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AGRICULTURE • INNOVATION • LIFE

SEARCA PROFESSORIAL CHAIR PUBLIC LECTURE

PLANT ADAPTATION TO ENVIRONMENTAL STRESSES: A KEY CHALLENGE TO RICE FOOD SECURITY

Professor Dr Mohd Razi Ismail

Food security

WHY MATTERS TO **RICE FOOD SECURITY**

When all people , at all times, have physical , social and nutritious food that meets their dietary needs and healthy life

FAO 2010

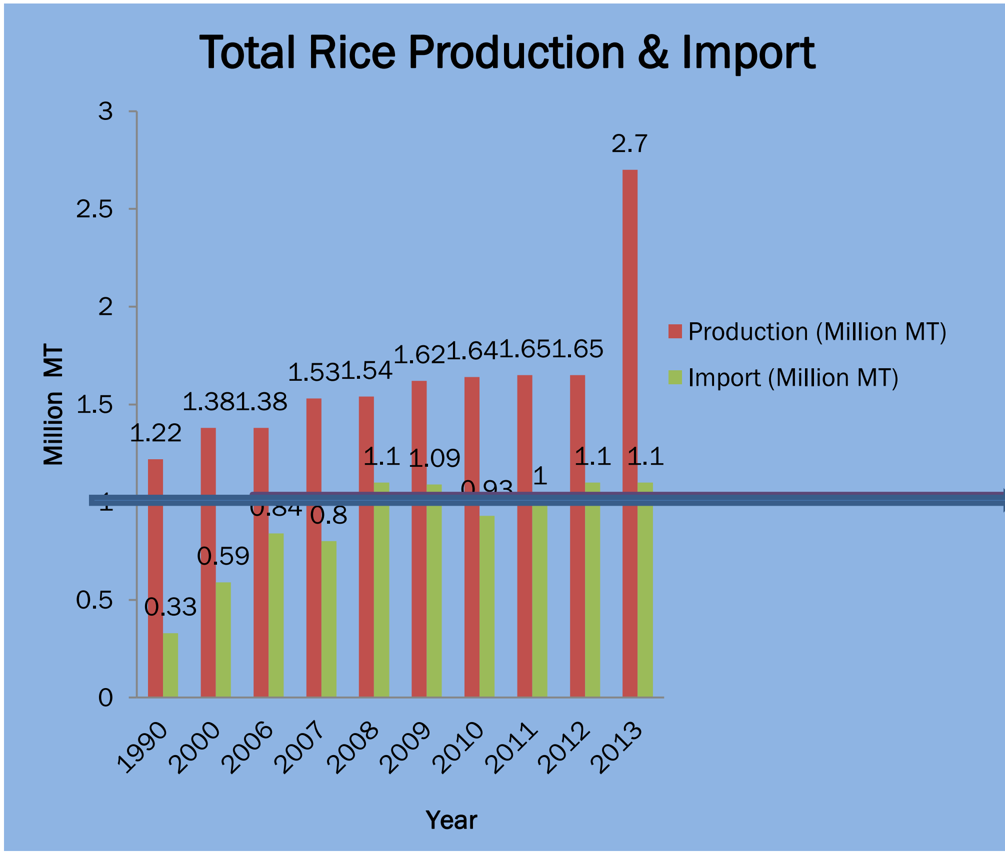
At present – Malaysian are food secured

National food security defined by some to mean self –sufficiency

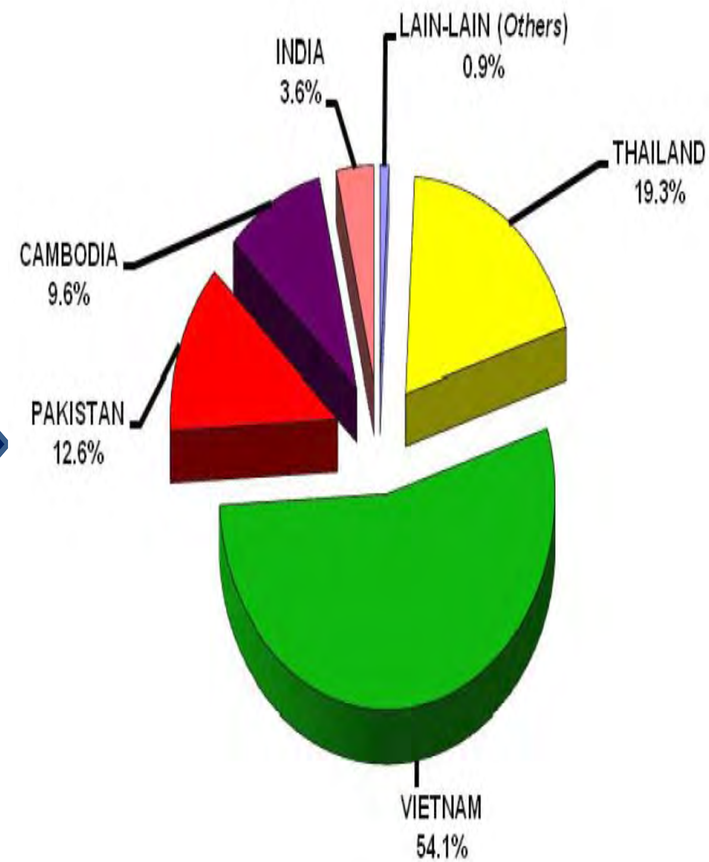
Andersen, 2009

National food sovereignty – measure extent to which the country had the means to make available to its people the food needed or demanded

Rice food security - Malaysia



73.5% Production



26.5% IMPORT

Sustained reliance on rice import ?

Scenario on importing countries, Vietnam and Thailand

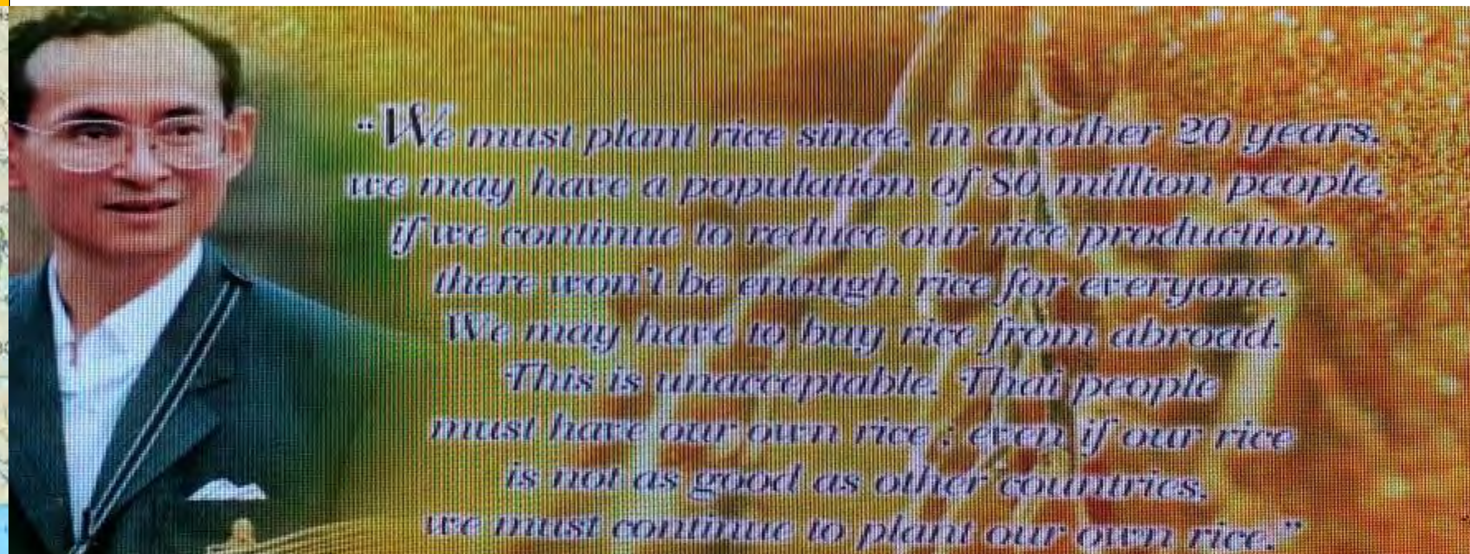
Future of Vietnam's rice production threatened by climate change
New IFAD project to aid Mekong Delta small farmers as rice crops are devastated by rising temperatures, sea levels ,
Source : International Fund For Agricultural Development Report 22 May 2014

The International Panel of Climate Change (IPCC) list Vietnam as one of the most affected countries by climate change

a decrease in agriculture land production area, averagely there is a loss between **50.000 to 70.000** hectare of agriculture land for industrial purposes, equivalent to **400.000 to 500.000 tons** loss of rice per year.
Source : **Revisiting Vietnam Rice Farming: Moving Towards Industrialization (2012)**

Sustained reliance on rice import ?

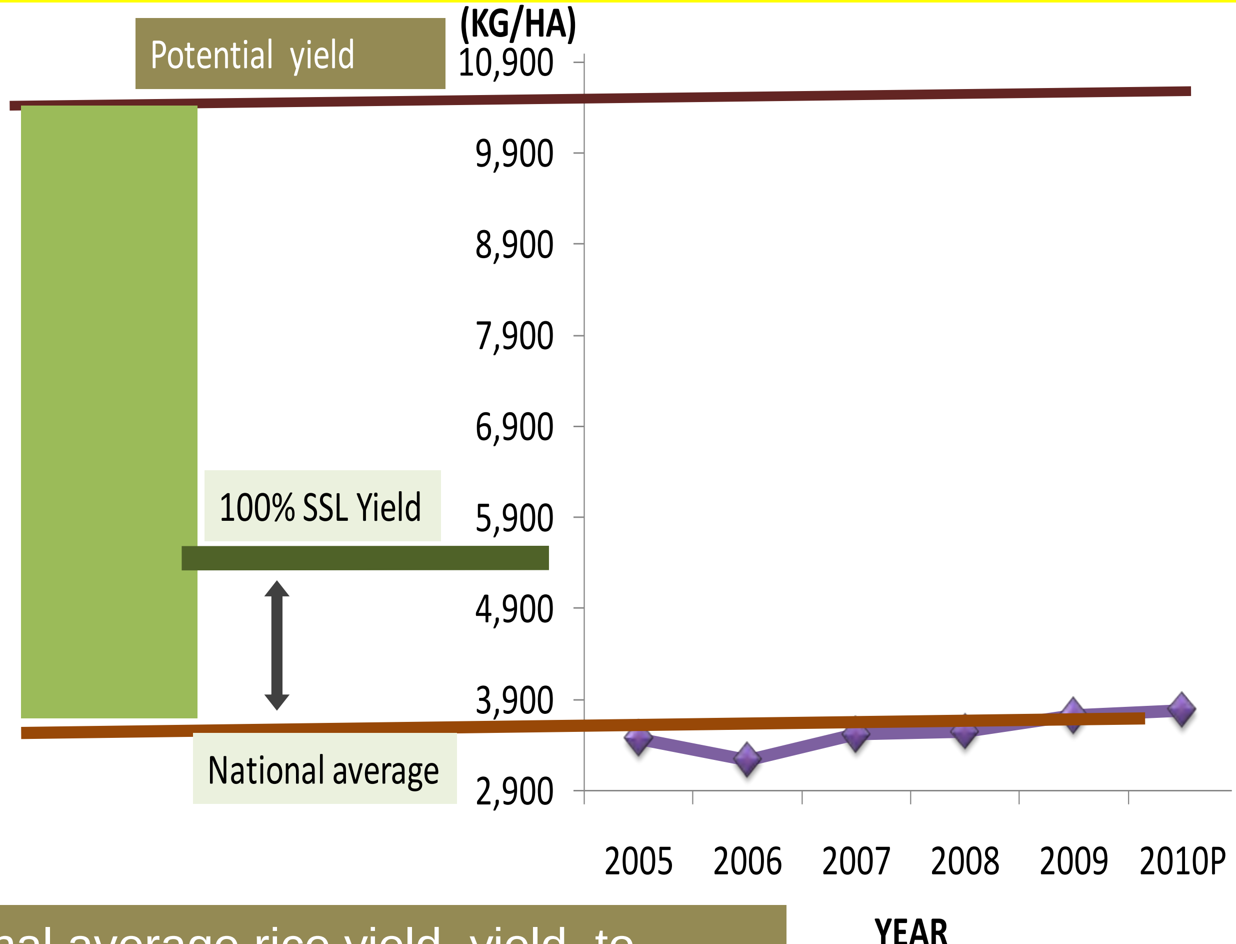
Concern of increase population and rice availability

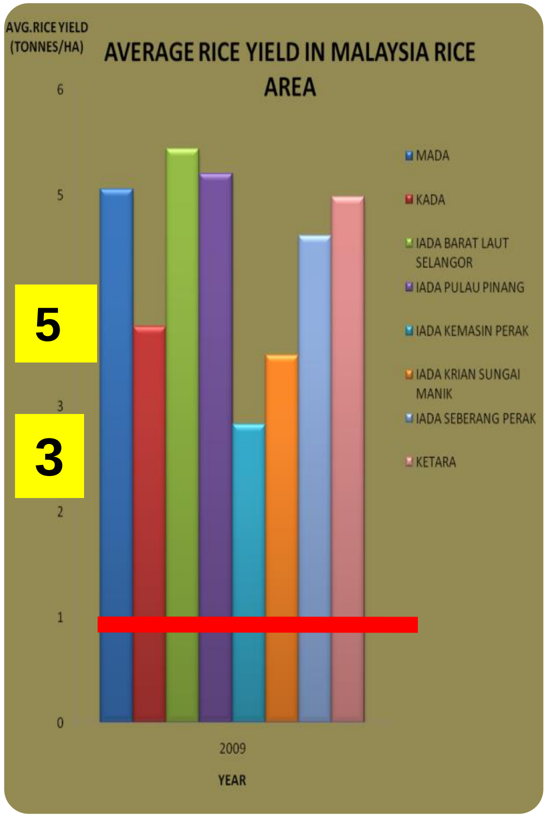


1n 2015 : 68 Million , 12 Million less than predicted

1. Internal policy –satisfying export market – safety and quality organic rice (quality rice)
2 Labor shortages
3 Climate change ***: yield of Thai rice expected to decline about 18% in the 2020s***
Mekong Wetlands Biodiversity Conservation and Sustainable Use Programme (MWBP) (2005) **the risk of losing paddy fields acreages.**

National Level : Boosting rice production is the main target- reducing yield gap

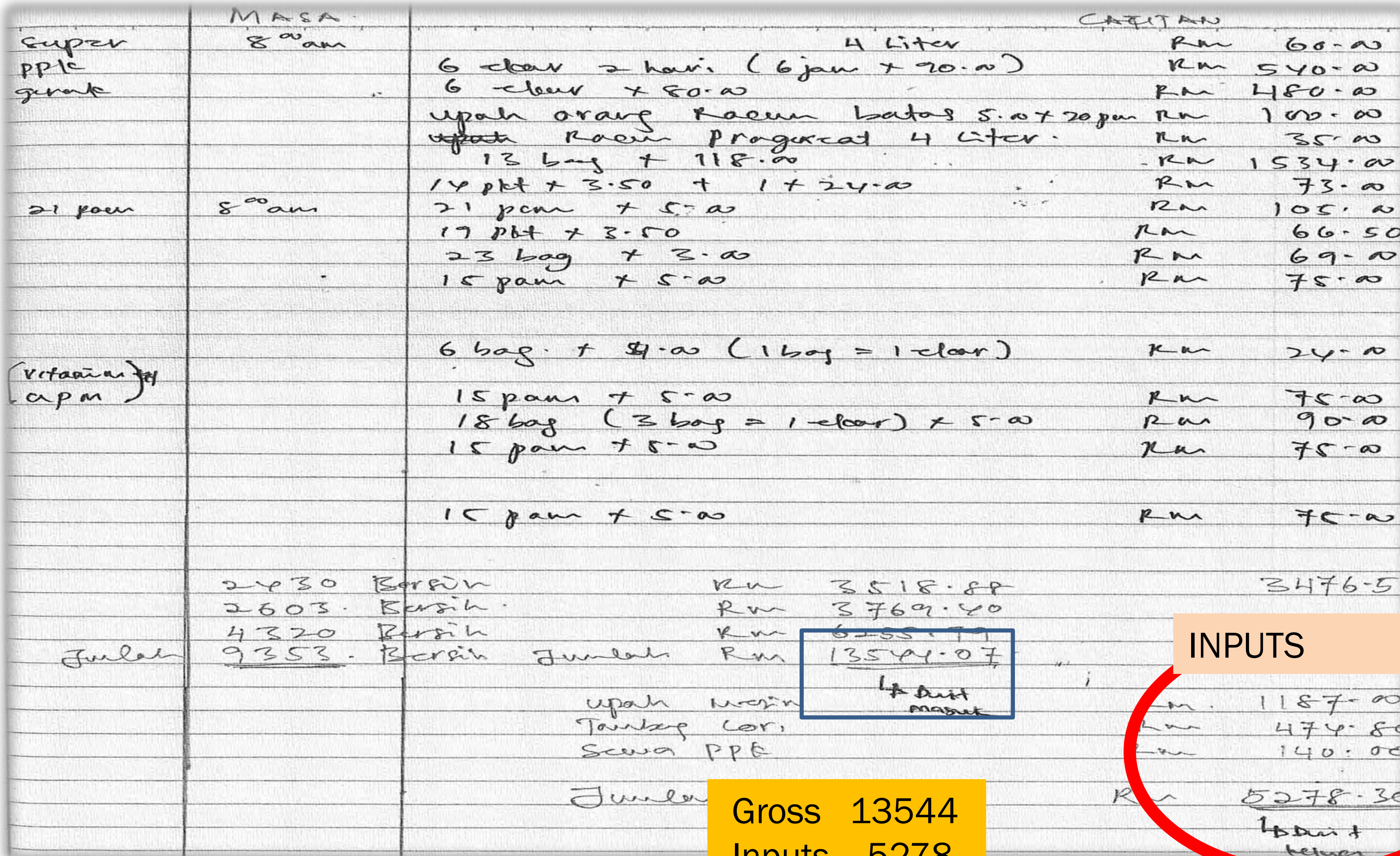




National average rice yield, yield to reach 100% SSL and potential yield.

2013: 73.5% Self sufficient (Rosnani, 2015)

Maximizing farmer's income (monthly take home pay) from NKEA ETP PROGRAM



	MASA		CATATAN	
super	8.00 am	4 Liter	RM	60.00
PPK		6 ekar 2 hari (6 jam + 90.00)	RM	540.00
gerak		6 ekar + 80.00	RM	480.00
		upah orang Racun batas 5.0 + 20 pm	RM	100.00
		upah Racun Pragurcat 4 Liter.	RM	35.00
		13 bag + 118.00	RM	1534.00
		14 pkt + 3.50 + 1 + 24.00	RM	73.00
21 peen	8.00 am	21 pam + 5.00	RM	105.00
		19 pkt + 3.50	RM	66.50
		23 bag + 3.00	RM	69.00
		15 pam + 5.00	RM	75.00
		6 bag + 4.00 (1 bag = 1 ekar)	RM	24.00
(vitamin apm)		15 pam + 5.00	RM	75.00
		18 bag (3 bag = 1 ekar) + 5.00	RM	90.00
		15 pam + 5.00	RM	75.00
		15 pam + 5.00	RM	75.00
	2430 Bersih		RM 3518.88	3476.50
	2603. Bersih.		RM 3769.40	
	4320 Bersih		RM [illegible]	
Jumlah	9353. Bersih	Jumlah	RM 13544.07 Duit masuk	
		upah mesin	RM	1187.00
		Tumbang Lori	RM	474.80
		Sewa PPE	RM	140.00
		Jumlah	RM	5278.30 Duit keluar

INPUTS

Gross 13544
Inputs 5278

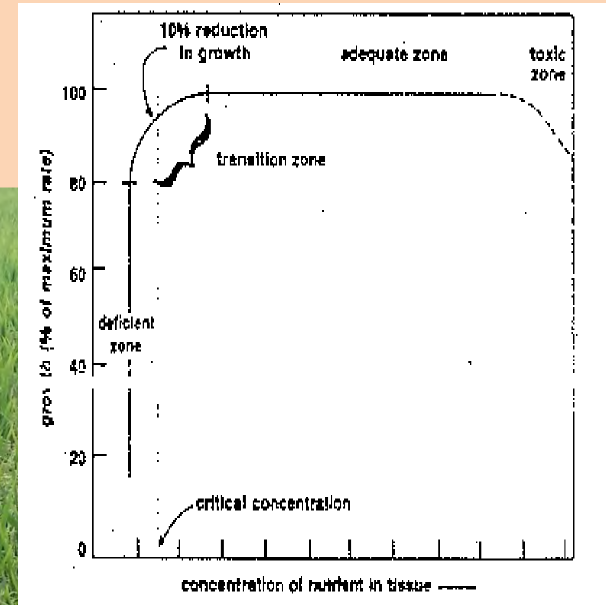
Net Income: 8266 for 6 acres @ RM 1366 per acre

Take home monthly:
RM 227 per acre (6 man –month)

Input management

Luxury consumption of inputs especially fertilizer – associated with pest and disease infestation – 20 days to harvest : neck blast (30%) - 19th April 2015

Pest and disease early warning system.



Managing rice plants under environmental stresses

Short – term

Intermediate

Long –term

Agronomic manipulation – immediate action plan for plant survival and farmers livelihood

Crop improvement program- crop breeding . Molecular research- C3 to C4, Transgenic rice etc.

Feb 24, 2014- Minister's visit to drought affected area in MADA

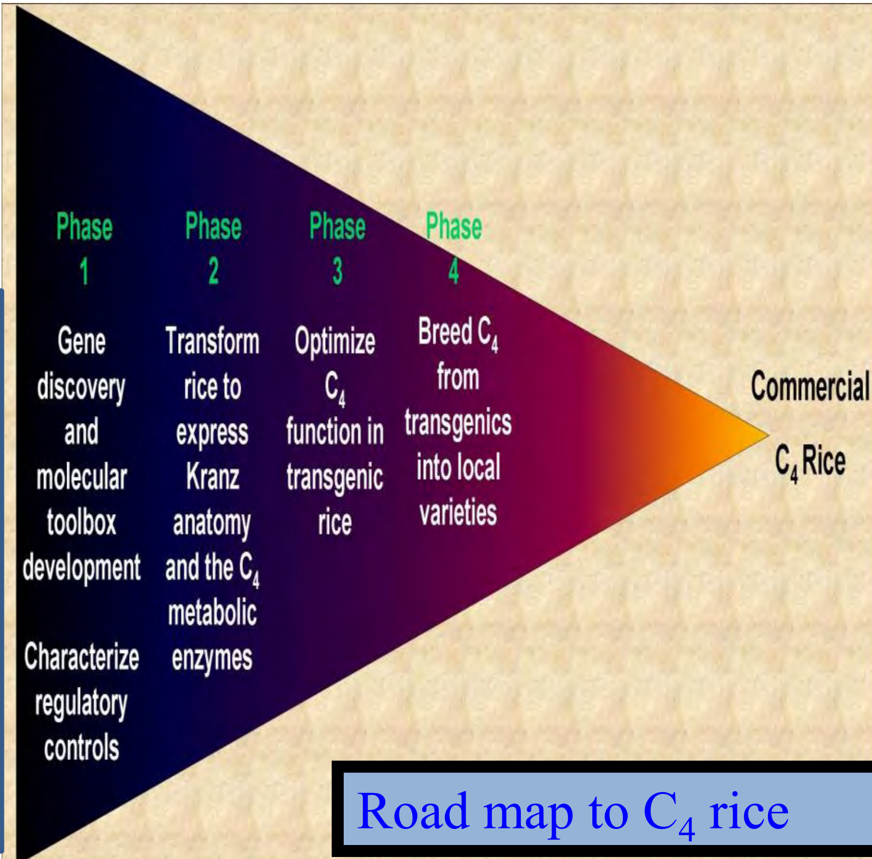
Bill Gates Pledges $20 Million For Rice Research

By news desk on January 28,2008

IRRI
INTERNATIONAL RICE RESEARCH INSTITUTE Microsoft founder Bill Gates has pledged to donate nearly $20 million to the International Rice Research Institute for research into helping rice farmers deal with global warming.

The Philippines-based institute said it would use the donation from the Microsoft founder to harness scientific advances and address major unsolved problems in agriculture. The Bill and Melinda Gates Foundation will release the $19.9-million grant over three years.

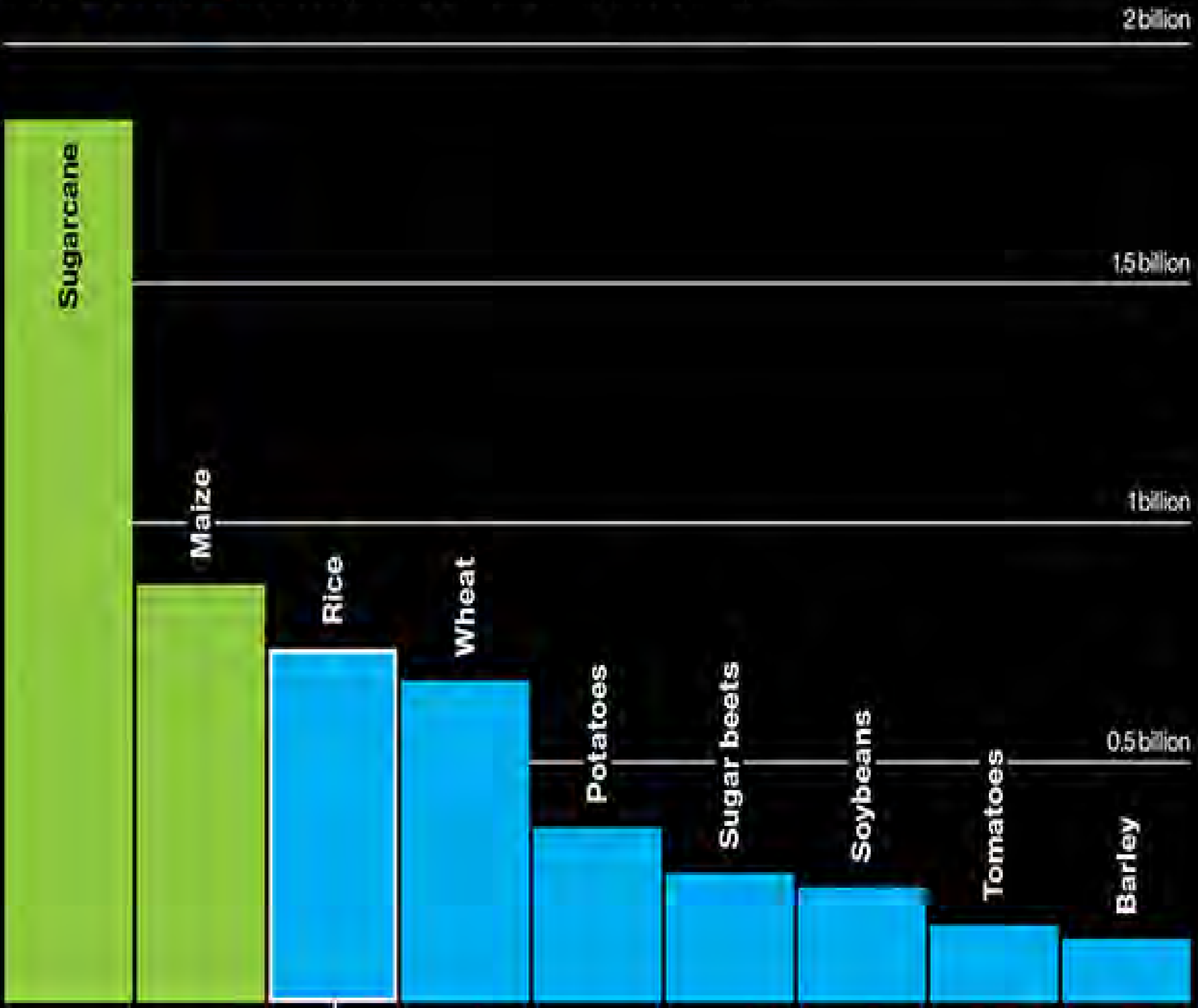
Rice is a staple food for 2.4 billion people. Annual rice output must increase by nearly 70% to nearly 880 million MT in 2025 to meet projected global demand.



Photosynthesis Boost

The world's highest-production crops use a super-efficient form of photosynthesis. It's known as C4 photosynthesis because the first step is the formation of a four-carbon molecule. C3 photosynthesis, found in most plant species, starts with a three-carbon molecule.

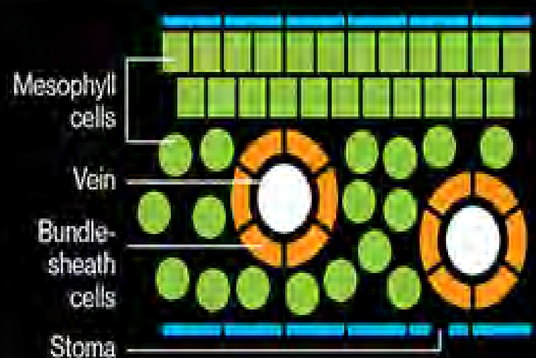
Major C4 and C3 crops (annual production in metric tons)



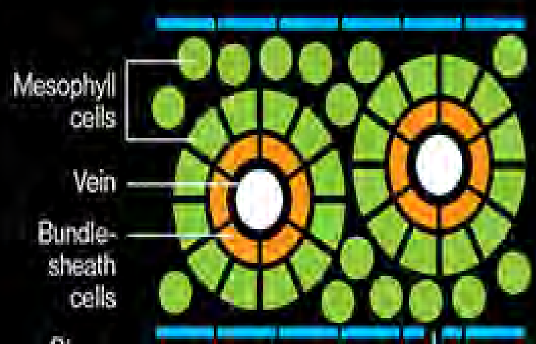
Carbon Concentrators

In C4 plants, a wreathlike arrangement of cells (lower image) helps concentrate carbon dioxide. A ring of mesophyll cells (green) captures the carbon dioxide, which is conveyed to an inner ring of bundle-sheath cells (orange). The arrangement is known as the Kranz anatomy, after the German word for wreath.

C3



C4



Rice Matters

Farmers are struggling to meet growing demand for rice, the staple for half of the world's population.

Projected shortfall in rice production (in millions of tons)

2050 expected demand: 1,309

Rice provides 19% of global dietary energy

Plateauing yields

1990

Last year that average rice yields increased in California

33%

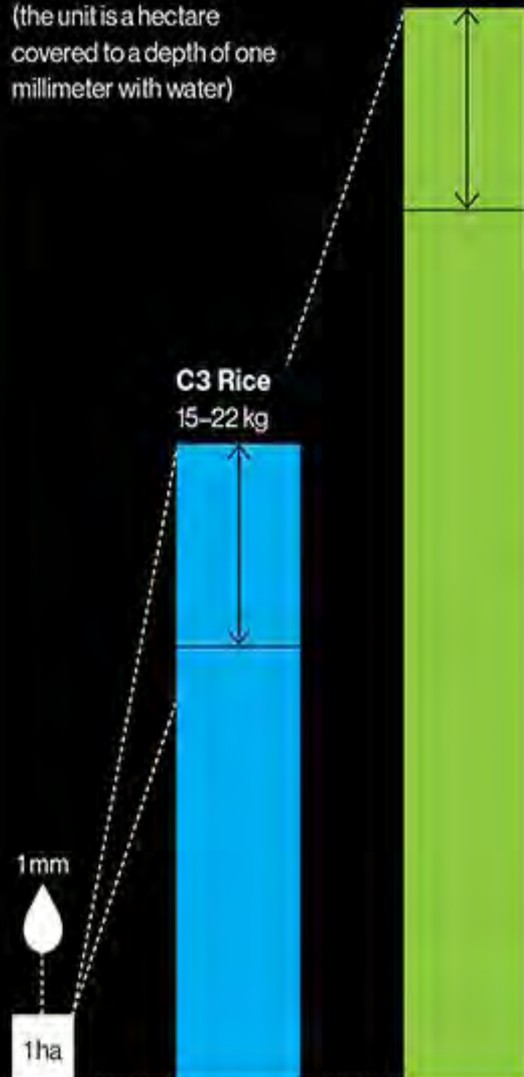
Percentage of rice-producing regions where yields have plateaued

Efficient Farming

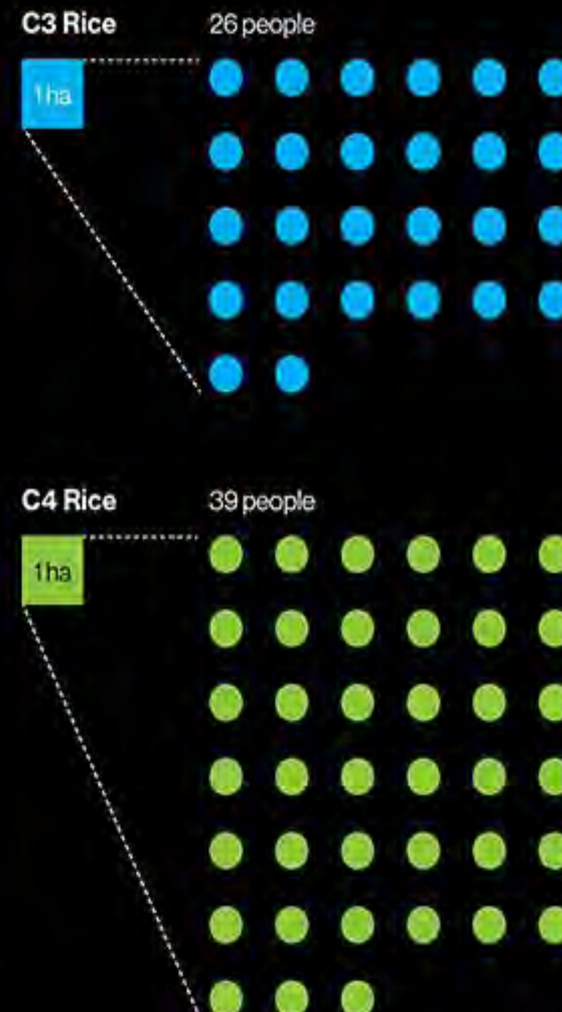
A unit of water goes further with C4 crops, producing far more food. In China, planting C4 rice could feed 50 percent more people per hectare.

Rice and corn grown with a given amount of water (the unit is a hectare covered to a depth of one millimeter with water)

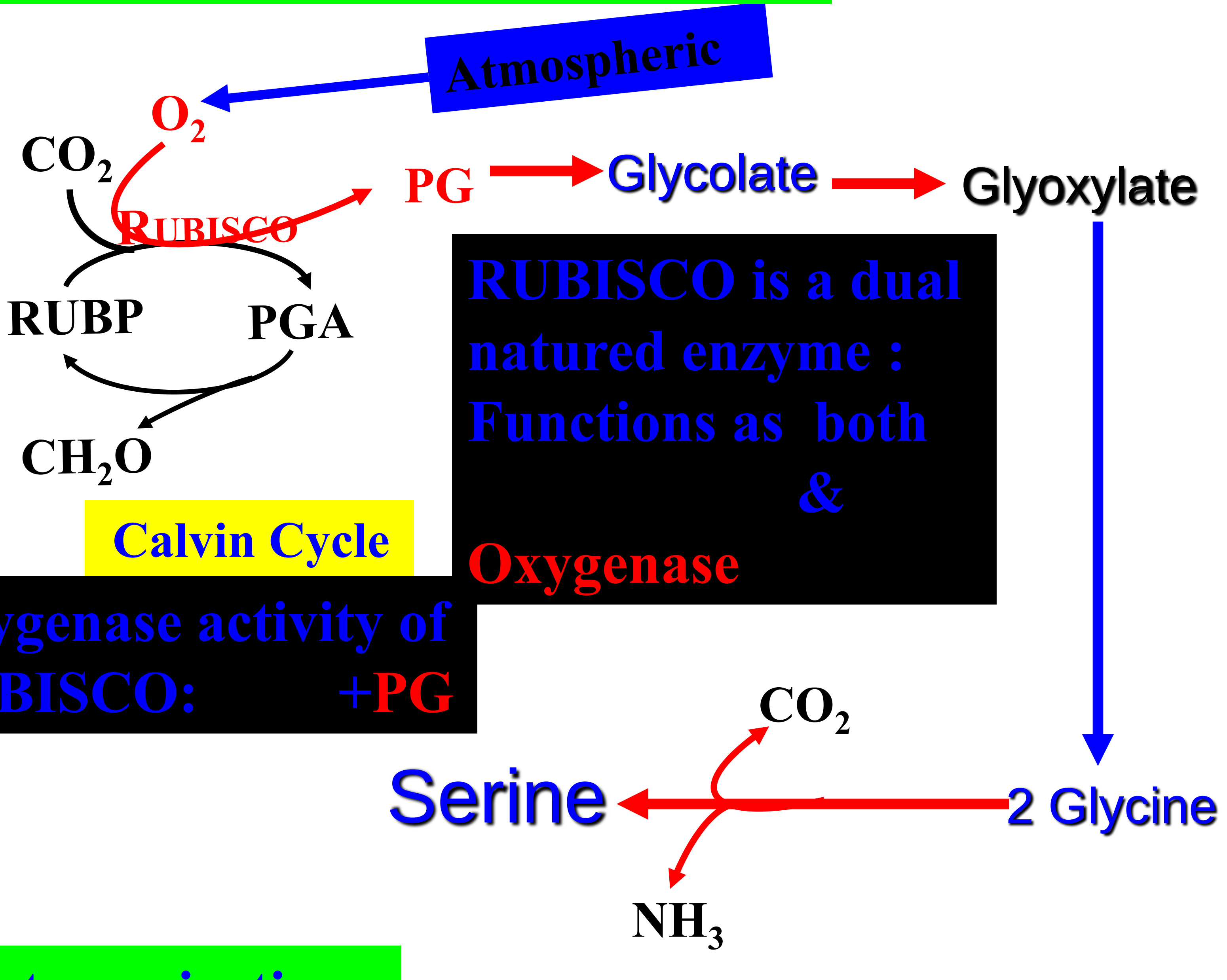
C4 Corn
30–37 kg



People fed yearly in China by one harvest from one hectare of C3 vs. C4 rice



C_3 Rice: Productivity low –Why (?)

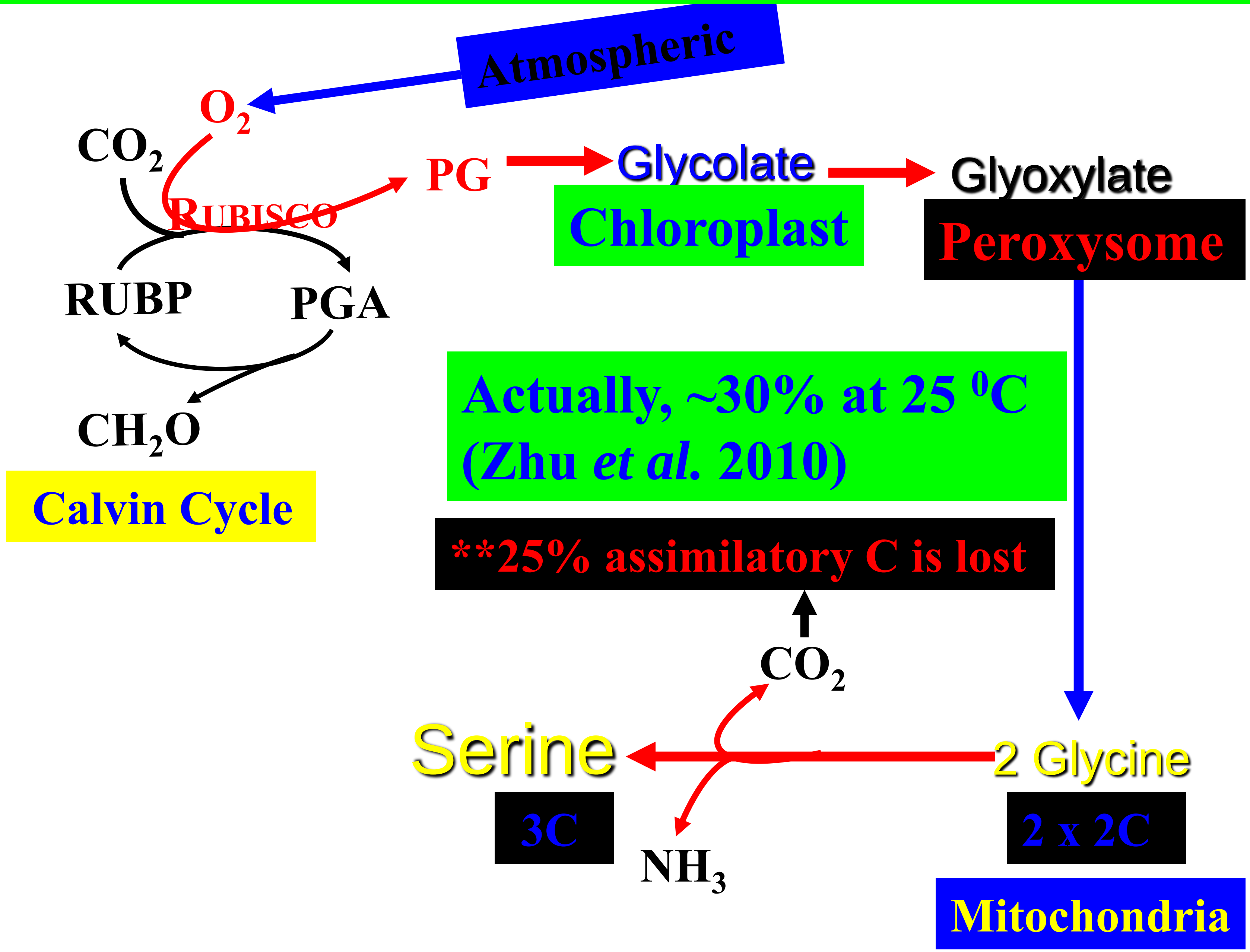


RUBISCO is a dual natured enzyme : Functions as both & Oxygenase

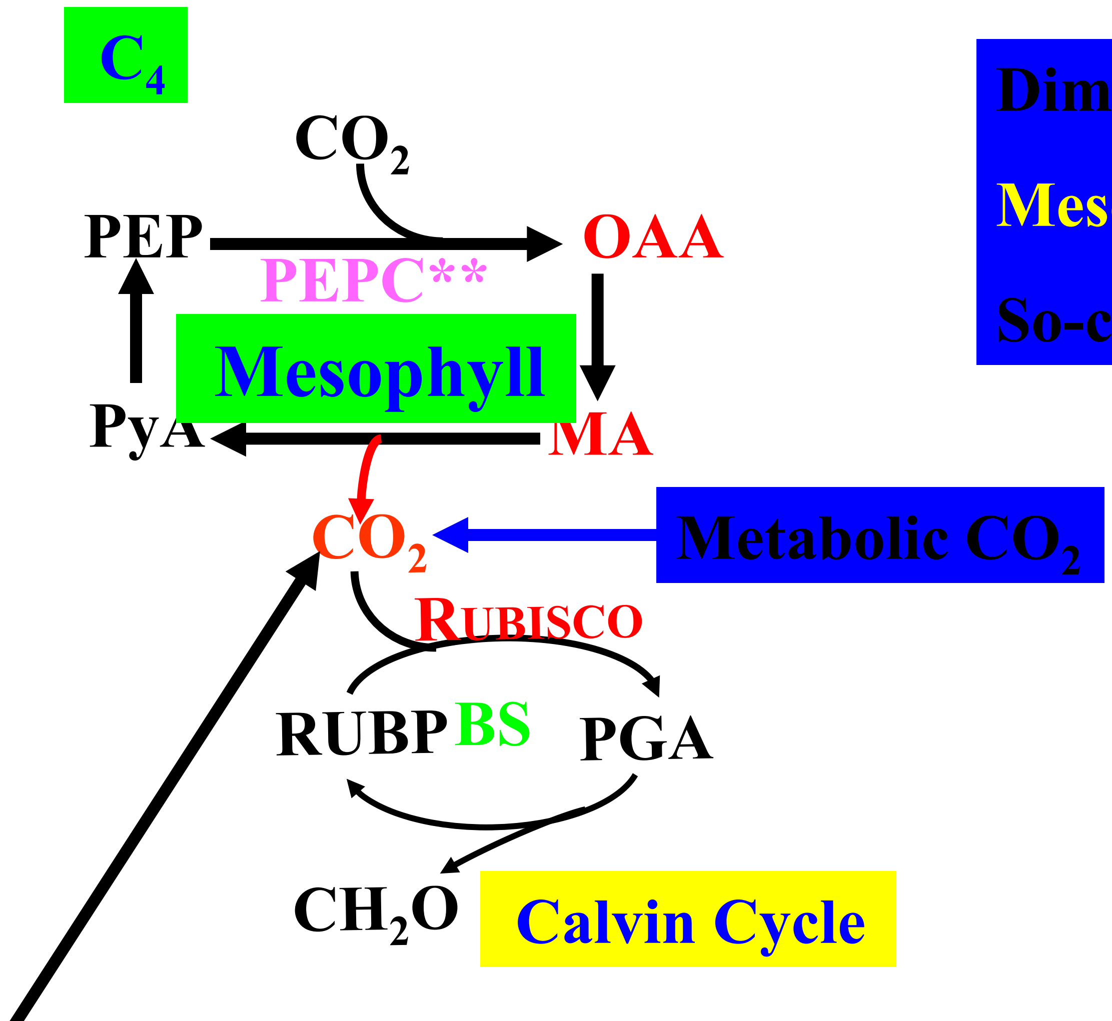
Oxygenase activity of RUBISCO: +PG

Photorespiration

Photorespiration: The major challenge for yield loss in rice



C_4 Photosynthesis : Highly productive



Dimorphic chloroplast

Mesophyll & Bundle sheath

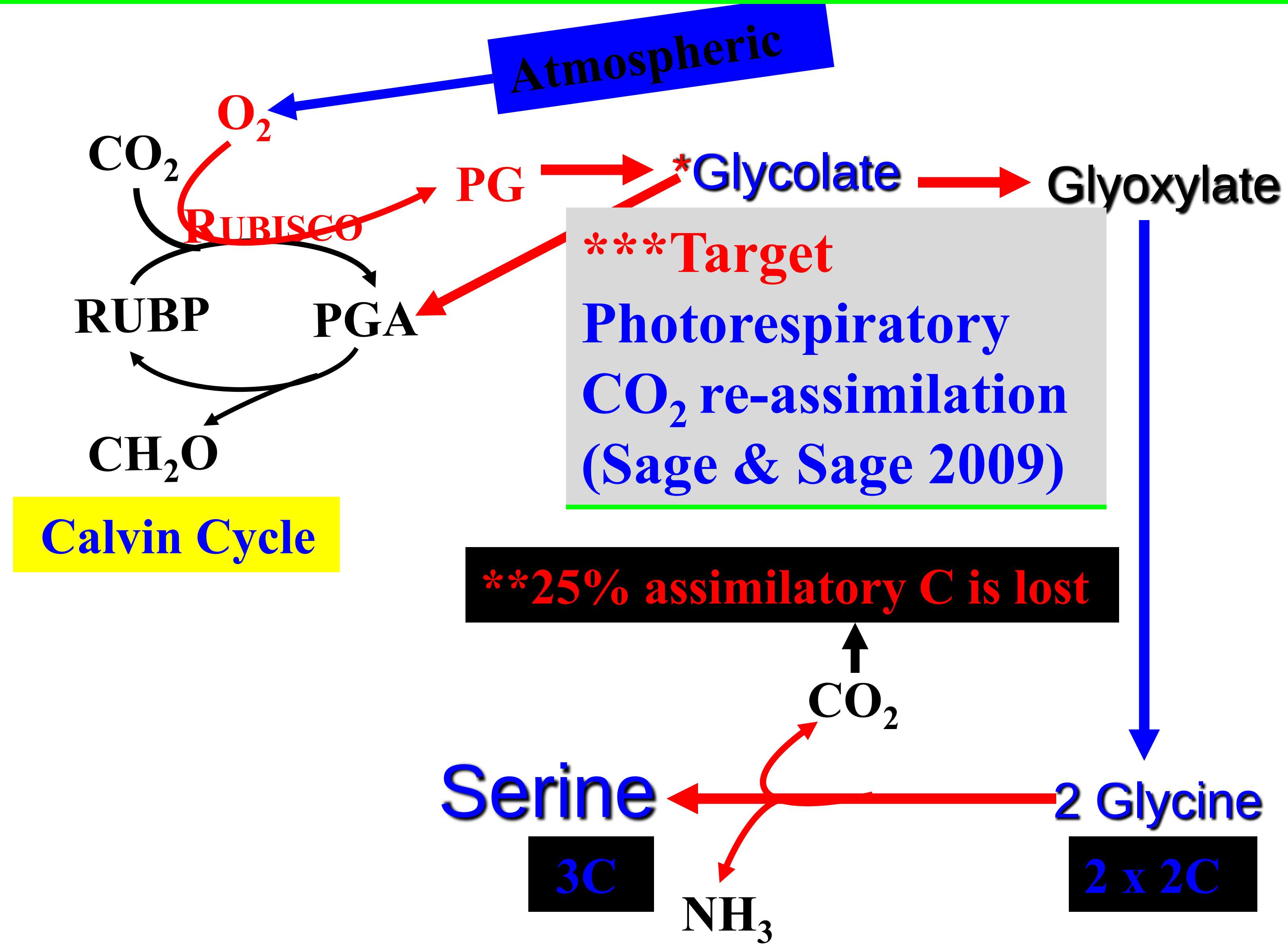
So-called "Kranz Anatomy".

- Photorespiration low
- WUE high
- NUE high (Brown 1999)
- LUE high
- CO_2 compensation low

CO_2 pumping mechanism; C supply remains unchanged

**Oxygenase activity of is suppressed in C_4 plant

Opportunities for yield improvement in rice (Meta. Engineering)



Metabolic engineering is one of the important tools to engineer C_4 rice

***Photorespiratory bypass**

**Photorespiratory CO_2 reassimilation

***Single-cell CO_2 pumping mecha. via PEPCase engineering

C_4 rice will be more efficient in CO_2 concentration

Increased efficiency in water and nitrogen use(Eco-efficient)

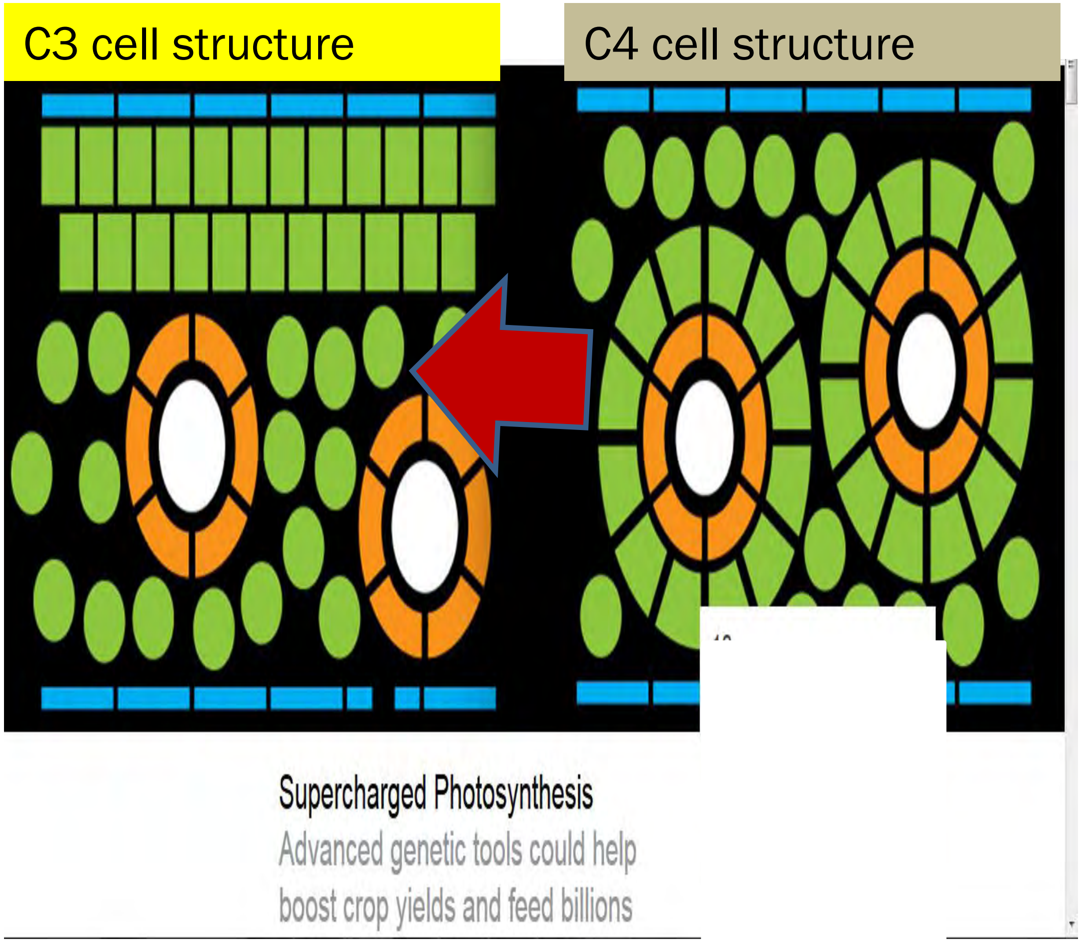
Improved adaptation to hotter and dryer environments (Climate change)

Updates

The December 2014 results, achieved by the C4 consortium and led by Paul Quick (IRRI) in the Philippines,

introduced key C4 photosynthesis genes into a rice plant and showed that it carried out a rudimentary version of the supercharged photosynthesis process.

(*The MIT Technology Review , Jan 2015)*



DEVELOPMENT OF SUBMERGENCE TOLERANT RICE

PRODUCTION OF SUBMERGENCE TOLERANT RICE

Crossed new panicle

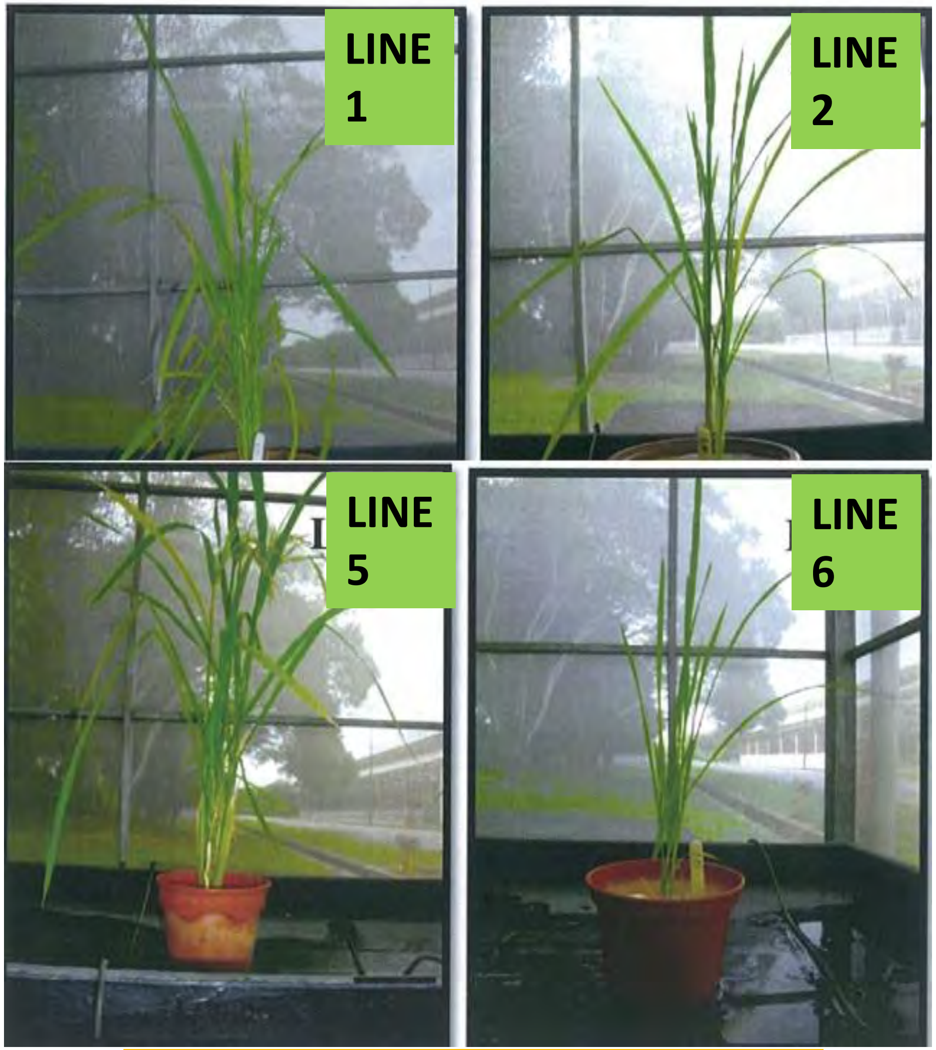
Selected lines in the plot

Crossed new panicle

Crop in the field

SALINITY TOLERANT LINES MR 219-4

SALINITY TOLERANT RICE LINES PLANTED IN GLASSHOUSE



6 INDEPENDENT SALINITY TOLERANT RICE LINES PRODUCED

NEW STRAITS TIMES SATURDAY, AUGUST 18, 2007

Chinese scientist and crop physiologist Peng Shaobing in inspecting rice samples at the International Rice Research institute in Los Banos Laguna. — AFP picture

Scientists fight threat to rice

LOS BANOS (Philippines): On an agricultural research station south of Manila, a group of scientists are battling against time to breed new varieties of rice as global warming threatens one of the world's major sources of food.

According to the International Rice Research Institute (IRRI), more than half the world's 6.6 billion people depend on rice for nourishment.

"Parts of the world will become drier and apparently that's already happening, and some parts will become even wetter," said Moroccan crop physiologist Rachid Serraj.

"But most importantly, it's going to shift the rainfall distribution. It's going to become more unpredictable, and that is the problem for rice cultivation," he said.

Chinese scientist Peng Shaobing wraps his padi fields with tarp and blasts them with cold air from air conditioners.

His colleague, Indian plant geneticist Kumar Singh, grows 2,000 rice varieties in giant metal cabinets, the seedlings sprouting above styrofoam trays soaked with varying degrees of brine to simulate the seawaters that threaten to engulf rice-growing areas over the next century.

The three IRRI scientists are entrusted with ensuring that the half of mankind who depend on rice will not go hungry as rising temperatures and ocean levels threaten the crops.

The Intergovernmental Panel on Climate Change projects that the globe will warm by 0.2° Celsius every 10 years, far higher than the 0.6° Celsius rise in the past century, with serious consequences for food production.

IRRI, a vital part of the "Green Revolution" that dramatically raised cereal yields in the 1970s, has gathered top experts to work on "new frontier projects" to meet the threat. This is apart from more conventional research to further boost yields, make the plants more resistant to pests and disease, and make the grain more palatable.

Rice yields would fall by 10 per cent for each one-degree rise in the minimum temperature at night, said crop physiologist Peng.

Between 1978 and 2003, minimum mean night-time temperatures rose by 1.5° Celsius, suggesting a 15 per cent production decline over 28 years, Peng said.

Higher night-time temperatures shorten the growing time for rice.

"The yield is reduced because the plant doesn't have enough time to grow. Higher night temperatures also lead to poorer grain quality."

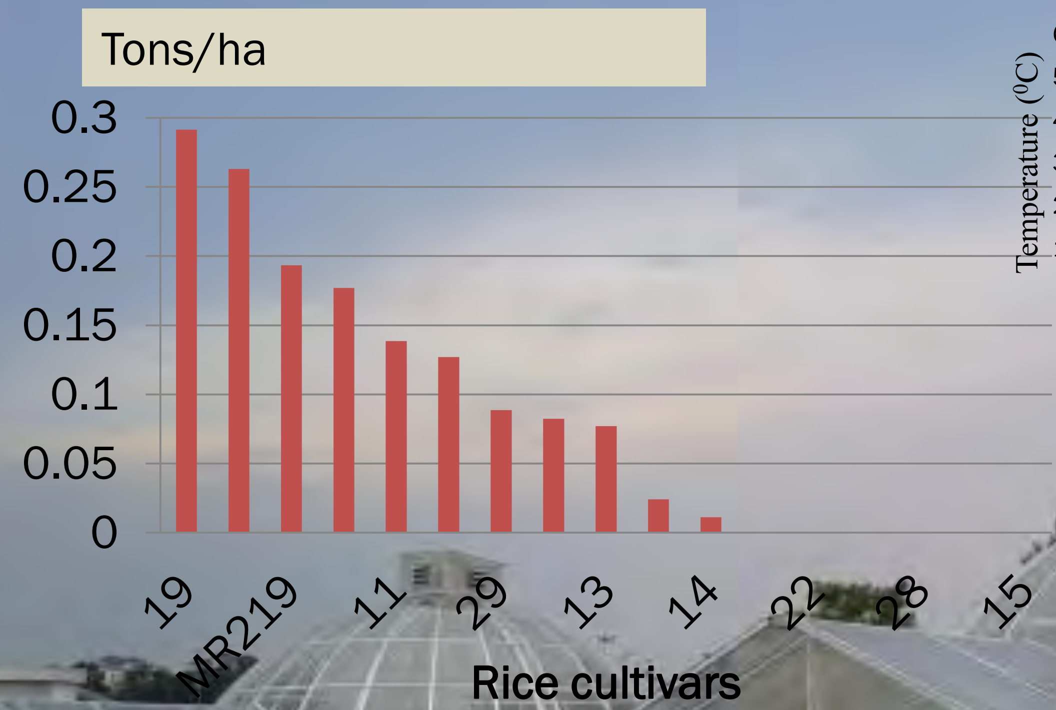
Drought and salinity are already major problems. Twenty-three million hectares or 18 per cent of the world's rice farms are considered "drought-prone", Serraj said.

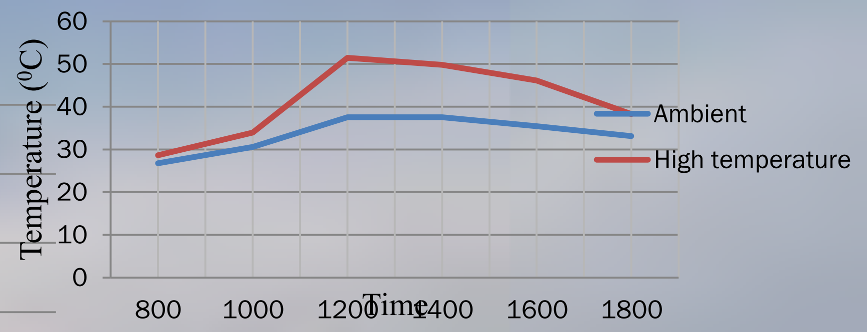
A dry spell in hot spots such as eastern India can push up to 15 million rain-fed rice farmers into poverty in a single year, he said.

Even in China, demand for water from industry and elsewhere was putting pressure on high-yield irrigated rice grown there, he added.

Next to drought, the influx of saltwater, not only in coastal, but also inland farms through careless irrigation practices was the Number 2 problem, said Kumar.

Some 6.3 per cent of the world's soil surface was already considered saline, and global warming or not, the problem affected most of the rice fields of South Asia and Southeast Asia, he added. — AFP





Identified few tolerant lines

High temperature tolerance

Drought /water limited rice cultivar

the development of cultivar that can tolerate water limited water condition.

UPM-MINT-MARDI-UMT - stress tolerant rice cultivar through induced mutation breeding.

Mutant MR219-4

unique because it performed very well under saturated conditions in irrigated areas and aerobic conditions (sprinkler assisted irrigation) under dryland regime (Abdullah et. al., 2010).

Plant physiological attributes :   higher stomatal conductance

Rice varieties	Normal flooding conditions	Water limited conditions
220	173	76
219	170	89
211	224	67
219Ai	390	151
219Aii	230	121
219Bi	309	327
219Bii	403	311
211Ci	335	82
211Cii	405	95
211Di	276	109
211Dii	251	185

MR219-4 Mutant developed Prioritised Research IRPA RMK8

Challenged with full submerged and salinity stresses

Physiological and biochemical attributes indicated promising traits for environmental stress tolerant (Maziah, Damanik, New Hew , Mohd Razi (UPM) Abdullah M Z (UMT)

Further exploration : LRGS program

Plants under aerobic condition in MARDI S..Perai (MR219-4) at ripening stage). Mutant MR219-4 was unique because it performed very well under saturated conditions in irrigated areas and aerobic conditions (sprinkler assisted irrigation) under dryland regime. In addition, the mutant can also tolerate submergence and therefore can be planted in flood- prone rainfed areas. The superior adaptation and yield performance of mutant MR219-4 under aerobic condition was obviously a very interesting finding because its parent, **MR219 has never been recommended for aerobic soil** (Abdullah et al, 2010)

Again – what are immediate measures for rice farmers to cope with drought or water limited


10,000 petani KADA rugi RM150j kerana kemarau

Bernama
5:40PM Jun 18 2012

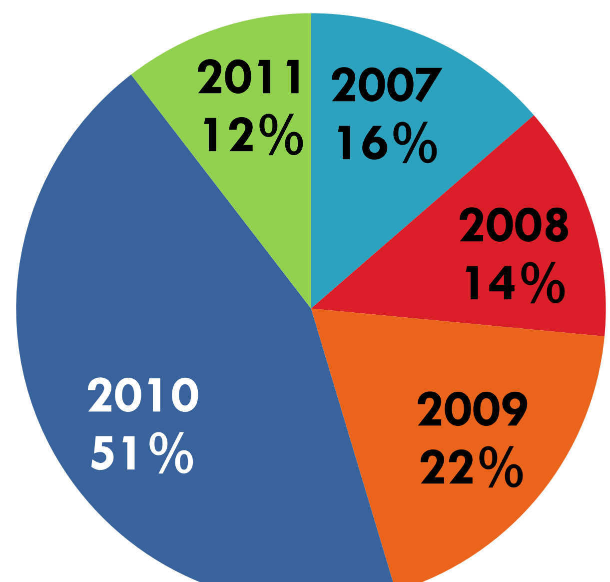
Kira-kira 10,000 petani dalam kawasan Lembaga Kemajuan Pertanian Kemubu (KADA) di Kelantan, mengalami kerugian RM150 juta ekoran kemerosotan pengeluaran padi kira-kira 120,000 tan metrik pada musim tanaman tahun ini akibat kemarau.

How and what to address

1. Drought prevails – problem with grain filling , at what phenological stages ?
2. What fertilization regimes to be applied
3. Intrusion of weeds , how to manage
4. If there are water resources available – how to make full use of water availability , e.g how much water/when to irrigate

Management under drought to lessen devastating damage to farmer's income and rice availability

Yield losses (drought stress) from 2008-2011



Physiological adaptation in major agricultural crops under field conditions

Main target : Carbon gain at low water potential(internal water deficit) creating plant adaptation under external stresses

The Challenge: maximize harvest index as a strategy for crop adaptation
regulated at several sites
high net photosynthetic rates do not necessarily contribute to high HI because a large part of the fixed CO2 may be diverted into starch or non harvestable biomass

Understanding of plant metabolism at different phenological stages / adjustment

Rice and other cereals;
Grainfilling : sensitive to climate changes

Agronomical manipulation of carbon fluxes

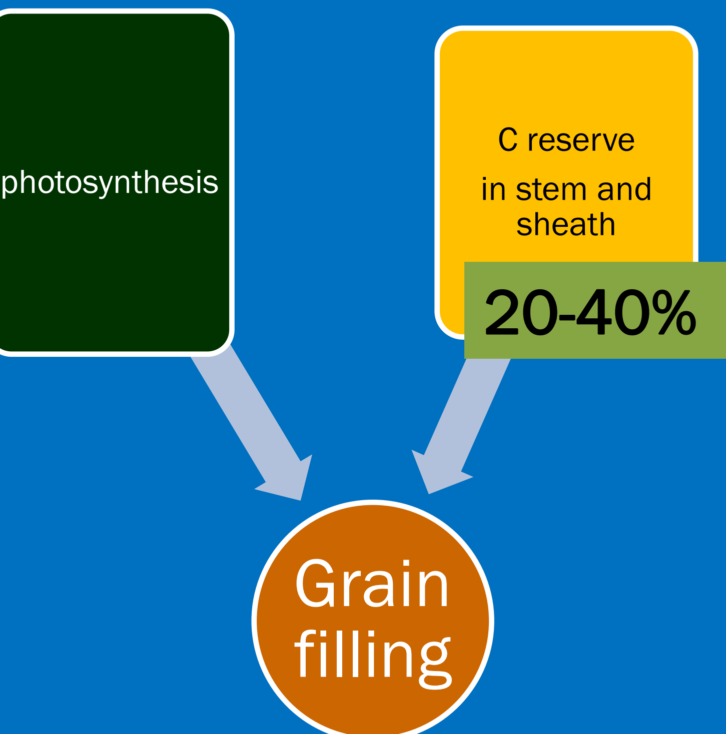
Theoretical background of grain filling:

Monocarpic plants such as rice need to initiate whole plant senescence to remobilize the pre-stored reserves.

Pre-stored reserves contribute 1/4 - 1/3 to the final weight of a grain, a big potential to exploit.

Delayed senescence delays such remobilization and leads to unused food in straws.

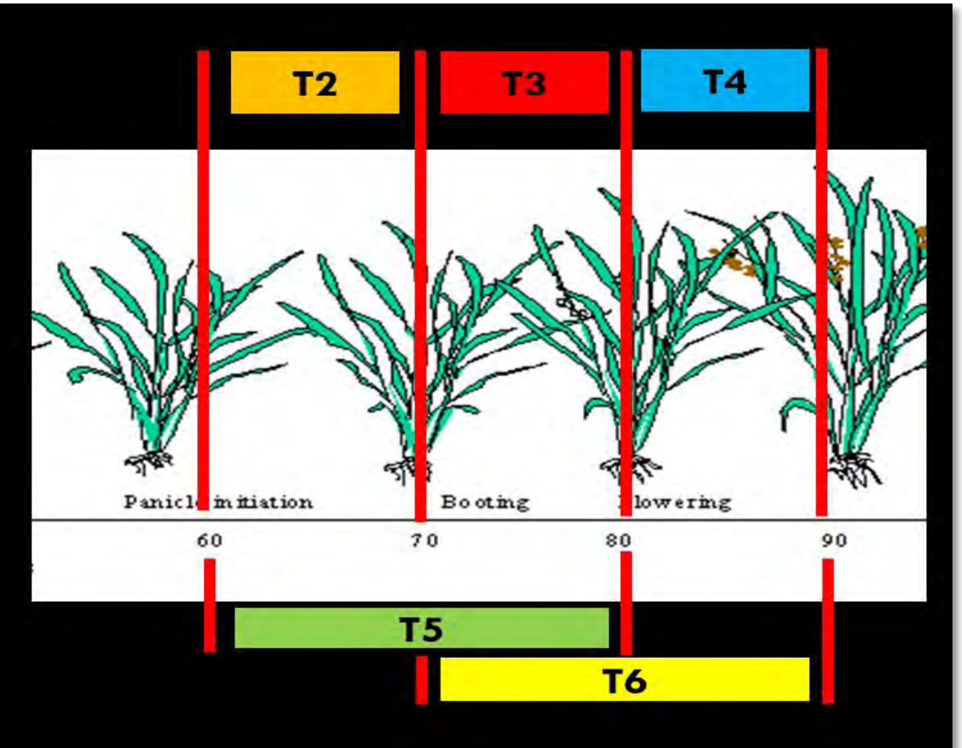
Grainfilling =efficient assimilate partitioning



Empty grains

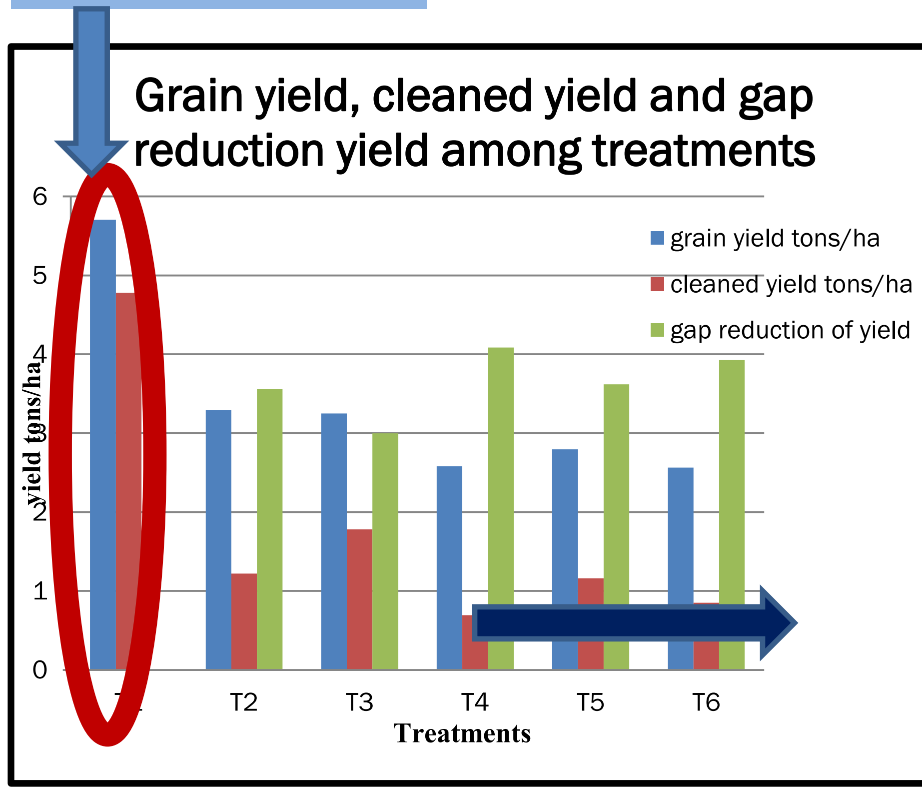
Full grains

Rice plant phenology and drought



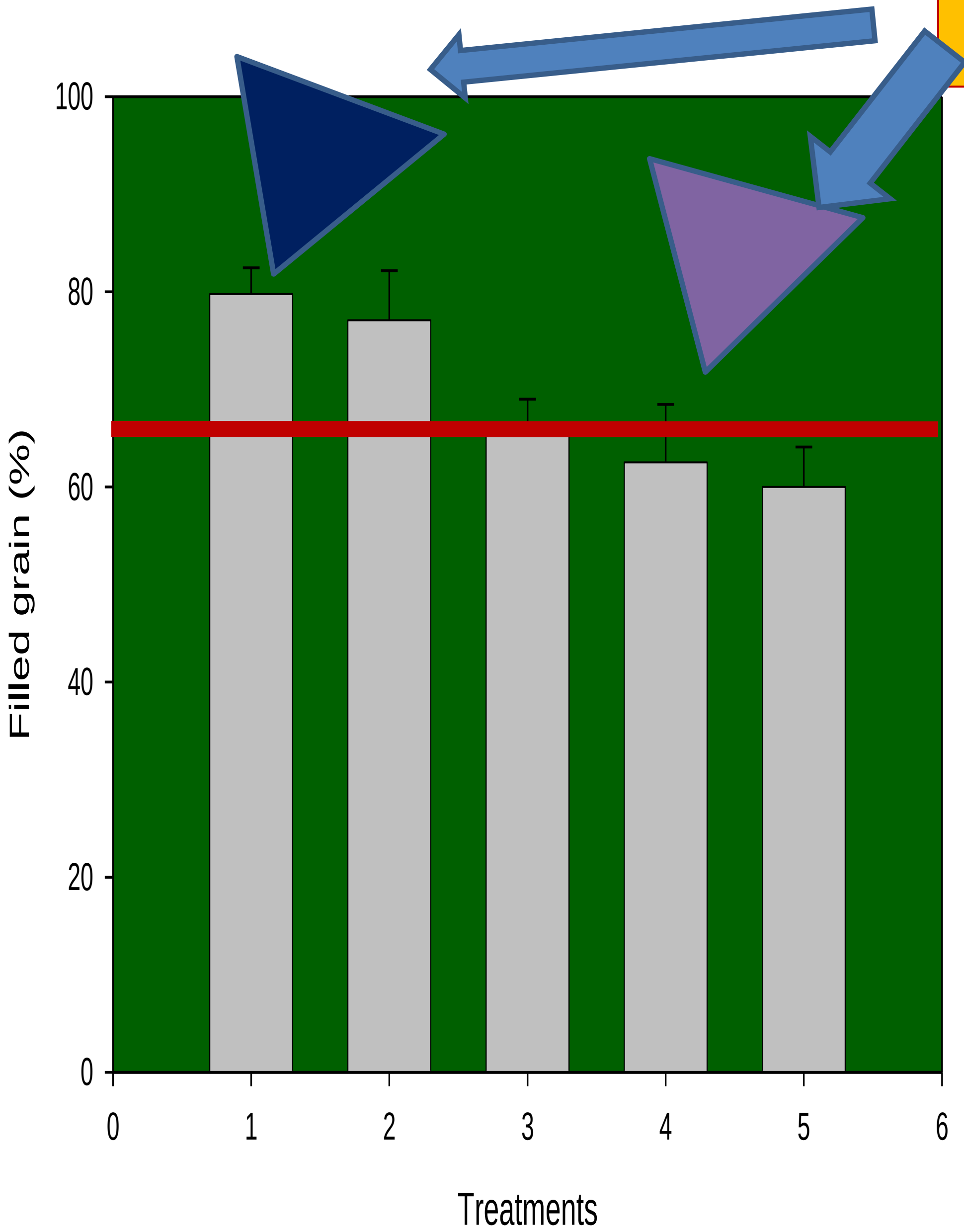
Type of treatments that had been imposed to rice plant experiment. T1 = well watered / control, T2 = WS at 60 - 70 DAS, T3 = WS at 70 - 80 DAS, T4 = WS at 80 - 90 DAS T5 = WS at 60 – 69 and 70 -80 DAS T6 = WS at 70 - 79 and 80 -90 DAS. *DAS = Day after Sowing. *WS = Water Stress

Control flooded plants



Drought prevails at reproductive stage resulted to 75-80% yield reduction

Yield optimization



Filled grain under different water availability at different phenological stages. (1: Flooded, 2: Field capacity at first flowering, 3: Field capacity at panicle initiation, 4: Field capacity at active tillering, 5: Field capacity)
Source: Zulkarnain et al, 2008

The problems:

Senescence is unfavorably delayed by

heavy-use of N-fertilizers,

introduction of lodging-resistant cultivars,
(stay 'green' for too long at maturity)

and utilization of heterosis (e.g. hybrid rice).

In all the cases, slow grain filling and unused food are the two problems.

In the field under water-saving culture:

Comparison between wheat plots that were well-watered or un-watered during grain-filling stage. Fate of fed ^{14}C was measured on day 18 from anthesis.

	Duration from anthesis to maturation (days)	Fate of fed ^{14}C ($^{14}CO_2$ applied 10 days early) % in kernels	% in stem	Total sugars left in stem (on day 26)
Well-watered	41	41.3	40.5	29%
Unwatered	31	81.3	9.6	8%

Soil drying can greatly promote senescence and C remobilization.

Yang et al. 2001

Rationale for controlled soil drying:

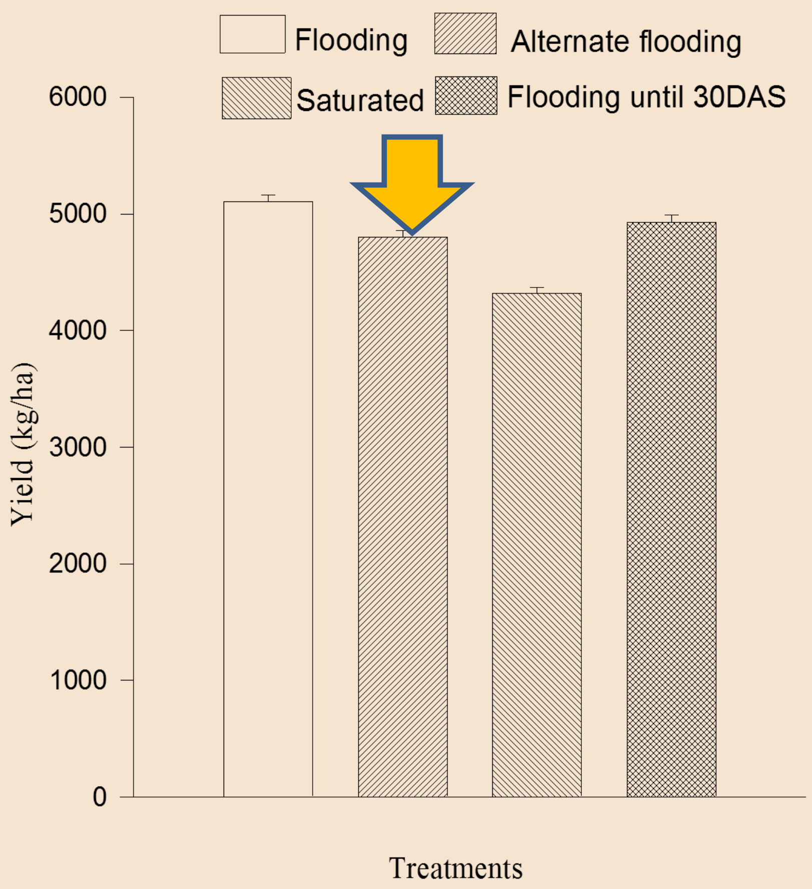
1. A mild soil drying may not seriously disrupt the phloem function.

2. A faster filling will have some advantages in “stay green” cultivars because the phloem link to grains may lose its function earlier than chlorophyll disappears.

3. The gain from an accelerated grain filling from pre-anthesis food reserve may outweigh any loss of photosynthesis as a result of imposed soil drying.

(Source: Davies, Bacon and Mohd Razi ,2004)

Effect of different water management and alternate irrigation practice on rice yield (kg/ha) at Ladang Merdeka Mulong, in KADA



Water saving in rice cultivation

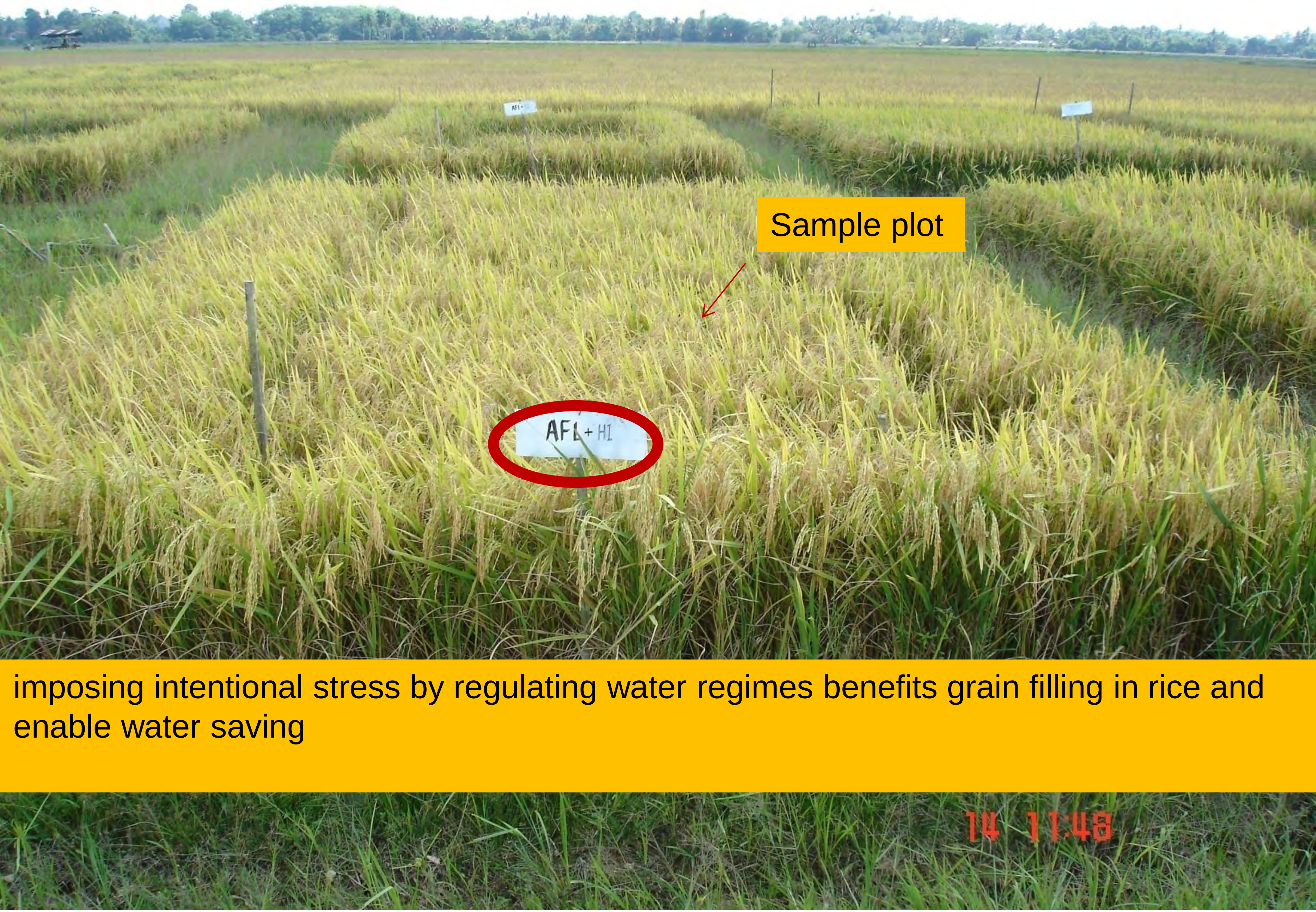
Control –continuous flooding

Deficit irrigation

Physiological adaptation –regulating water regimes based on phenological adjustment

Continuous flooding

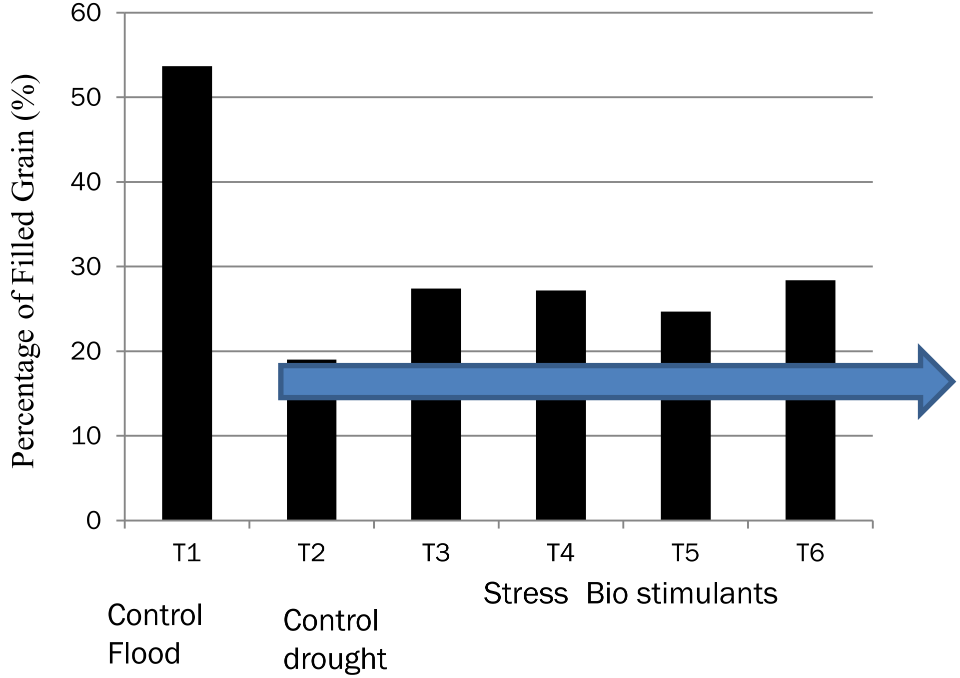
Mild water deficit imposed



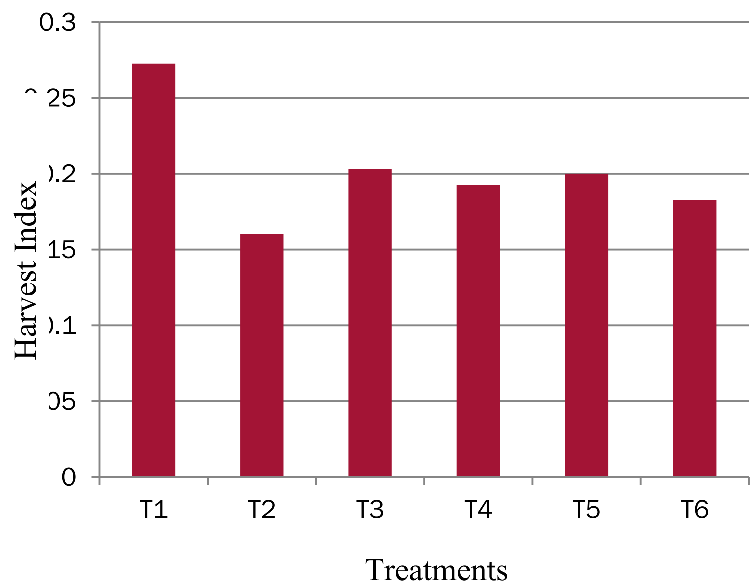
imposing intentional stress by regulating water regimes benefits grain filling in rice and enable water saving

Grain filling =efficient assimilate partitioning

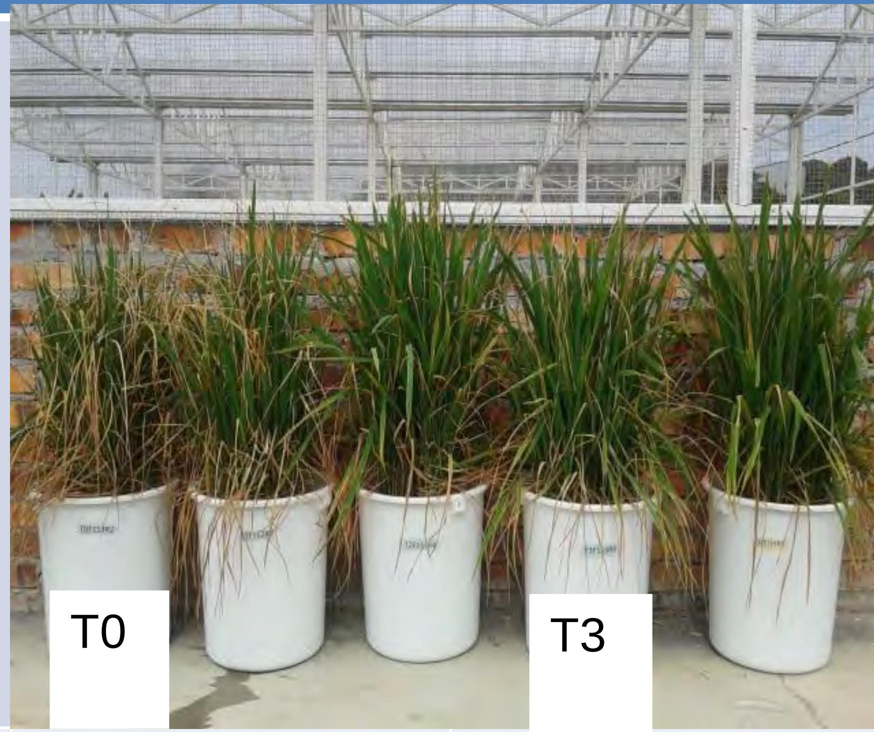
1. Endogenous enrichment of growth stimulants



Under drought conditions, endogenous application of growth bio stimulants can improve grain filling attributed to high HI (assimilate partitioning) .




1. Growth enhancers for drought alleviation



(T0= control,and T3=Polyamines

I. 66% yield increased over untreated control.

2. grain filling increased by 20%

2. Foliar fertilizer and growth stimulants

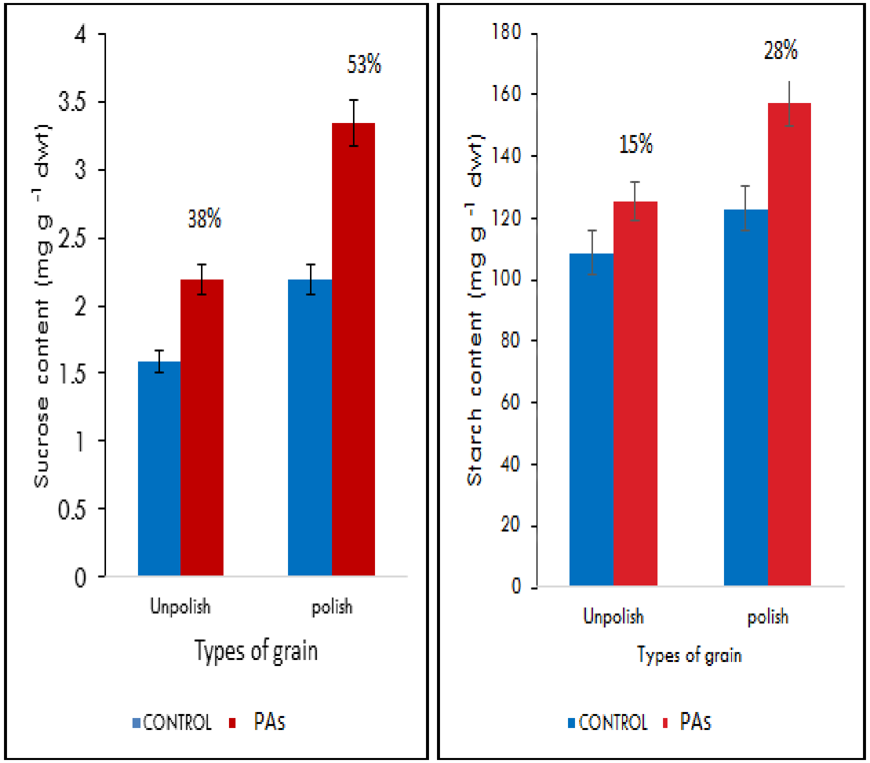
Polyamines for drought alleviation

improve the assimilate partitioning in favor of spikelet on the secondary branches

raise the number of high-density grains in the panicle

increases the remobilization

Synthesis of sucrose synthase enzyme activities



Sucrose and starch content in the grains at 105 day after sowing (DAS) in- between control and PAs under water stress conditions.

2. Potassium fertilization and drought stress in rice

Treatments	Plant Height, cm	Leaves No./hill	Tillers No./hill	Days to flowering	Grain yield (g/pot)
CF	102.89±0.44^{a}	22±0.33^{c}	5±0.17^{a}	80±1.25^{a}	91.403±1.99^{a}
WS	95.22±0.45^{c}	25±0.44^{b}	4±0.29^{b}	74±1.20^{b}	45.907±3.19^{c}
WSK	98.78±0.89^{b}	29±0.22^{a}	5±0.22^{a}	77±0.67^{b}	75.163±2.94^{b}

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Drought Tolerance and Ion Accumulation of Rice Following Application of Additional Potassium Fertilizer

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pages 2502-2514

Conclusion

Plants adjust to a changing environment by various means of adaptation mechanism.

A great challenge for plant biologists in the 21st century is to enhance crop development under challenges of environmental stresses to sustain and improve rice food security

The key challenge is to find adaptation to environmental threats imposed by climate changes. The ultimate aim is to improve livelihood of farmers as they are the active players whom through them with Allah swt permission, we and our future generation will able to continue feeding on
with RICE

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Terima Kasih | *Thank You*