わが国のこれまで77年にわたる陸稲育種研究の成果
Achievements of Upland Rice Breeding in Japan in the Past 77 Years

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要　約

わが国における陸稲育種研究は，食糧自給率の向上を目的として1929年に農林省が全国の5ヵ所（秋田，茨城，三重，鳥取，鹿児島）に陸稲育種指定試験地を設置したことに始まる。戦後の組織再編以降は，茨城県農業総合センターが唯一の指定試験地として品種育成を担ってきたが，作付面積の減少等の理由から2005年度で終了した。この77年の間に61品種が育成されている。

この間の研究内容および成果は時代背景ごとに大きく分けると以下のとおりである。

1929-1950

食糧の増産が強く求められた時期である。とくに開拓地では，陸稲は経営が安定するまでの欠かせない食糧として重視された。品種育成は，耐干性の向上と多収性を目標として推進され，この結果，短強稈で栽培しやすく，当時としては良食味の「農林12号」や多収品種「農林糯26号」等が育成された。また，播種期や栽植密度，敷わら効果等の陸稲栽培に関する基本的な研究やカリ欠乏土壌やリン酸欠乏土壌等の開拓地で栽培するための品種比較試験が行われた。

1951-1970

引き続き食糧の増産が求められる中で，畑地かんがい設備が整備され始めた。水稲品種ではいもち病の多発等のため，畑かん栽培への転用が困難なことから，畑地かんがいを前提とした専用品種の育成が目標とされ，主に水稲と陸稲との交配により品種育成が進められた。この結果，強稈・多収品種「オカミノリ」（農林24号×水稲農林29号），良質・多収品種「ミズハタモチ」（越路早生×ハタコガネモチ）等が育成された。また，かん水栽培法や陸稲の麦間栽培法に関する研究が多くなされた。

1971-1988

米の生産調整が開始される中で，陸稲は野菜の連作障害を緩和する効果があることから，クリーニングクロップとして野菜作の輪作体系に取り入れられ始めた。このため，野菜作との組合せが容易で干ばつ回避効果も期待される早生品種の育成が主目標とされ，早生熟期「トヨハタモチ」や「キヨハタモチ」が育成された。また，陸稲により連作障害が緩和される仕組みに関する研究や外国陸稲の耐干性（深根性）の評価と交配母本としての利用，ハウスを利用した独自の耐干性検定方法の開発が進められた。

1989-2005

野菜作を中心とする畑作経営が一段と集約化する中で，野菜作との組合せがより容易な極早生熟期で，安定生産が可能となる高度耐干性品種の育成を目標として品種育成が推進された。この結果，まず，外国陸稲「JC81」に由来する深根性を導入した中生・高度耐干性品種「ゆめのはたもち」が育成され，次に「ゆめのはたもち」の耐干性と「関東糯 166 号」の早生・耐冷性を集積することに成功した早生・安定多収品種「ひたちはたもち」が育成された。また，陸稲需要の拡大を図るための加工特性に関する研究やイネゲノム研究の進展にあわせて陸稲を遺伝資源として利用し，陸稲の有する新規いもち病圃場抵抗性遺伝子を水稲へ導入する研究が進められた。

本発表では、主として演者らがこれまでに行ってきた研究成果をたどりながら、土壌環境の中で、とくに、土壌水分を中心にその作物根の発育や機能に及ぼす影響を、可塑性をキーワードに考えてみたい。

Achievements of Upland Rice Breeding in Japan in the Past 77 Years

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Abstract

In 1929, the government breeding program began upland rice breeding research at five breeding stations (Akita, Ibaraki, Mie, Tottori and Kagoshima). Though only Ibaraki Agricultural Center continued upland rice breeding after the post war reorganization, upland rice breeding ended in March 2006 because of a sharp decrease in cultivation area. Sixty-one varieties were bred from 1929 to 2006. Many studies had been carried out on drought resistance and other similar conditions.

The achievements of upland rice breeding in each time period are as follows:

1929-1950

The increase of crop production was strongly requested. Upland rice played an important role until farming managements stabilized particularly at reclaimed field. The breeding objectives in this period were mainly high yielding and drought resistance. As a result "Norin 12" which is a high yielding variety with relative short culm and "Norinmochi 26" which is a high yielding glutinous variety and others were released. There were also discussions on basic cultivation studies such as sowing time, sowing quantity and straw mulch effect as well as a variety of screening tests for reclaimed fields suffering from potassium and/or phosphorus deficiency.

1951-1970

The field irrigation systems began to be equipped in upland field, while the increase of crop production was still requested. As the paddy rice was not suitable for upland cultivation due to damage from blast disease, the specific varieties were requested for the cultivation at upland fields with irrigation systems. Therefore breeding was mainly promoted by a cross between paddy rice and upland rice. As a result high yielding varieties such as "Okaminori", "Mizuhatamochi" and others were released. Additionally many studies on the cultivation methods using field irrigation and cropping systems with wheat or barley cultivation were carried out.

1971-1988

When the overproduction of paddy rice became a serious issue, upland rice began to be used as a rotation crop because it had an effect on the decrease in continuous cropping injury of vegetables. Thus, the breeding of early maturing varieties which made the rotation with vegetable cultivation efficient and were expected to have the effect on drought escape was promoted. As a result early maturing varieties such as "Toyohatamochi" and "Kiyohatamochi" were released and evaluations of deep rooting of foreign upland rice cultivars as well as their utilization as breeding materials were conducted. The greenhouse method for evaluation of drought resistance was also originally exploited.

1989-2005

As vegetable cultivation became more intensive, the very early maturing varieties with high drought resistance were requested for the stable management of crop rotation. As a result, first medium maturing variety "Yumenohatamochi" with deep rooting which was derived from foreign upland cultivar "JC81" was released. Then a very early maturing and stably high yielding variety "Hitachihatamochi" which had the drought resistance acquired from "Yumenohatamochi" and very early maturation and cold tolerance acquired from "Kantomochi 166" was released. Additionally, studies on the processing suitability for the promotion of upland rice consumption were discussed.

Based on the idea of using upland rice as a genetic resource, the introgression of blast resistance genes from upland rice into several types of paddy rice by using DNA markers was also promoted.

In 1929, the governmental breeding program began upland rice breeding research at five breeding stations (Akita, Ibaraki, Mie, Tottori and Kagoshima). Though only the Ibaraki Agricultural Center continued upland rice breeding after the post-war reorganization, upland rice breeding ended in March 2006 because of a sharp decrease in cultivation area. Sixty-one varieties were bred from 1929 to 2006.

In this article, first, I outline the achievements of upland rice breeding on the basis of historical background, then, I focus on the drought resistant breeding which had been carried out consistently during this period mainly based on the results of Ibaraki Agr. Center.

1. Transition of acreage and yield of upland rice

Fig. 1 shows the transition of cultivation area and yield per hectare of upland rice in Japan after 1900. Upland rice was an important crop for staple food until 1960's. The cultivation of upland rice was encouraged for a production increase of rice after World War II. The largest cultivation area of upland rice was 180,000 hectares in 1960. However its cultivation was dramatically decreased under the overproduction of paddy rice. At present, the yield is about 2.4 t/ha that is about half of paddy rice in Japan.

2. The achievements of upland rice breeding in each time period

1) I period (1929-1950)

The increase of crop production was strongly requested. Upland rice played an important role especially at reclaimed fields until farming managements stabilized. The breeding objectives in this period were mainly high yielding and drought resistance. As a result, "Norin No. 12" (1936) which is a high yielding variety with relative short culm and "Norinmochi No.26" (1947) which is a high yielding glutinous variety and others were released. There were also discussions on basic cultivation studies such as sowing time, sowing quantity and straw mulch effect as well as a variety of screening tests for reclaimed fields suffering from potassium and/or phosphorus deficiency.

2) II period (1951-1970)

The field irrigation systems began to be equipped in upland field, while the increase of crop production was still requested. As the paddy rice was not suitable for upland cultivation due to damage from blast disease, the specific varieties were requested for the cultivation at upland fields with irrigation systems. Therefore, breeding was mainly promoted by a cross between paddy rice and upland rice. as a result high-yielding variety

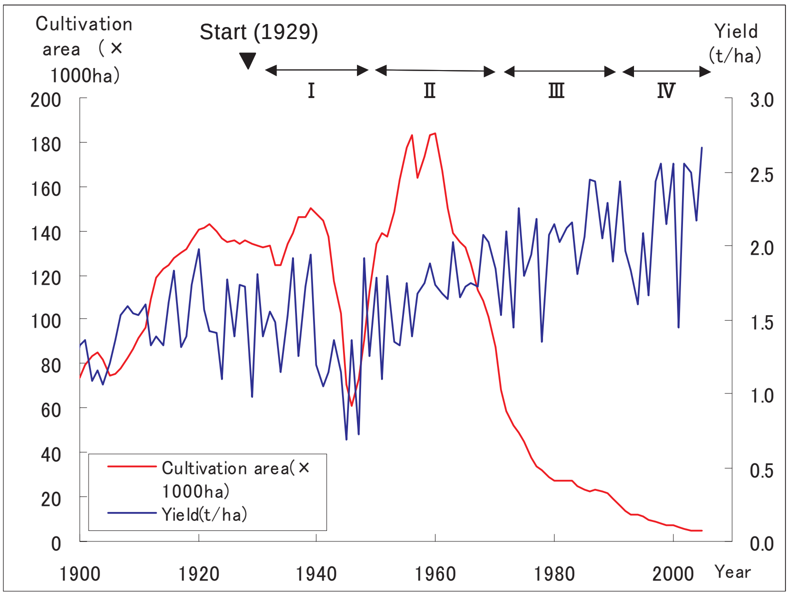

Fig. 1 Transition of cultivation area and yield per hectare of upland rice in Japan

"Okaminori" (1966), and high-yielding with good quality "Mizuhatamochi" (1969), *etc*. were released. “Okaminori” was bred from the cross between “Norin No.24” and paddy rice “Norin No.29”, and “Mizuhatamochi” was bred from the cross between paddy rice “Kosijiwase” and “Hatakoganemochi”. Additionally many studies on the cultivation methods using field irrigation and cropping systems with wheat or barley cultivation were carried out.

3) III period (1971-1988)

When the overproduction of paddy rice became a serious issue, upland rice began to be used as a rotation crop because it had an effect on the decrease in continuous cropping injury of vegetables (Fig. 2). Thus, the breeding of early maturing varieties which made the rotation with vegetable cultivation efficient and were expected to have the effect on drought escape was promoted. As a result early maturing varieties such as “Toyohatamochi” (1985) and “Kiyohatamochi” (1988) were released (explained later). Evaluations of deep rooting of foreign upland rice cultivars and their utilization as breeding materials were conducted. The greenhouse method for evaluation of drought resistance was also originally exploited (explained later).

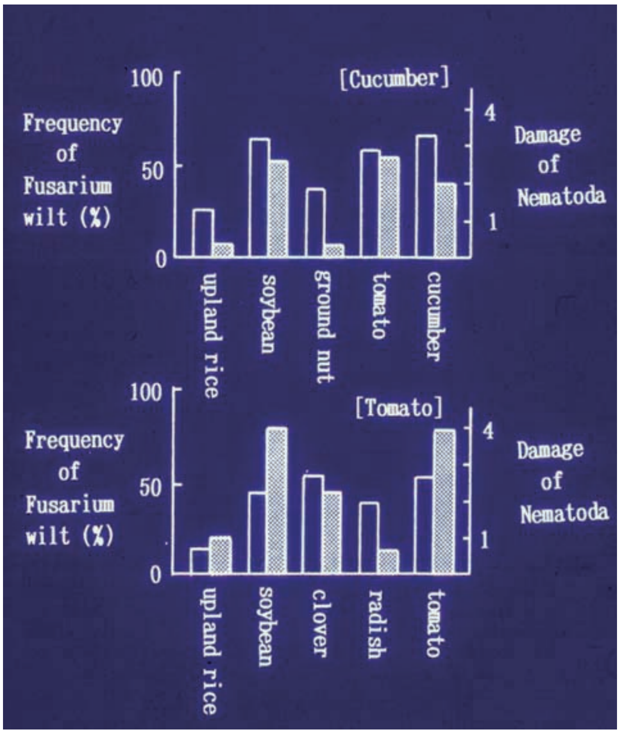

Fig. 2 Effectiveness of upland rice to control injuries of vegetables under continuous cropping (Matsuda 1974)

4) IV period (1989-2006)

As vegetable cultivation became more intensive, the very early maturing varieties with high drought resistance were requested for the stable management of crop rotation. As a result, medium maturing variety “Yumenohatamochi” (1996) with deep rooting which was derived from foreign upland cultivar “JC81” was released (explained later). Then a very early maturing and stably high yielding variety “Hitachihatamochi” (2005) which had the drought resistance acquired from “Yumenohatamochi” and very early maturation and cold tolerance acquired from “Kantomochi No.166” was released (explained later). Additionally, studies on the processing suitability for the promotion of upland rice consumption were discussed. Based on the idea of using upland rice as genetic resources, the introgression of blast resistance genes from upland rice into several types of paddy rice by using DNA markers was also promoted.

Breeding strategy to improve drought resistance in Japan

Two breeding strategies can be considered as the drought-resistance mechanisms of upland rice, "drought escape" and "physiological resistance" in Japan. We had been working to improve drought resistance by the following three steps; 1) breed early maturing varieties to avoid drought damage, 2) breed deep rooting varieties to develop physiological resistance, and 3) combine early maturation and deep rooting.

1) Early maturation

In Japan, rainy season is from early June to late July. After this period, season enters summer and drought damage becomes serious. The reproductive stage is the most susceptible for drought. Thus it is possible to avoid drought damage if this stage can be shifted away from the period when the possibility of drought is high.

We bred an early maturing variety, “Toyohatamochi” in 1985. Its heading date is about two weeks earlier than that of “Tsukubahatamochi”, a medium maturing variety.

Photo 1 shows the upland rice field in August 1994 when there was a serious drought. “Tsukubahatamochi” (Photo 1, right), which heading date is in middle August, suffered serious damage. However, “Toyohatamochi”(Photo 1, left), which had already passed its heading stage in late July showed the growth condition that would bring a certain level of yield and this variety can be described as succeeding in avoiding the drought. As “Toyohatamochi” shows drought resistance, its cultivation area represents about 70% of the total acreage of upland rice now.

Photo 1　Upland rice after rainy season August. Left half of photo is very early maturing variety “Toyohatamochi”, right is medium maturing “Tsukubahatamochi”.

Photo 2　Observation of root by the trench method

2) Deep rooting

The root distribution at lower soil is related to drought tolerance because deep rooting varieties can absorb much water from deep soil layer even in a year of drought and can thus minimize drought damage.

We used the trench method to evaluate root depth of local varieties including foreign varieties from South and Southeast Asia, China, Taiwan, Africa, USA, Europe, etc (Photo 2). In this method, a power shovel was used to dig a 60cm groove along the plant rows after harvesting, then distribution and quantity of roots at each soil depth were investigated directly.

As a result, we found some African, Indian and Chinese varieties having deeper roots than Japanese upland rice varieties. In particular, Jaypole collection No.81 (abbreviated as JC81), IR3646, IRAT10, IRAT109, IRAT110, and Nam Sugai 19 were among those with highly developed root systems (Nemoto *et al.* 1998) and these were crossed with Japanese upland rice varieties to obtain superior deep rooting varieties.

Backcrossing of “Norinmochi No.4”, a Japanese upland rice variety with “JC81”, a deep-rooting Indian variety was promoted. After continuous strain selection of the progenies of the cross by the trench method, we succeeded in breeding "Yumenohatamochi", a medium maturing variety with deep rooting in 1996 (Photo 3). The trench method is the reliable method as evaluation of drought resistance, but it needs much labor. Therefore, we developed a simple evaluation method of using test beds installed in a greenhouse (Photo 4). The process of evaluation of drought resistance is as follows (Suga *et al.*)

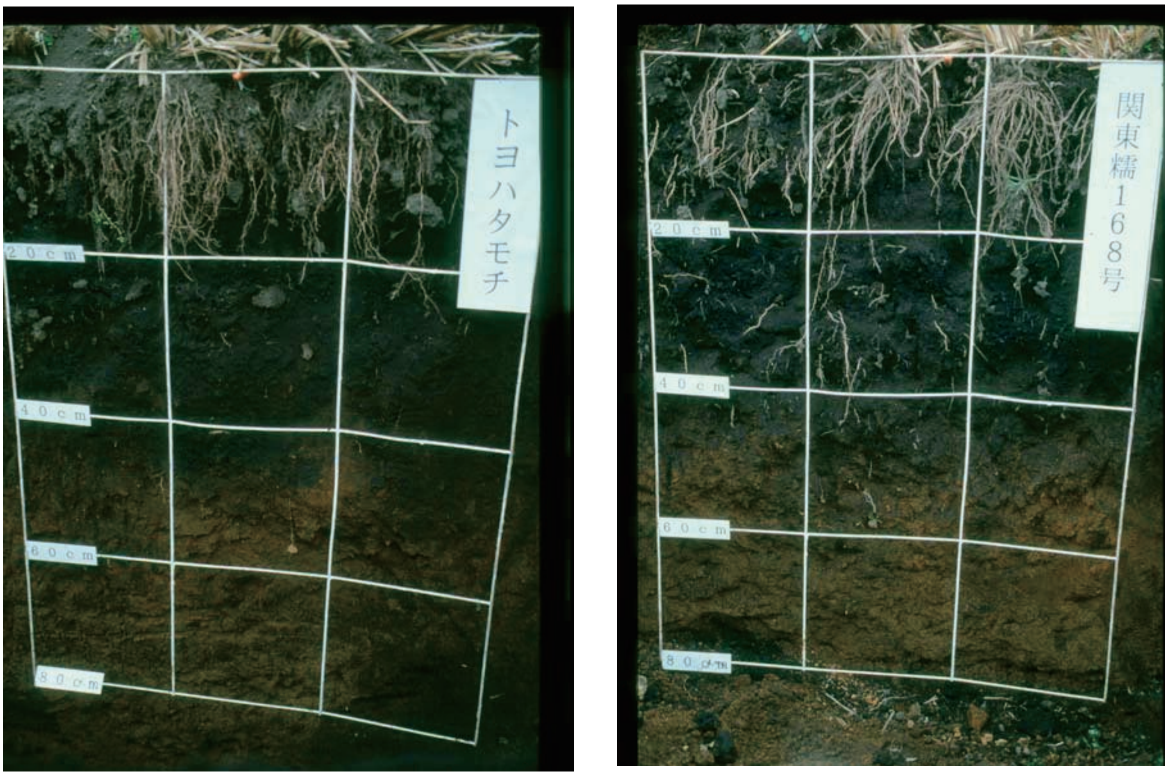

Photo 3　Comparison of root distribution of “Toyohatamochi” (left) and Yumenohatamochi (right)

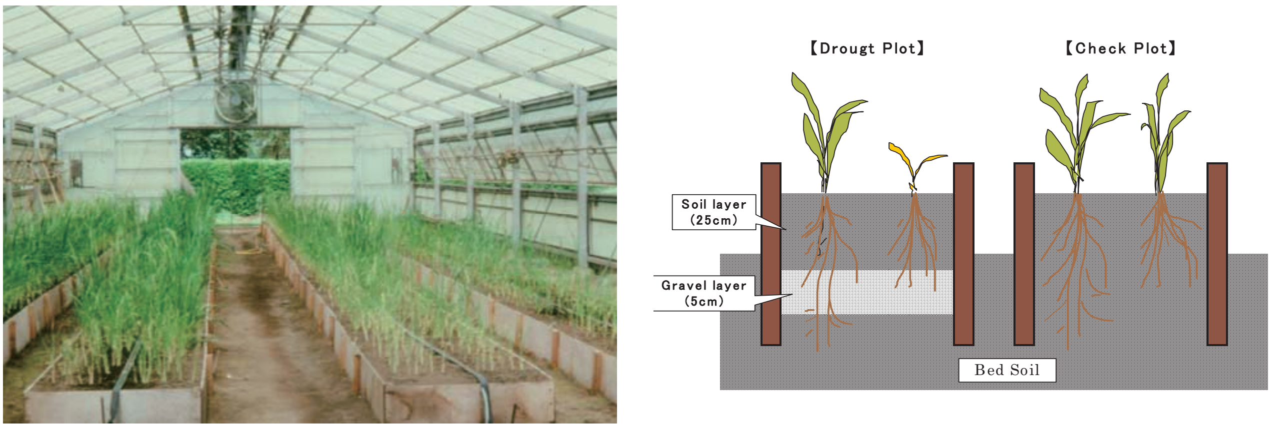

Photo 4　Screening house of deep rooting upland rice (left) and structure of bed (right)

The upland rice sown in the test beds are grown by sprinkling water over the soil surface and the irrigation is stopped at the reproductive stage when the plant is sensitive to water shortage. The bed of drought plot has a gravel layer 30 cm below the surface. Because the gravel layer serves as a water shutting-off layer, it prevents the moisture in the bed soil layer from rising up to the upper plowed soil layer. Thus after sprinkling over the soil surface is stopped, the moisture of the plowed soil layer decreases greatly. Deep rooting upland rice can continue growing because their root extend through the gravel layer and can absorb moisture from the bed soil, but shallow rooting one suffers serious drought damage since its roots are distributed only up to the plowed soil layer. The degree of reduction in yield in the plot where drought treatment is made is affected greatly by the length of roots and so the method is very effective in evaluating the deep rooting character of bred strains.

3) Combination of early maturing and deep rooting character

We succeeded in breeding “Hitachihatamochi” by combining the very early maturing character and the deep rooting character in 2005. This new variety was selected from the cross between early maturing variety "Kantomochi No.166" and the hybrid of "Kantomochi No.166" and "Yumenohatamochi". "Hitachihatamochi" is an early maturing variety with slightly short culm length. Its yielding ability is higher than that of standard variety "Kiyohatamochi" by 20% almost every year. It also shows high cold tolerance as well as drought resistance.

Photo 5 shows that drought resistance of “Hitachihatamochi” is stronger than that of early maturing varieties such as “Toyohatamochi” and “Kiyohatamochi” (Photo 5). The leaves of “Hitachihatamochi” did not wither, whereas those of “Toyohatamochi” and “Kiyohatamochi” withered up.

“Hitachihatamochi” was adopted as a recommended variety in Ibaraki Pref., which holds about 70 % of total Japanese upland rice area, in 2005. The release of this variety is expected to stabilize upland rice cultivation in Ibaraki Pref. and also in Japan.

4. Future directions

Upland rice has not been used so much as breeding materials of paddy rice, because it was difficult to remove bad characters linked with upland rice. But upland rice varieties are expected to become handy genetic resources to improve paddy rice because selection technologies using DNA markers have being developing rapidly nowadays.

When seeing worldwide, upland rice is one of the most important crops in the developing countries such as Western Africa and Latin America. Moreover, the water resources has being deteriorated globally, various characters of upland rice by which water-saving cultivation becomes possible, will get more attention in the near future.

Photo 5　Drought resistance of “Hitachihatamochi”, “Toyohatamochi”, “Kiyohatamochi” and “Yumenohatamochi” (from left to right)

References

1) 60th anniversary journal of Ibaraki Agricultural experimental station
2) 70th anniversary journal of Ibaraki Agricultural experimental station
3) 80th anniversary journal of Ibaraki Agricultural experimental station
4) 90th anniversary journal of Ibaraki Agricultural experimental station
5) 100th anniversary journal of Ibaraki Agricultural research institute
6) 50th anniversary journal of governmental breeding program
7) 70th anniversary journal of governmental breeding program
8) Matsuda A (1974) Nogyo Ibaraki 20 –22.
9) Nemoto *et al*. (1998)

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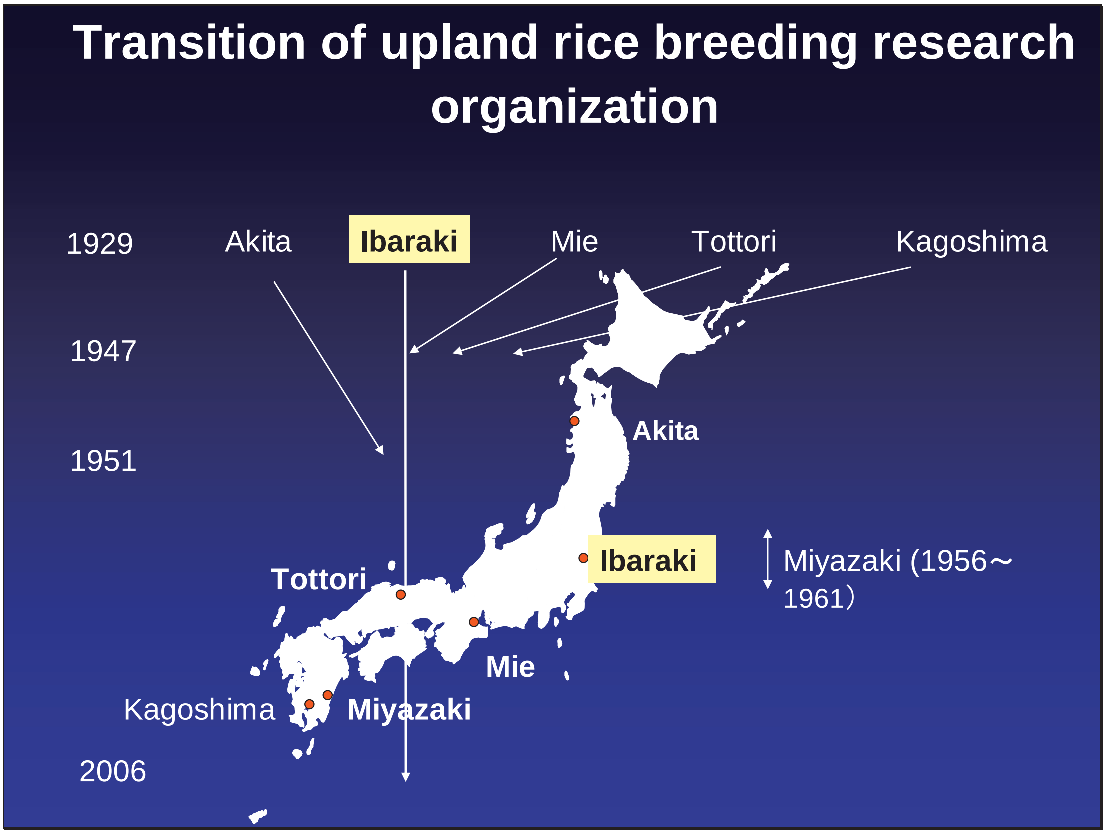
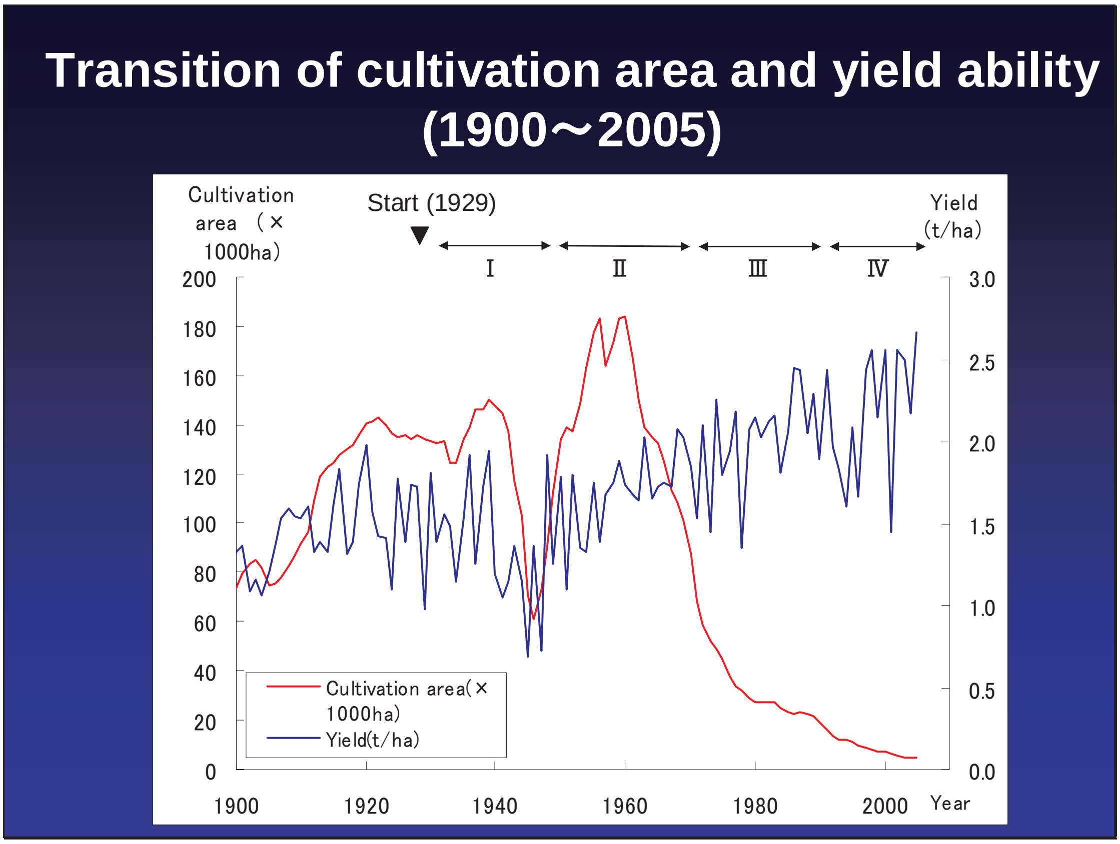
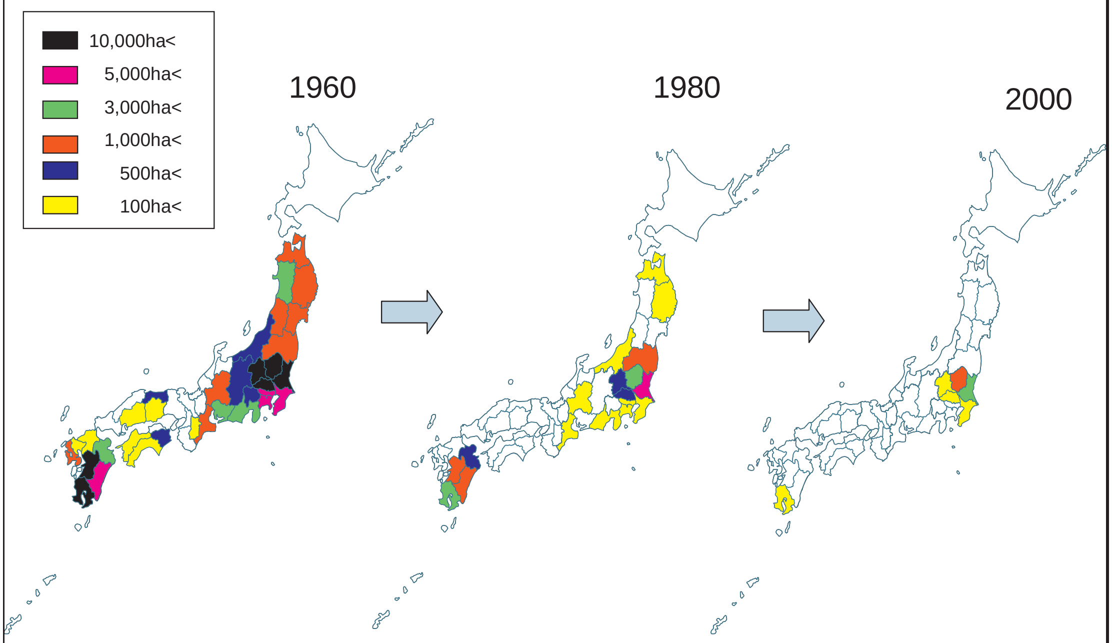

Transition of upland rice breeding research organization
1929
1947
1951
2006
Akita
Ibaraki
Mie
Tottori
Kagoshima
Akita
Ibaraki
Miyazaki (1956～1961)
Tottori
Mie
Kagoshima
Miyazaki

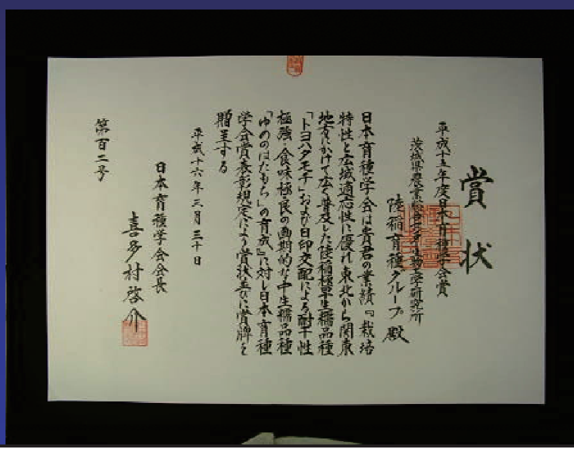

Transition of cultivation area and yield ability (1900～2005)
Cultivation area (×1000ha)
Start (1929)
Yield (t/ha)
Ⅰ
Ⅱ
Ⅲ
Ⅳ
200
180
160
140
120
100
80
60
40
20
0
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1900
1920
1940
1960
1980
2000
Year
Cultivation area(×1000ha)
Yield(t/ha)

Distribution of upland rice cultivation

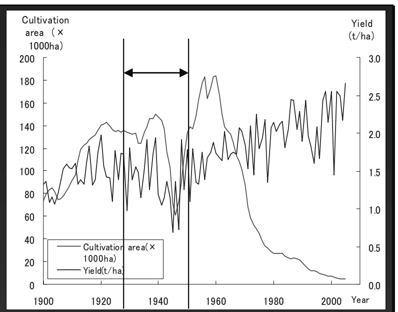


Main achievements

- Sixty-one varieties were released; Toyohatamochi, Yumenohatamochi, Hitachihatamochi, *etc*.
- Prize of Japanese society of breeding（Ibaraki Agr. Center, 2004)



Period Ⅰ（1929～1950）



○ Background
request for increase of crop production,
promotion of reclamation

○ Breeding objectives
high yielding, drought resistance

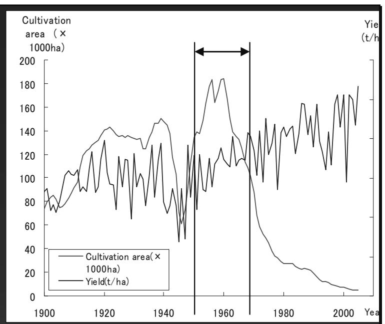
○ Varieties released (27 varieties)
Norin 12 (1940): high yielding, good eating quality
Norinmochi 26（1947) : high yielding, drought resistance

Period Ⅰ（1929～1950）

○ Related studies

- Cultivation methods: desirable pattern of sowing; time, quantity, density,row width, *etc.*
- Variety screening：for reclaimed fields suffering from K or P deficiency
- Drought resistance：effects of planting density, transplanting, straw mulch, cut-off leaves, *etc.*

Period Ⅱ（1951～1970）



○ Background

request for increase of crop production, promotion of field irrigation system

○ Breeding objectives

specific varieties for cultivation under irrigation system, high yielding, good quality

○ Varieties released (23 varieties)

Okaminori（1966): high yielding,（Norin24× Norin 29(paddy rice))

Mizuhatamochi（1969): high yielding, good quality,（Koshijiwase (paddy rice) ×Hatakoganemochi）

Period Ⅱ（1951～1970）

○ Related studies

➢Cultivation methods：

◆Sowing or transplanting time, influence of shading, *etc*. under cropping system with wheat or barley

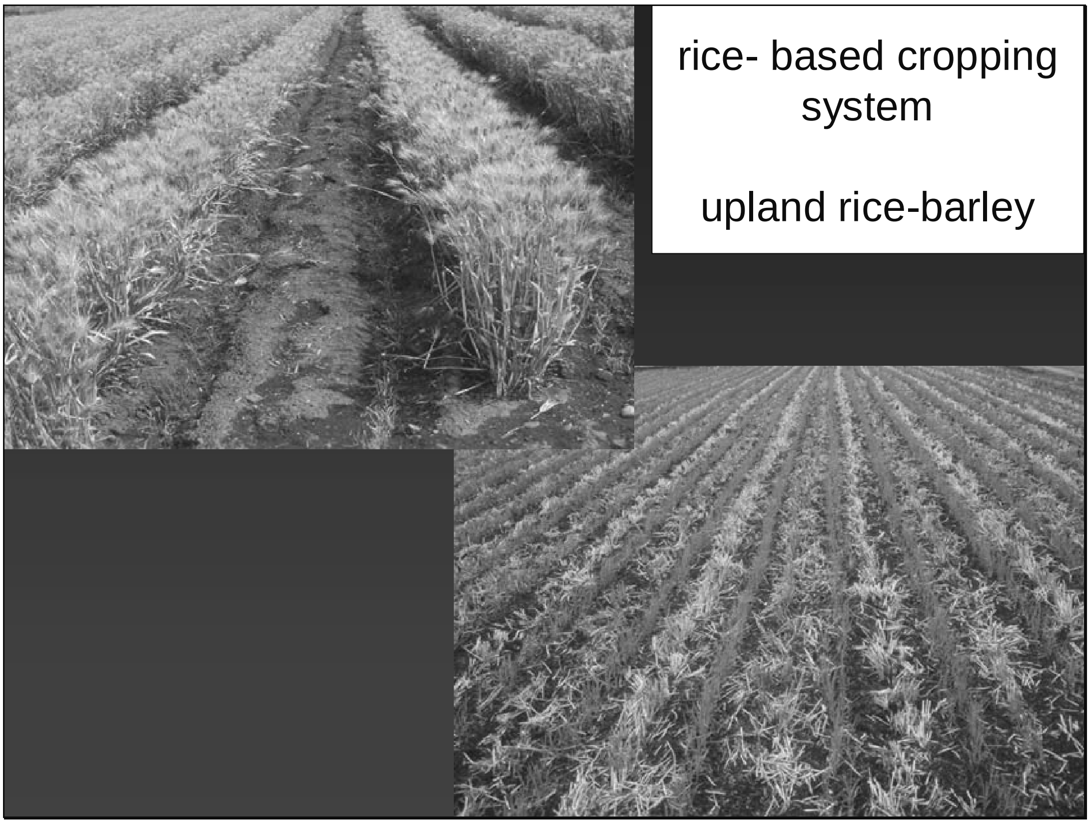
◆Yield test, grain quality, relationship between sowing time and heading date, *etc*. under irrigation system

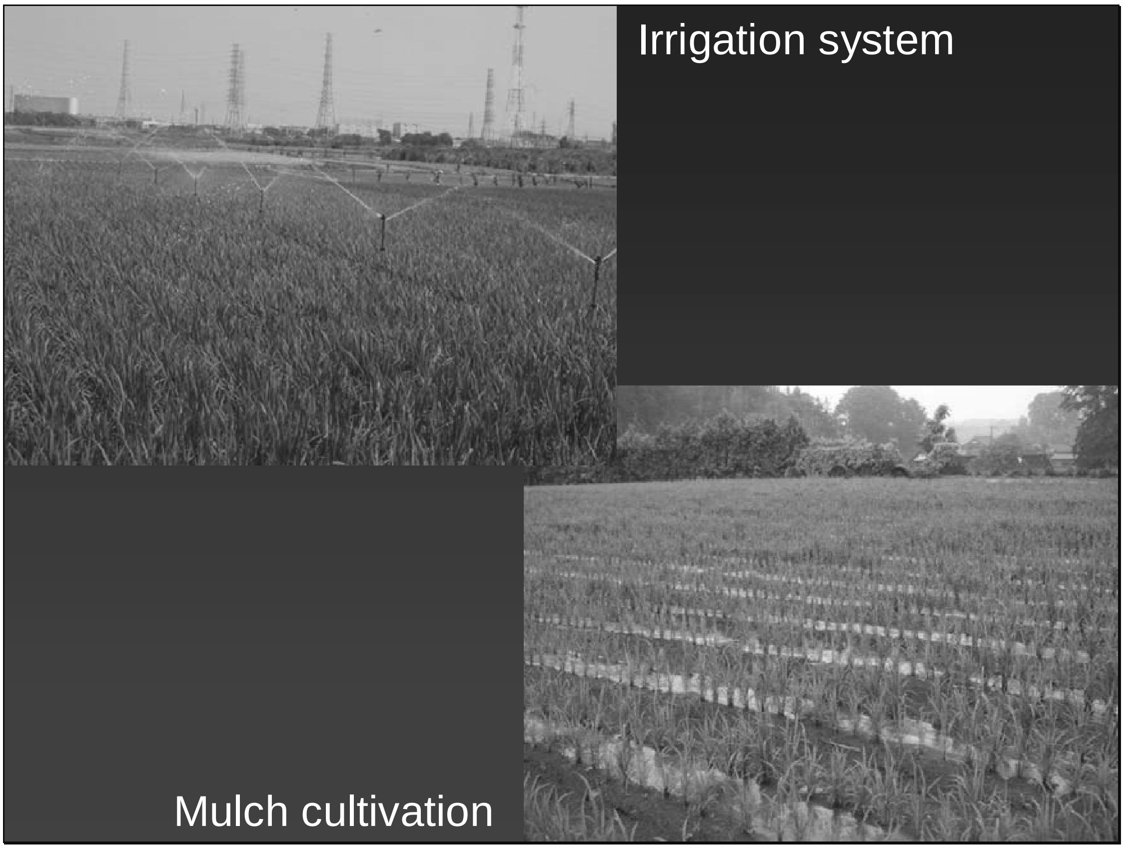
◆Mulch cultivation

➢Drought resistance：

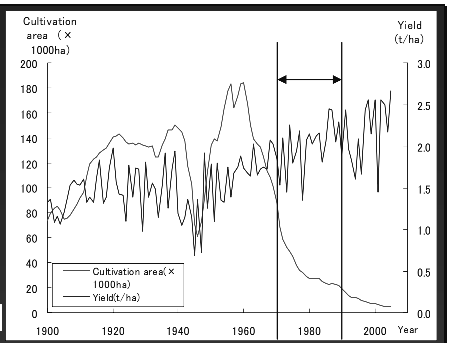
◆Difference in T / R’ ratio (weight of top / weight of roots) among varieties

◆ Relationship between T/R’ ratio and planting density, top dressing, types at seedling stage,*etc*.


rice- based cropping system
upland rice-barley


Irrigation system
Mulch cultivation

Period Ⅲ（1971～1988）



○ Background

overproduction of paddy rice,

increase of high value crop production (vegetables) in upland field

○ Breeding objectives

early maturing, high yielding, drought resistance

○ Varieties released（8 varieties）

early maturing：Fukuhatamochi (1978) ,
Toyohatamochi (1985) ,
Kiyohatamochi（1988)

Period Ⅲ（1971～1988）

○ Related studies

➢Cropping system: effectiveness to control continuous cropping injury of vegetables,

mechanisms of decreasing continuous cropping injury

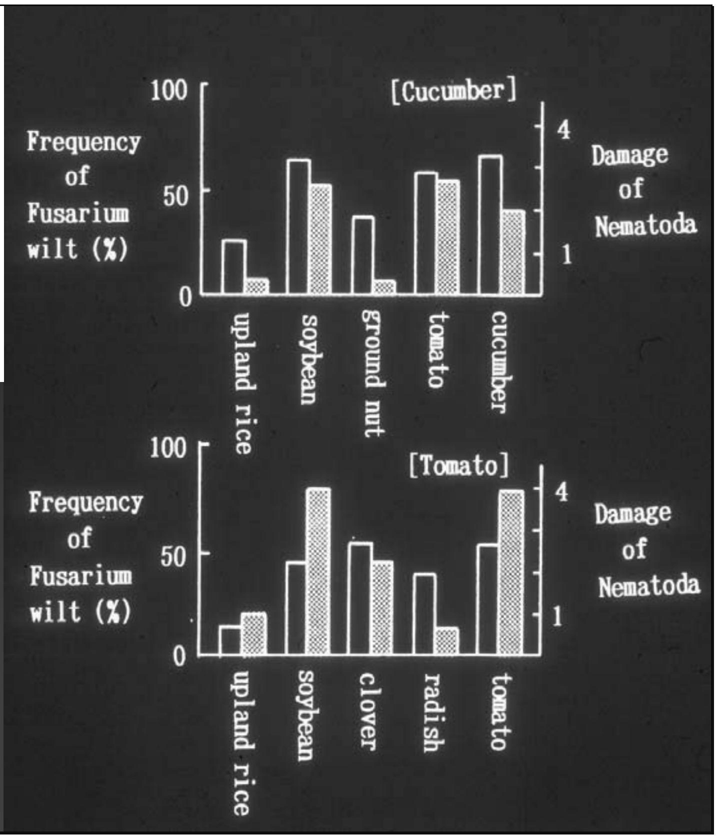
➢Drought resistance: screening of foreign varieties with deep rooting

green house method for evaluation

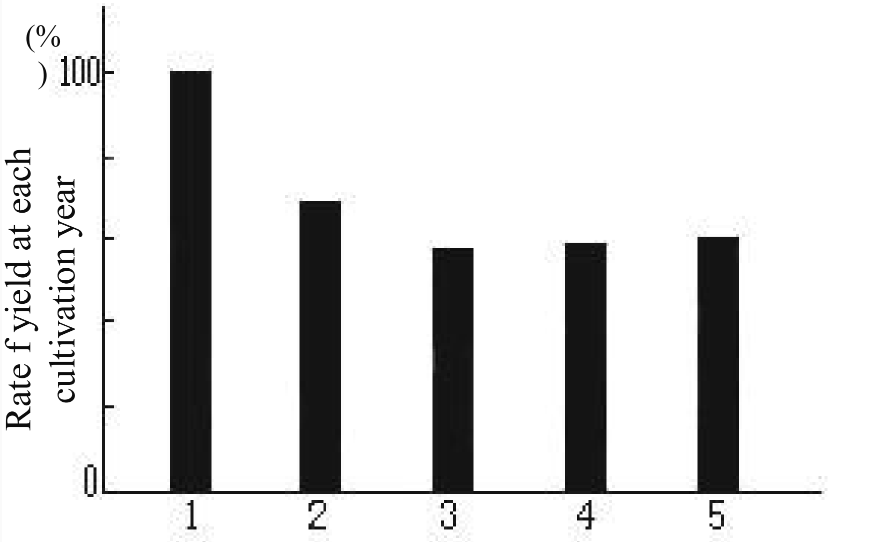
➢Disease resistance: inoculation method for evaluation of “Bakanae disease”

Cropping system with vegetables

Effectiveness of upland rice to control injury disease of vegetable under continuous cropping
(Matsuda 1974)

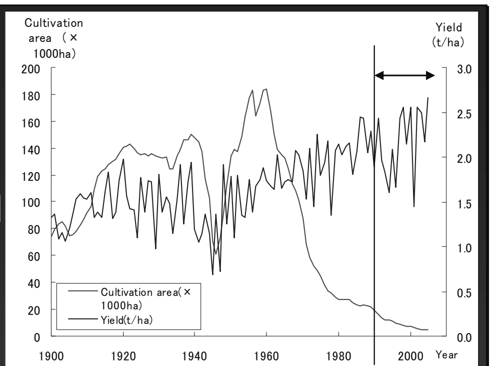


Yield of upland rice under continuous cropping



(Hasegawa *et al*. 1964)

Period Ⅳ（1989～2006）



○ Background

acceleration of intensive upland field management

○ Breeding objectives

very early maturing, stably high yielding, processing suitability

○ Varieties released（3 varieties）

Yumenohatamochi(1996) : medium maturity, deep rooting, good eating quality

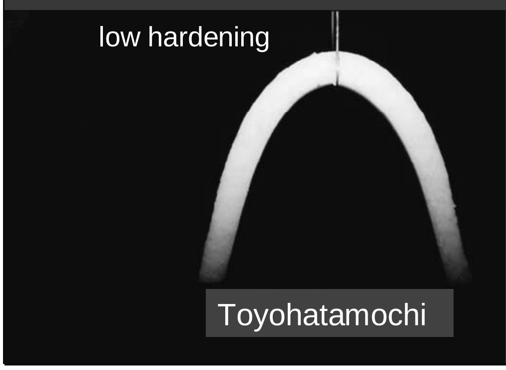
Hitachihatamochi（2005）: early maturity, stably high yielding

Period Ⅳ（1989～2006）

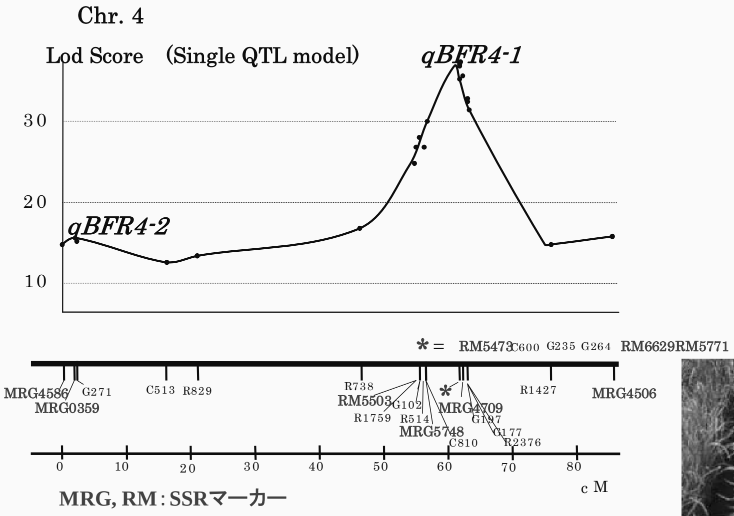
○ Related studies

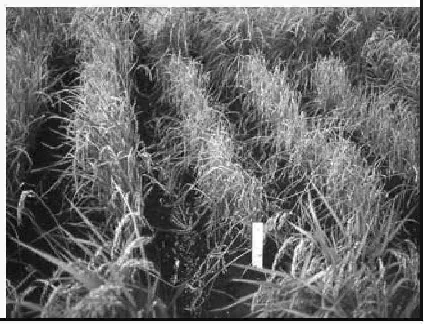
- Processing suitability：fast hardening lines
- Drought resistance：detection of QTLs
- Utilization as genetic resources：
  Introgression of blast resistant genes to paddy rice,
  Core collection from local upland rice varieties

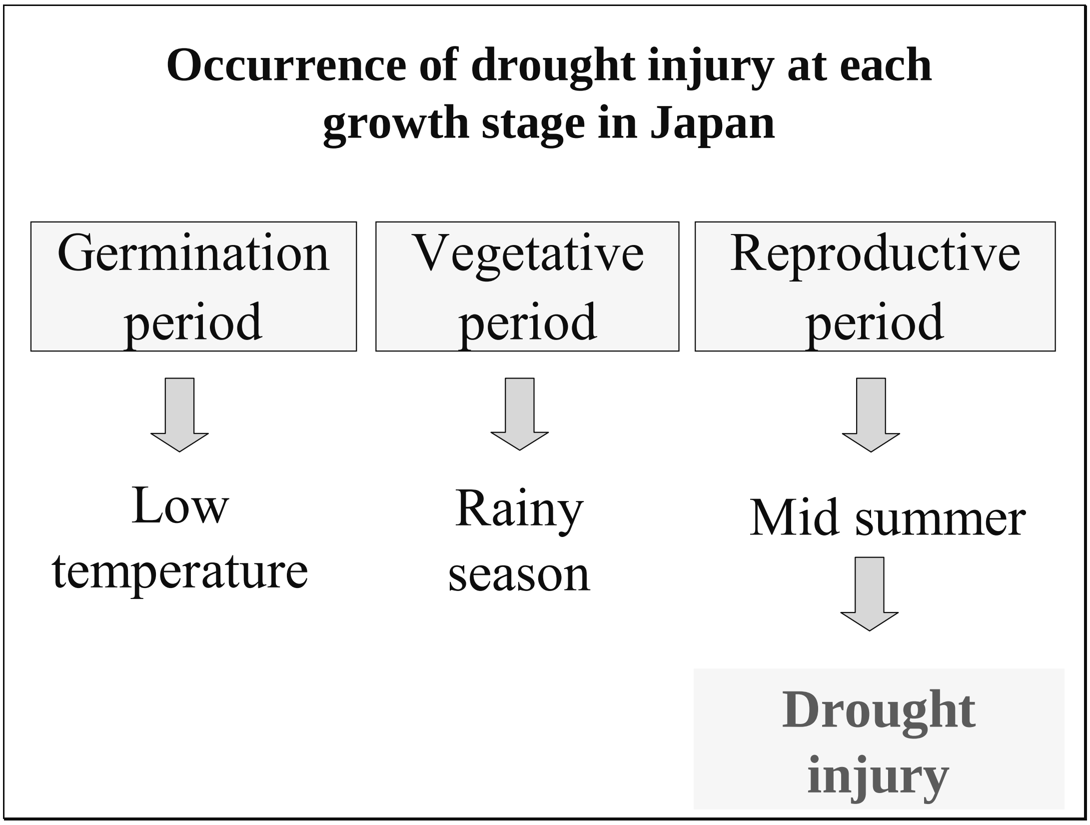
Processing suitability

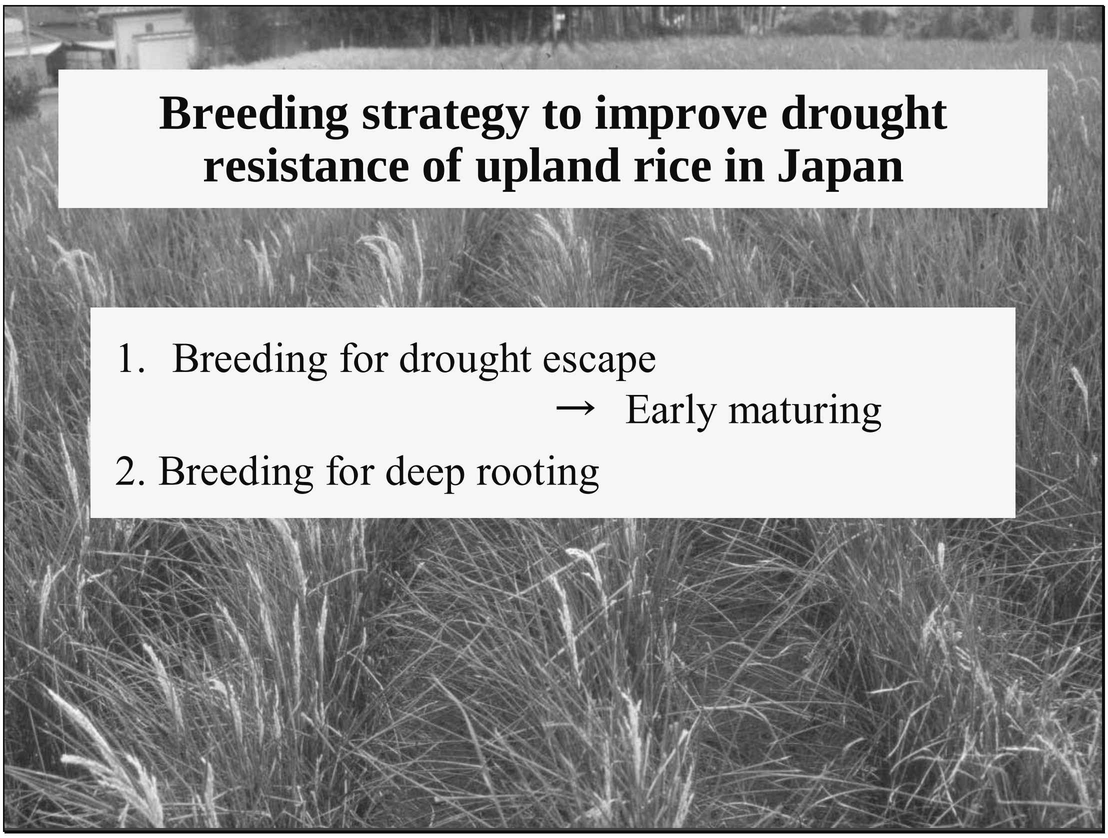


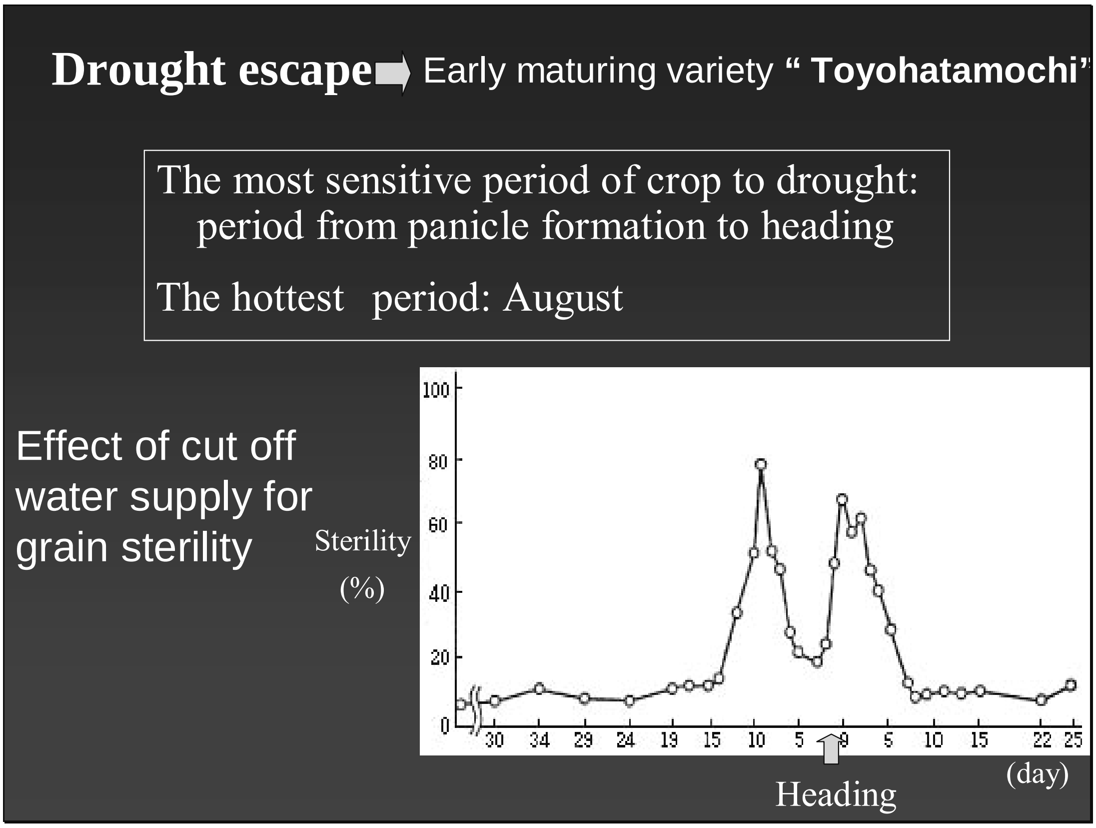
New QTLs of blast field resistance from upland rice "Kahei"






Occurrence of drought injury at each growth stage in Japan
Germination period
Vegetative period
Reproductive period
Low temperature
Rainy season
Mid summer
Drought injury


Breeding strategy to improve drought resistance of upland rice in Japan
1. Breeding for drought escape
→ Early maturing
2. Breeding for deep rooting


Drought escape
Early maturing variety " Toyohatamochi"
The most sensitive period of crop to drought: period from panicle formation to heading
The hottest period: August
Effect of cut off water supply for grain sterility
Sterility (%)
100
80
60
40
20
0
30 34 29 24 19 15 10 5 9 5 10 15 22 25
(day)
Heading


1994.Aug.
Toyohatamochi: early maturing
Tsukubahatamochi: medium maturing

Breeding of deep rooting in Ibaraki Agriculture Center

1. Enlargement of genetic resource;

   Varietal screening of foreign varieties with deep rooting by using "*Trench method*"

2. Establishment of selection method

   Utilization of evaluation system of progeny lines by using "*Specific nursery bed* " (green house method)

Varietal screening of deep rooting by the trench method

Observed characters

Root volume, Thickness

Depth of root tip

Varietal screening of rooting under trench method

Detected foreign varieties with deep rooting

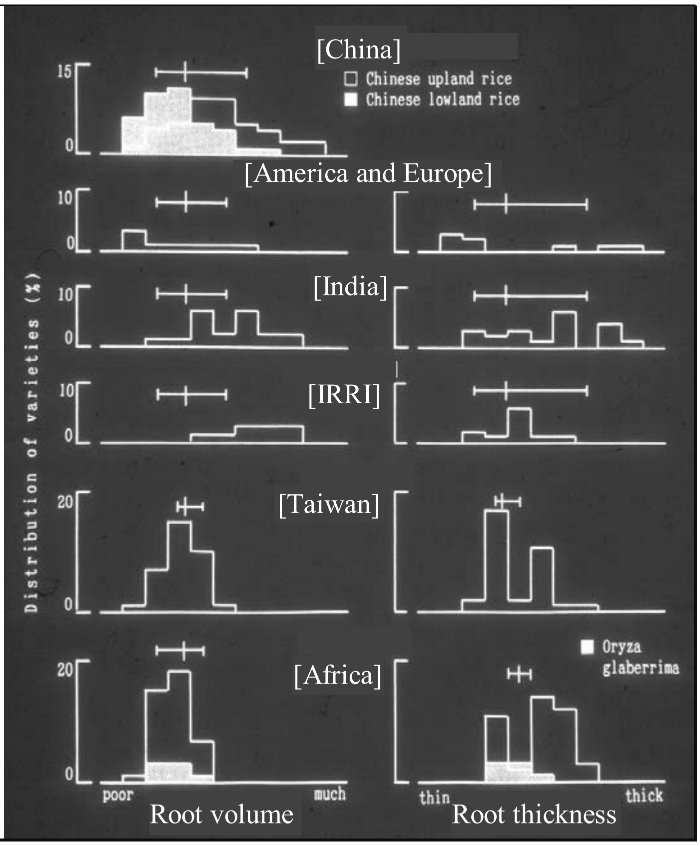
JC81, B5416（India）

IRAT10, 109（Liberia）

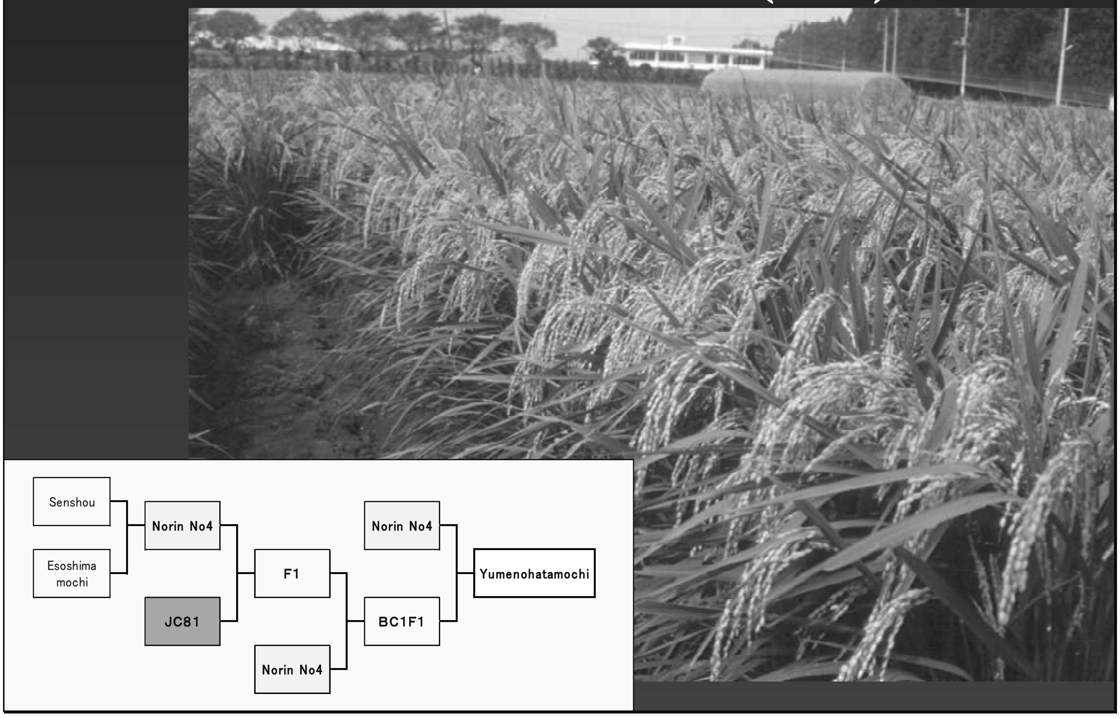
Nam Sugai（China）

IR3646(IRRI), etc.

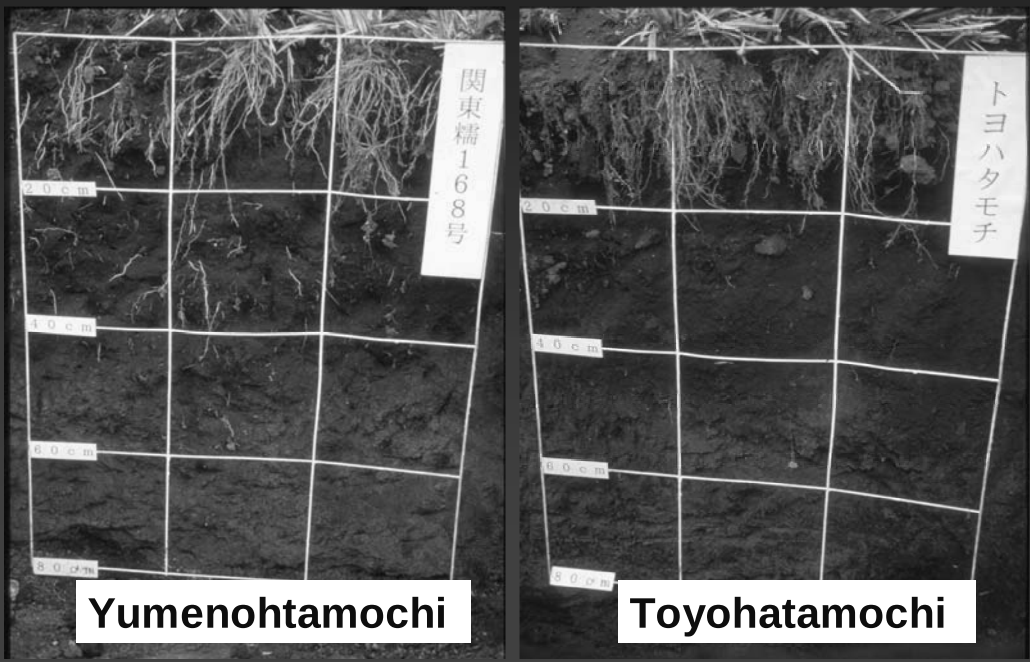
(Ibaraki Agri. Center 1979 to 1983)



Establishment of deep rooting variety “Yumenohatamochi” (1996)

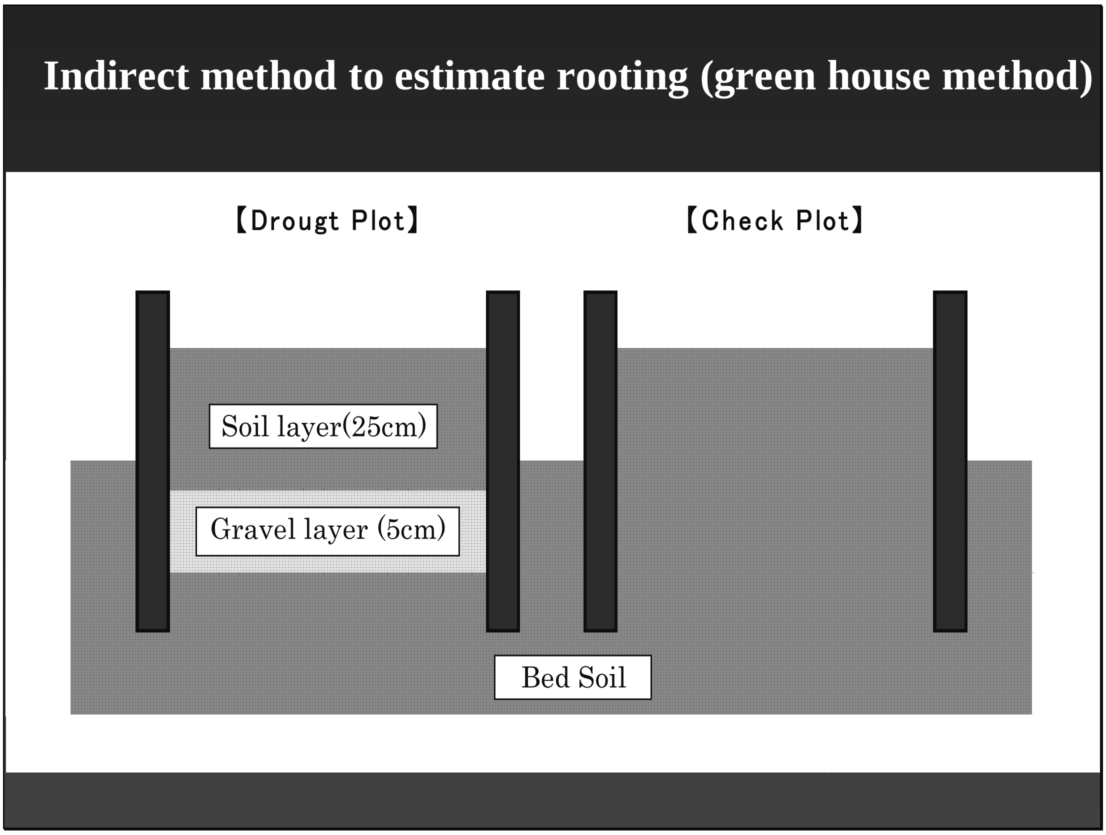


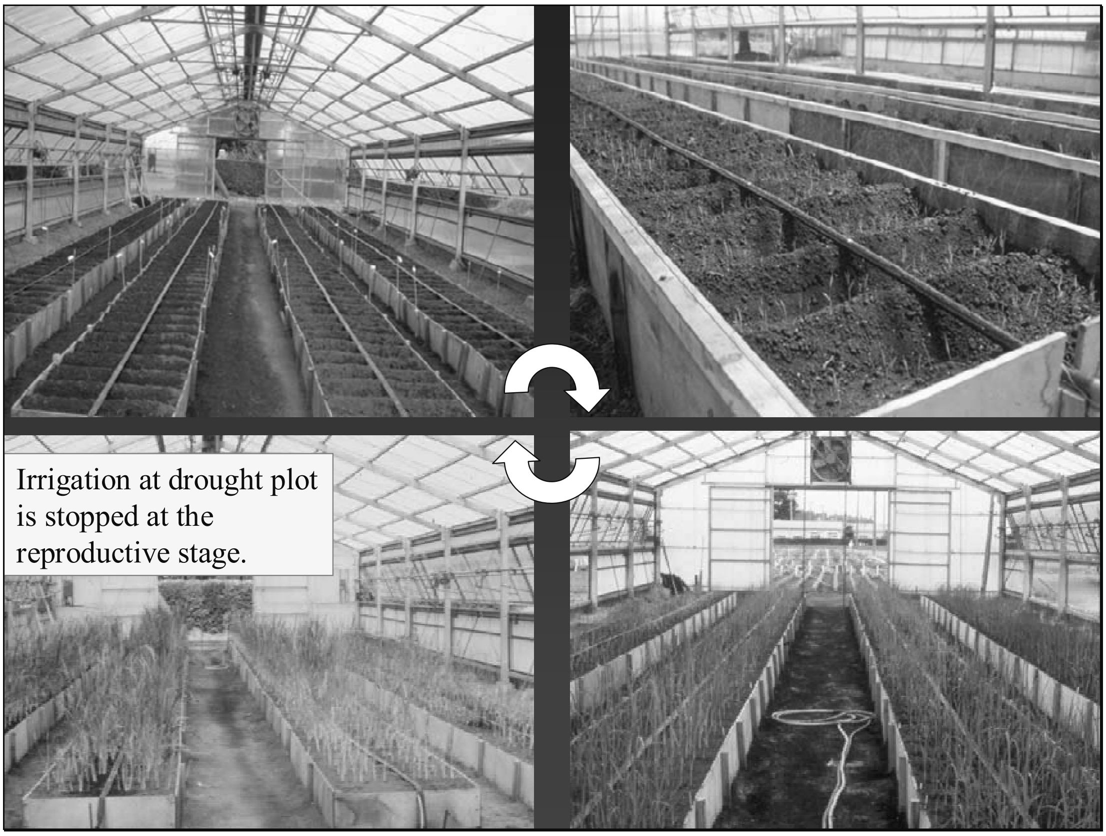
Deep rooting variety "Yumenohatamochi"

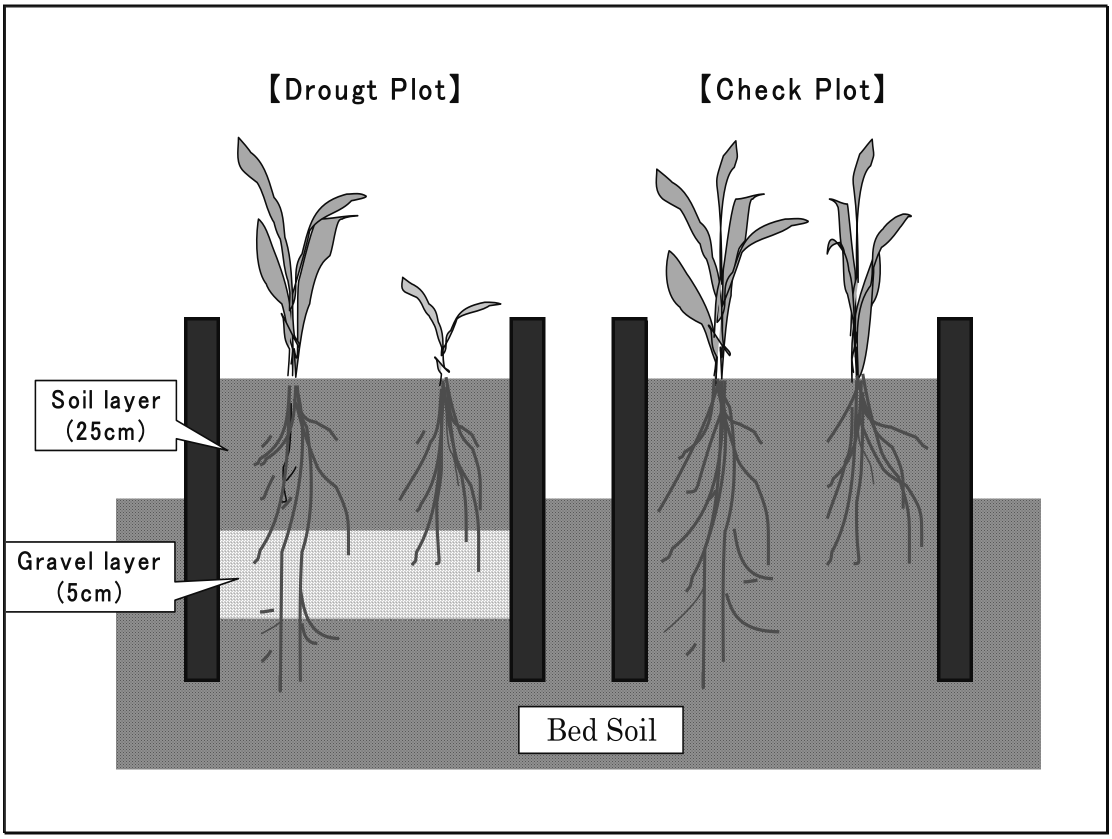


Yield of "Yumenohatamochi" in drought year

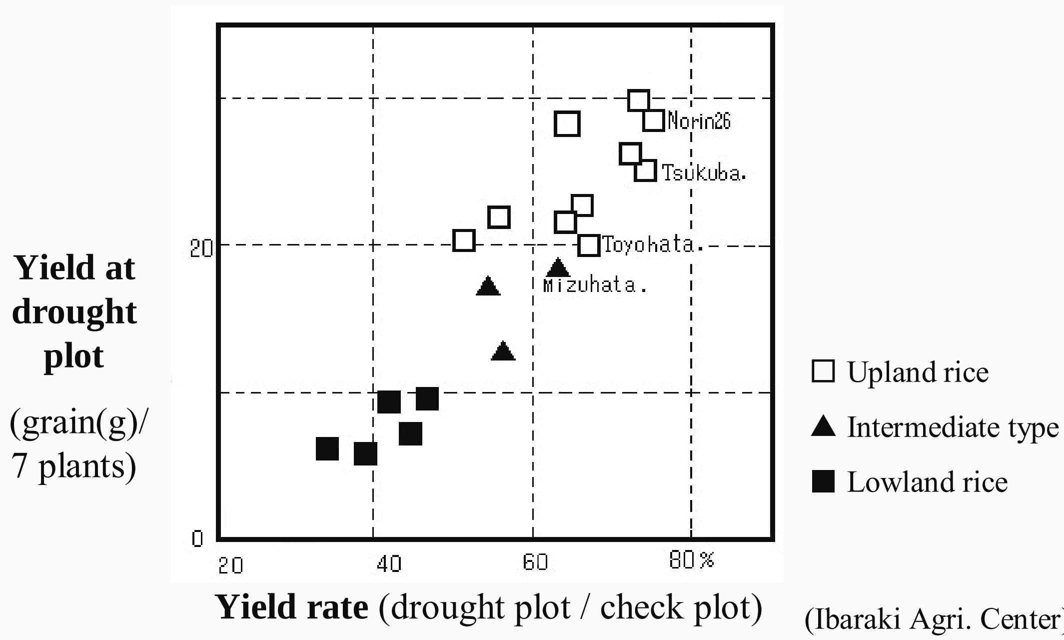
Varieties	Average yield from 1989 to 1995		Average yield in drought years 1992 and 1994	
	Yield (t/ha)	Rate (%)	Yield (t/ha)	Rate (%)
Yumenohatamochi	3.42	111	1.64	148
Tsukubahatamochi	3.09	100	1.11	100
Norinmochi26	2.74	89	0.58	52


Indirect method to estimate rooting (green house method)
【Drougt Plot】
【Check Plot】
Soil layer(25cm)
Gravel layer (5cm)
Bed Soil


Irrigation at drought plot is stopped at the reproductive stage.



Distribution of grain yield of rice varieties in specific nursery bed method



(Ibaraki Agri. Center)

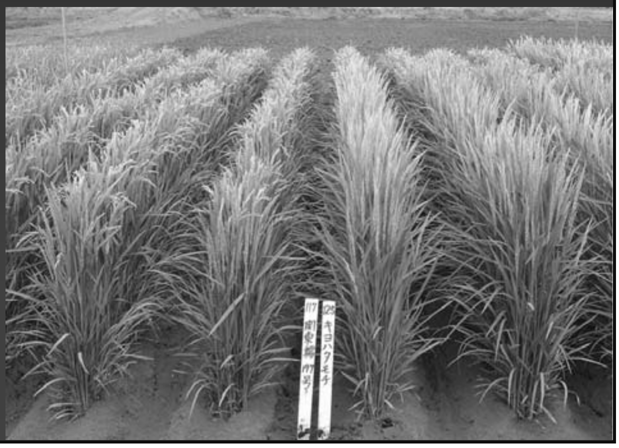
Combination of drought escape and deep rooting

↓

New variety “Hitachihatamochi” (2005)

Early maturing, stably high yielding variety “Hitachihatamochi” (left)

(right: Kiyohatamochi)



Drought resistance of early maturing and high yielding variety “Hitachihatamochi”

Hitachihatamochi Toyohatamochi Kiyohatamochi

Characteristics of "Hitachihatamochi"

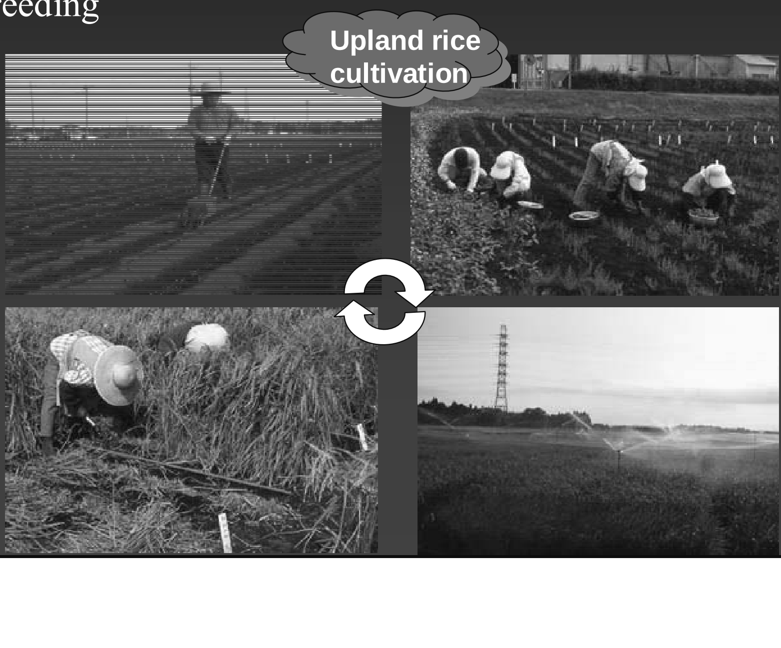
Variety name	Heading date	Culm length (cm)	Pancle length (cm)	Panicle number (/m^2)	Whole weight (t/ha)	Brown rice weight (t/ha)	Yield ratio (%)
Hitachihatamochi	7.29	69	19.3	297	9.3	3.6	120
Kiyohatamochi	8. 2	73	20.2	289	9.6	3.1	100
Toyohatamochi	7.28	71	19.7	265	8.2	2.7	85

(1999-2004)

Acknowledgement

Agriculture, Forestry and Fisheries Research Council of Ministry of Agriculture, Forestry and Fisheries (MAFF) for financial aid,

Ibaraki local government for assistance for promotion of breeding



質疑応答
Question and Answer Session

わが国のこれまで77年にわたる陸稲育種研究の成果
Achievements of Upland Rice Breeding in Japan in the Past 77 Years

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National Institute of Crop Science,
National Agriculture and Food Research Organization (NARO), Japan

司会：　杉本　充邦　　Chair person: Mitsukuni Sugimoto
名古屋大学農学国際教育協力研究センター　准教授
Associate Professor, ICCAE, Nagoya University

杉本（司会）：

Thank you very much for your presentation.　Mr. Ishii has briefly explained Japanese government's experience of Japanese government for seventy-seven years over upland rice varieties, and drought resistance, as well as deep-root varieties.
Are there any questions?

二口：　先ほど若月さんからもNERICAの問題に関連して質問させていただいたのですが、4トンほど取るためには、窒素などの肥料を入れないといけないだろうということでした。実は私は「アフリカ人造りプロジェクト」にまだ関係していますので参考までに伺いたいのですが、例えば nitrogen response という言い方をしますが、paddy の場合は還元層というのがあり、有機物が非常に緩行的にゆるくリリースされると聞いています。しかも多分硫安などが多いものですから、陸稲の場合とか NERICA の場合だとウレア(尿素)とかそういうものを使うことになるのかというのが一点と、その施肥の方法が、還元層があるためにリリースされるのが割にゆっくりだと我々作物屋は聞いていたので、そういう点からすると、NERICA などに対する upland の実験をなさってきた経験からNERICAのようなuplandの場合の肥料のやり方、もしくはnitrogen response、かつてIR-8の場合、非常に問題になったわけですが、栽植密度やrainy seasonとの関係もありますし、簡単にいいますと、窒素反応の lowland rice とupland riceにおける違いについてひとつお話しを伺いたいと思います。

石井：　私どもでは、施肥量は窒素レベルでだいたい 12 キログらい与えていまして、それがごく一般的な栽培方法だと思います。窒素を与えれば与えるほど取れますが、ただ、全重が重くなると今度干ばつに弱くなるわけですし、蒸散量も増えることになりますので、あまりやりすぎるのは良くないと思います。10キログらいが最適な量ということで落ち着いているのだと思います。ただ、品種によってかなり窒素反応の差があります。

日本の在来品種と比べてみましても、すぐに茎数、穂数が増えて反応するものとなかなか反応しないものもあります。あまり穂数が増えない場合はどんどんやればいいのでしょうが、すぐに増える品種だとなかなかやれないというところで、当時の施肥試験などもいろいろやられているわけですが、品種ごとにこの品種にはこういうふうにやる、という結果になっていまして、NERICA の場合もそれぞれに応じて最適な施肥量を見つけていかなくてはならないだろうと思っております。

二口： 施肥には普通はやはりウレアを使うのですか？

石井： 私どもでは硫安で普通の追肥です。

二口： 私達の場合は硫安の割合が優勢なのですけれども、upland の場合は農家もウレアを畑作物的な考えかたで使うのですか？　日本の場合についてはどうでしょうか。

石井： 日本の場合は水稲に準じたような形で与えています。

二口： はい、どうもありがとうございました。

神代： JIRCAS の神代ですが、耐乾性の品種についておたずねします。深根性ということで「ゆめのはたもち」とか、「ひたちはたもち」といった2つの乾燥耐性のものについて述べておられたのですが、これはいわゆる乾燥耐性を構成している形質、例えば、蒸散量、気孔開度というのは深根性と何かリンクして関わっているのでしょうか。

石井： ちょっとそこまでは見ていないのですが、「ゆめのはたもち」の場合は葉の温度がやや低いというような話は聞いたことがあります、蒸散が激しいですから。「ひたちはたもち」の場合はちょっとそこまで確認しておりません。ただおそらく蒸散は激しく出ているような気がします。

神代： 私たちも乾燥耐性のことをやっていますが非常に複雑な形質で何をメルクマールに選抜していいのか、ちょっといろいろ難しいところがあります。例えば深根性のものは乾燥耐性の何％ぐらいを説明できると見積もっていますか？

石井： それは、何％と答えるのは難しいですね。ただ、今日本で育種する場合にいろいろ幼苗期で検定したりしていろいろやってきたわけですが、結局は成熟期の根の重さを量るのが一番正しいだろうということとでやってまいりました。深根性の根量というのが一番大きな形質になると思います。それ以外の形質はちょっとわかりません。深根性のものが葉面の温度が低いという報告を聞いたこともありますが、葉っぱの温度を

測るというのも、葉の温度は一日の間でもかなり変わるので、実際は根を測るのが一番早いと思います。

若月：　近畿大学の若月です。アフリカと日本では土の固さがかなり違いますね。日本だと山中式の硬度計で 20 でかなり高いですけれど、むこうは 30 ぐらい軽く出ますよね。強さ、硬さ、深さ、そして先ほどの施肥でも相違が出ましたが、それを突破できるような性質、その深根性プラス何か強さみたいな、確か坂上さんが何かされていたようですが、そのあたりは何かやっておられたことありますでしょうか？

石井：　それは私はやっていませんが、昔は表土の深さということで、何センチぐらいまで耕すのが陸稲にとって一番よいかという試験をしたと読んだことがあります。そうしますと、要は深く耕せば耕すほど根が下まで入るので良いというような昭和 15～16 年の試験結果ですが、そういうのはあります。ただ、根の入る強さ、貫通力については日本というか、私たちの研究室では実験をやったことがないです。ただひたすら掘るのみです。

杉本（司会）：

他に質問はありますか？　なければ終わらせていただきます。

ありがとうございました。

Profile

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1989年京都大学大学院農学研究科修士課程修了。愛知県農業総合試験場で野菜の栽培生理研究に従事した後、1991年から中国農業試験場で水稲の育種研究に従事。1999年から農水省農産園芸局および農林水産技術会議事務局で、土地利用型農業の経営展望の立案業務や水田作を中心とした研究プロジェクトの調査・企画業務に従事。2001年から農業生物資源研究所で遺伝資源の多様性保全の研究に従事した後、2003年から茨城県生物工学研究所（農水省陸稲育種指定試験地）で陸稲育種に従事。2006年4月から農研機構作物研究所稲マーカー育種研究チームで上席研究員として再び水稲育種に従事し、現在に至る。専門分野は、育種学、統計遺伝学。

Academic career

Mr. Takuro Ishii graduated from Graduate School of Agriculture, Kyoto University, in 1989.

Professional career

After the graduation, Mr. Takuro Ishii worked for the Aichi Agricultural Experiment Station in Japan for two years on vegetable physiology.　From 1991 to 1999, Mr. Ishii served as a rice breeder for the Chugoku National Agricultural Experiment Station.　For the following two years, he worked as a research coordinator for the Bureau of Crop Production and Agriculture, Forestry and Fisheries Research Council of the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF).　In 2001, he moved to the National Institute of Agrobiological Sciences (NIAS) to study genetic diversity conservation.　In 2003, he moved to the Ibaraki Plant Biotechnology Institute and served as an upland rice breeder.　In April 2006, Mr. Ishii joined the National Institute of Crop Science as a chief researcher and is currently working on improvement of rice varieties by using the method of marker-assisted selection.