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Integration of breeding and physiology for developing new rice varieties with higher yield potential

S. Peng, F. Xie, T. Lafarge, P. Virk, and A. Dobermann

International Rice Research Institute

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Outline

- Current status of rice yield potential
- IRRI's new research focus on rice yield potential
- Scientific issues and collaborating areas with NSFC

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Definition of yield potential

Yield potential is defined as the yield of a culitvar when grown in environments to which it is adapted; with nutrients and water non-limiting; and with pests, diseases, weeds, lodging, and other stresses effectively controlled.

Evans, 1993

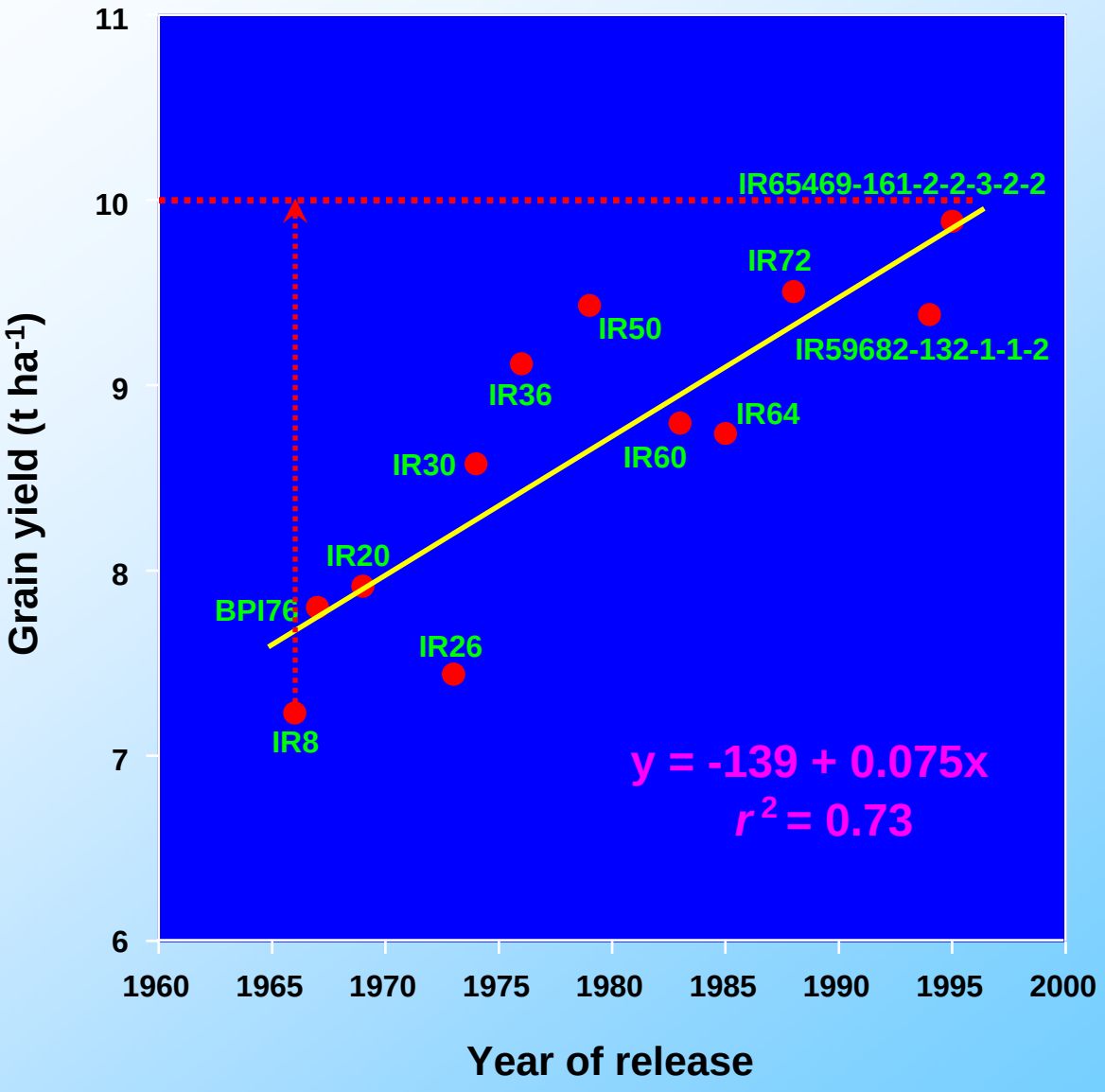
It is used mainly for measured comparison of cultivars.

Evans and Fischer, 1999

Mistakes in determining yield potential

- Cultivars do not have agronomic fitness to local environment.
- Nutrient, water, and other crop management are not optimal.
- Yield loss occurs due to biotic and abiotic stresses.
- Focus only on percent increase but not absolute yield level.
- There is no information on plant traits that cause increase in yield potential.
- Confused with yield increase due to maintenance breeding (new vs. old cultivars).

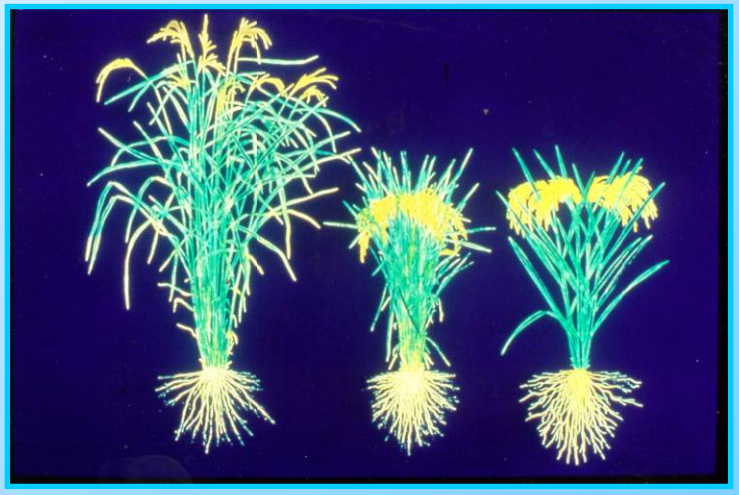
Yield trend of cultivars and lines developed since 1966

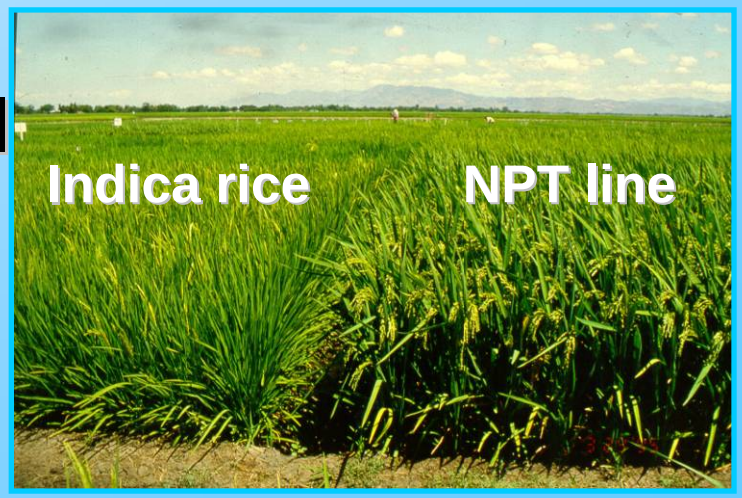


(Peng et al. 2000; Crop Sci 40:307)

Development of new plant type at IRRI

1989	Identification of donors
1990 DS	Hybridization
1990 WS	F_1 were grown
1991 DS	F_2 were grown
1991 WS	Pedigree nursery
1994 DS	First agronomic trial





Development of “super” rice in China

Stimulated by IRRI’s NPT work, China established a nationwide mega project on the development of “super” rice in 1996

Development of “super” hybrid rice

The “super” hybrid rice breeding program was initiated in 1998 by Prof. Longping Yuan.

The strategy was to combine an ideotype approach with utilization of intersubspecific heterosis.

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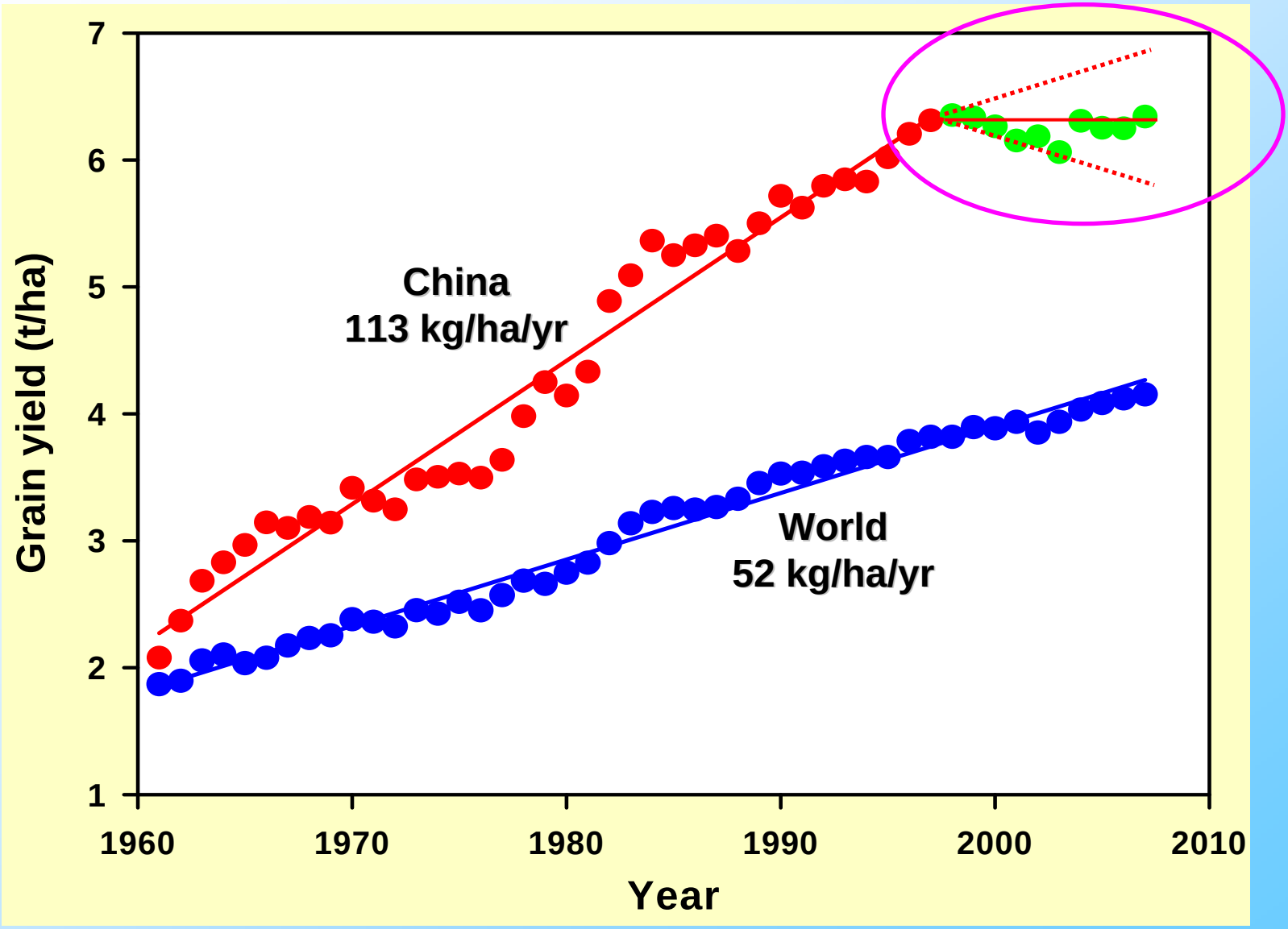
Does “super” hybrid rice increase yield potential?

Trend of rice yield from 1961 to 2007



(FAO, 2008)

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Yield would increase if no “super” rice

- “Super” rice does not have yield advantage in rice growing areas with low-moderate yield levels.
- Yield reduction occurs in “super” rice when inputs are not high.
- “Super” rice yields poorly without intensive crop management.
- “Super” rice does not have multiple and durable resistance to diseases and insects.
- Other breeding program has suffered because of the focus on “super” rice breeding.

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Yield would decrease if no “super” rice

- Many farmers adapt labour-saving technologies which reduce rice yield.
- There has been an increase in disease and insect pressures in recent years.
- Farmers apply excessive N which causes yield reduction.
- Frequency of drought increases due to global climate changes.
- Farmers have no access to good technologies due to poor function of extension system.

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"Super" hybrid rice in Kyoto, Japan, 2004

Variety	Yield (t/ha)	TDW (t/ha)	Rad_I (MJ/m^2)	LAD (day)	RUE (g/MJ)
Nipponbare	7.7 b	14.7 c	945 b	287 b	1.56 a
Takanari	11.4 ab	15.7 b	953 b	293 b	1.64 a
Liangyoupeijiu	11.8 a	16.4 a	1077 a	354 a	1.52 a

"Liangyoupeijiu exhibited higher yield than any previously recorded yield under the environment at Kyoto, Japan"

(Katsura et al, FCR, 2007)

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"Super" hybrid rice in Yunan, China, 2003

Variety	Yield (t/ha)	TDW (t/ha)	Rad_I (MJ/m^2)	Rad_I (%)	RUE (g/MJ)
Nipponbare	8.6 c	13.2 c	960 d	57 d	1.37 b
Shanguichao	13.0 b	19.7 b	1430 b	66 b	1.37 b
Takanari	13.6 b	19.5 b	1330 c	63 c	1.46 a
Liangyoupeijiu	15.4 a	23.0 a	1580 a	70 a	1.45 a

N rate = 140 kg/ha

(Katsura et al, FCR, 2008)

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16.5 t/ha from Liangyoupeijiu, Yunan, 2003

24.4	t/ha biomass	157	days duration
0.58	harvest index	105	kg grain/ha/day
324	panicle/m^2	19.2	g/m^2/day CGR
66,800	spikelets/m^2	7.6	LAI at heading
206	spikelets/panicle	1.54	g/MJ RUE
85	grain filling %	311	kg/ha N uptake
24.2	mg grain weight	53	kg grain/kg N uptake

N rate = 280 kg/ha

(Katsura et al, FCR, 2008)

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Grain yield (t/ha), Hunan, 2007

Variety	Yong'an	Guidong
Liangyoupeijiu	9.41 a	11.52 a
Liangyou293	9.16 a	11.38 a
Ilyou838	8.14 c	10.21 b
Shanyou63	8.40 bc	9.67 c
Yangdao6	8.74 b	10.40 b
Huanghuazhan	8.62 b	10.29 b

N1 = 135 kg/ha at YA and 150 at GD; N2 = 225 at YA and 250 at GD

“Super” hybrid rice grown in Hunan

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Revival NPT breeding - strategies

- Follow Chinese experience in donor selection and utilization of heterosis.
- Emphasize more on the top three leaves and the position of panicle within canopy.
- Extremes in plant traits (e.g. panicle size and tillering) should be avoided. Early vigor should be maintained.
- Selection should be done at moderate N level.
- Use multiple traits instead of single trait. Consider compensation among various traits.

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Proposed plant traits for improvement

- Early vigor, moderate tillering capacity, and thin leaves at vegetative stages.
- Taller plants, lower panicle height, thicker and stronger stems.
- Erect, thick, dark green, and v-shaped leaves, high LAI, and delayed leaf senescence in late stages.
- Large and compact panicles, heavy grain weight, long grain filling duration.

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New mode of action

- Integrate plant physiology with breeding.
- Impose selection pressure in early generations.
- Develop measurable indicators to use in selection.
- Link with crop management.
- Expand and standardize multi-location yield trials.

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New opportunities at IRRI

- Cereal Systems Initiative For South Asia (CSISA)
- Green super rice project (GSR)
- C4 rice project
- Japan-World Bank project
- Hybrid Rice Research & Development Consortium (HRDC)

Replicated yield trial, Dr. Virk's field, 2008 dry season

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Selected 52 from 200 NPTII and indica lines

- Disease and insect damage
- Lodging
- Uniformity
- Plant height (around 110 cm)
- Top three leaves (erect, length, width, stay green)
- Panicle morphology (compact, height, grain wt)

Based on yield

Entry	Yield
IR79505-51-2-2-2	7684
IR78581-12-3-2-2	7679
IR80658-67-2-1-2	7464
IR81330-29-3-1-2	7287
IR77032-47-2-3-3	7081
IR77498-127-3-2-3-2	7019
IR81330-19-2-1-3	7019
IR73885-1-4-3-2-1-6	7012
IR71700-247-1-1-2	6974
IR80404-28-2-3-2	6968
IR73012-15-2-2-1	6965
IR74646-96-2-3-3	6937
IR75298-59-3-1-3	6900
IR80397-87-1-2-3	6879
IR79203-132-1-2-2	6876
IR78585-98-2-2-1	6872
IR77700-84-2-2-2	6866

Based on plant traits

Entry	TDW	Filling%
IR77032-47-2-3-3	2441	83
IR77533-29-2-2-2	1867	89
IR77700-84-2-2-2	1848	90
IR78585-98-2-2-1	2021	84
IR80655-33-3-2-1	1810	81
IR79218-43-2-1-2	1849	87
IR81852-120-2-1-3	1934	88
IR79233-28-2-1-2	1770	75
IR72892-77-2-2-2	1647	90
IR79201-101-1-2-2	1990	83
IR81336-39-3-3-3	1924	73
IR80894-18-2-2-3	2123	82
IR75287-19-3-3-3	1716	87
IR79218-69-2-2-2	1801	81
IR80864-57-1-5-3	1971	88
IR79525-20-2-2-2	1815	85
IR79515-25-1-6-1	1749	83

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Proof of concept

Lines with ideal plant traits and with potential to express high yield under optimal crop management condition may be discarded in the breeding nursery if the selection is based on yield per se.

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Scientific issues and collaborating areas

- How much room is left in plant type improvement for achieving greater yield potential?
- How much gain in yield potential is possible by delayed leaf senescence and extended grain filling duration?
- Which one is limiting more, source or sink? How to quantify sink strength?
- Can improvement in RUE through high photosynthetic rate contribute to high yield potential?
- What are the real impact of advanced molecular technology on breeding varieties with high yield potential?


Thank you