abundant water and a cool climate. In Heilongjiang 27% of China's Japonica rice harvest is produced.

Now, let me talk about the agricultural weather in Tohoku. Here we have the temperature trends for 1950 to 2010. I have shown here the deviation from the normal year. In the 1980s the annual mean and the winter mean increased and from there onward it increased by one degree. However, if you look at the summer temperatures we do not see an increasing trend. Prior to the 1970s, there was low volatility in terms of temperature. However, from the end of the 1970s that volatility has become greater. These red circles indicate hot summers and the blue circles indicate cool summers. The end of the 1970s is a milestone transition period where changes have occurred thereafter.

Here we are looking at the changes in the grain yields of brown rice in the Tohoku region. In 1881 it was about 1.5 tonnes per hectare but it continued to increase and in the 1970s it exceeded 5 tonnes on a constant basis. But even then, we can see deterioration in terms of yield even though we have seen this increase. In 1993 and 2003 there were significant aberrations. That we talk about these cool summer damages. Usually if we standardize a regular year to be 100 then the price production index for 1993 was 56. In terms of the total damage rate for the rice paddies it was 54.2%. 48.7% was due to cool weather damage and 4.9% buy rice blast disease. The losses amounted to JPY 469 billion.

In order to reduce the damage from cool weather in rice production we embarked upon the development of an early warning system. We are trying to provide the information necessary to mitigate the detrimental impact of

cool weather damage on the part of farmers. This is the main menu of this website. If you go to this website the information is available to everyone free of charge.

This is the real-time meteorological data that has been provided. This is an example of 2003. Information on temperature, sunshine hours, precipitation and wind speed and direction are available. Throughout the cultivation period, the time series of temperature can be identified as well.

Now, we are looking at the estimated rice growing stage by model. We are collecting cultivation data from some farms' monitors. By so doing, we are able to reduce the damage incurred by cool weather.

The cool weather damage is an important issue in Japan. However, in Taiwan, Bangladesh, India, Nepal and other countries, similar problems have been reported, so this is not just limited to Japan. We took this system to Heilongjiang, where production is increasing yearly for rice paddies, but the time for rice paddy cultivation is limited and the temperature is also lower so cool weather damage occurs once every four to five years. In 2002, because of the cool weather damage in the Jamsui area the yield was unusually low, 33% below normal. That is why we created the early warning system for this area as well. August 2002 information is shown here; summertime weather was relatively low.

This is the Japanese version. After we created the system the first cool-weather damage occurred in 2003. The rice production index was 80%, so the yield came down by 20%. Please refer to this photograph; you can see the rice ear coming out. 40 days after emergence it can be harvested, but in this case we saw a significant number of empty glumes, even after this period.

Use of the early warning system can mitigate the damage. As you can see here, the sterility percentage is lower, and yield is 20% more than in a regular year. The yield in 2004 is in line with the regional average, although there are some ups and downs. Therefore, using the early warning system they are able to control the cultivation, including the rice blast disease, as well as controlling water.

The effectiveness of the early warning system has been verified. Therefore, we have embarked upon improvements to the current system. There are four improvements that we have made. First of all we are now providing access to information via mobile phones and email. Farmers can only use desktop computers at night, but if the information is available via mobile phone it can be accessed from the field as well, so if there is information that we would like to share with the farmers we are sending it to mobile phones.

The second improvement is use of Google Maps. Farmers are able to register their fields. Up until now we have been identifying the AMeDAS (Automated Meteorological Data Acquisition System) point and information was provided for certain farmers. But now farmers are able to make an estimate for their own fields on any given date and receive services accordingly. So far we have been using historical meteorological data but we are now able to incorporate forecast data from the Japan Meteorological Agency (JMA). By so doing we can forecast the weather and bring this information to bear on cultivation management.

This is by membership, but you can access information on this website. We are also providing warning information regarding cool weather damages. We are also sending email of this kind. We are able to provide information including two-week low temperature prediction, taking into account the location of the farmers' fields, and in line with the stage of cultivation. When we send such emails, server access will increase, which allows us to verify that many farmers are receiving the necessary information.

Another important point to consider is the rice blast disease. By predicting the weather, infection can be avoided, and we are providing such necessary information. This is information relating to rice blast outbreaks, providing information on which particular days are high risk for rice blast.

In the past, in the Tohoku region people were happy when there was a hot summer; high temperature gave a good harvest. But currently there are examples where high temperature will lower the quality of the rice grain. We are therefore providing such warnings as well. When there is low temperature there is rice blast disease and when there is high temperature, there are occurrences of sheath blast disease. We have a prototype providing information on predictions for occurrence of sheath blight disease as well.

Now, with respect to future systems, this is an early warning system for nationwide use. We have given it the name Agriculture and Meteorology Alert Transmission and Expert Regional Assistant System (AMATERAS). Any Japanese person will know what Amateras means, as it is the goddess that controls the sun. So our system is now relying on divine powers as well.

We are now focusing on the early warning system for cool weather damage for rice production but we would also like to cover other crops as well as other problems. We also want to take into consideration the mitigation of climate change. We would like to provide new cultivation technology through the system so that we may contribute to agriculture in Japan going forward.

Lastly, let me summarize. In Tohoku, the summer weather has shown large year to year variations in the past 30 years, which is having a severe impact on rice production in the Tohoku region. The early warning system is effective in reducing cool weather damage to rice. The early warning system can be used by farmers free of charge, and by so doing, the cool weather damage can be alleviated. Going forward, we would like to develop a nationwide system.

That is all. Thank you.

Chairman: Thank you very much for that presentation and its inclusion of some very impressive new technology.