Aerobic Rice

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Los Baños, Philippines

Aerobic rice: a technology in R&D

Key characteristics: no puddling, no standing water, no soil saturation, dry land preparation, direct dry seeding, “high” inputs => high yields, special “aerobic rice” varieties

Target domain: water-short irrigated lands, favorable uplands and rainfed lowlands (where water is Insufficient to grow flooded rice)

Upland rice

Breeding:

Aerobic soil
Drought tolerant
Weed competitive
Adverse soil conditions
Low inputs (!)
=> Stable but low yields

Unfavorable uplands

Different idea of rice like upland crop

Breeding: from upland rice…

↓

Aerobic soil ← ***Lowland HYV traits***
Input responsive
Lodging resistant
Weed competitive
=> Stable and high yields

↓

Water-short irrigated areas
'Favorable' uplands

Water use of a hypothetical aerobic rice crop and of a lowland rice on different soils

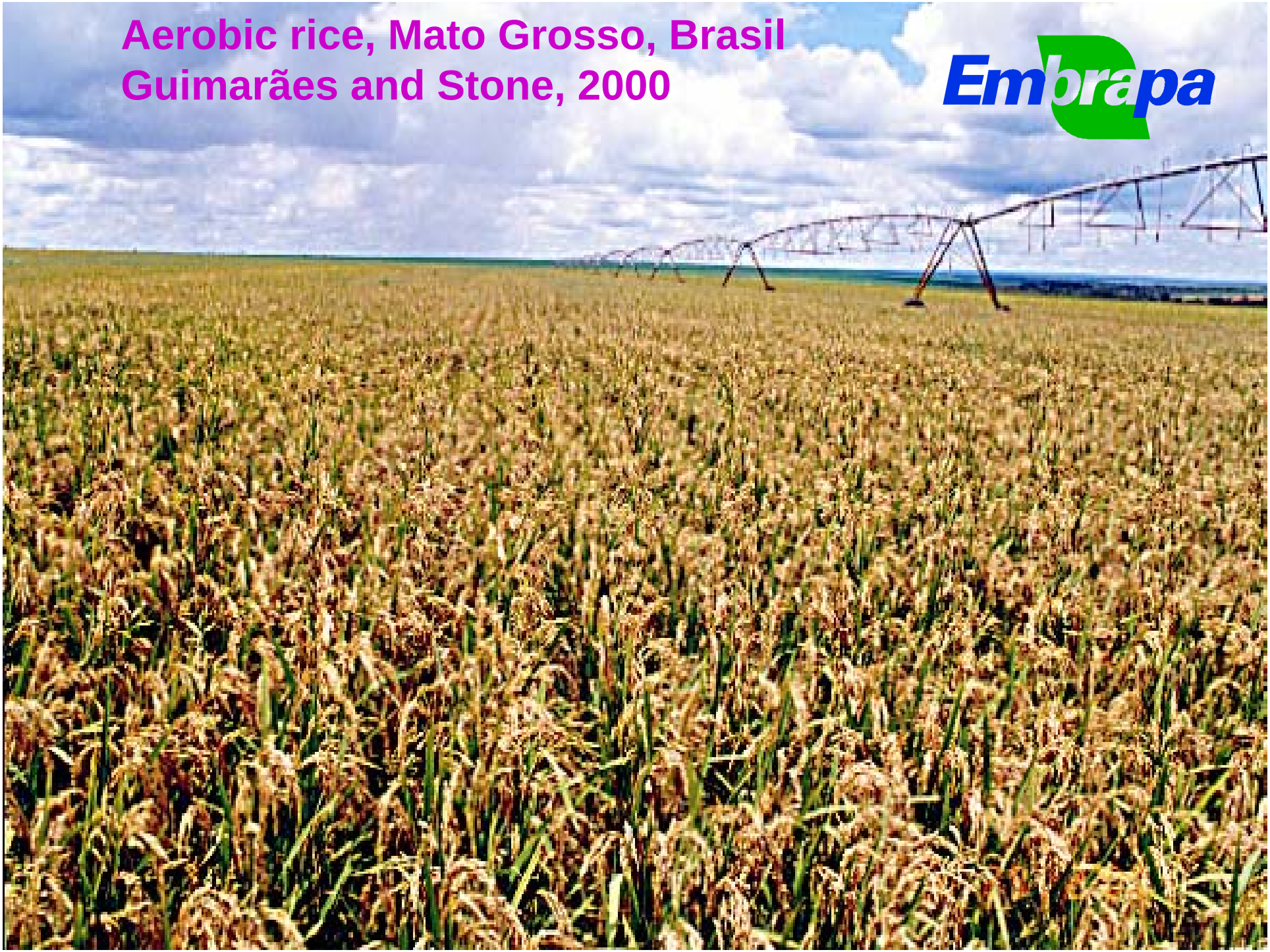
Water flow process	Aerobic rice (mm)		Lowland rice (mm)		
Lowland soil SP rate	-	-	1 mm d^{-1}	5 mm d^{-1}	15 mm d^{-1}
Irrigation efficiency	85%	60%	-	-	-
Evaporation	100	100	200	200	200
Transpiration	400	400	400	400	400
Seepage and percolation	–	–	100	500	1,500
Irrigation inefficiency loss	90	335	–	–	–
Total	590	835	700	1,100	2,100

Practical evidence: Brazil

- Active program to develop upland rice varieties and management techniques since the 80's

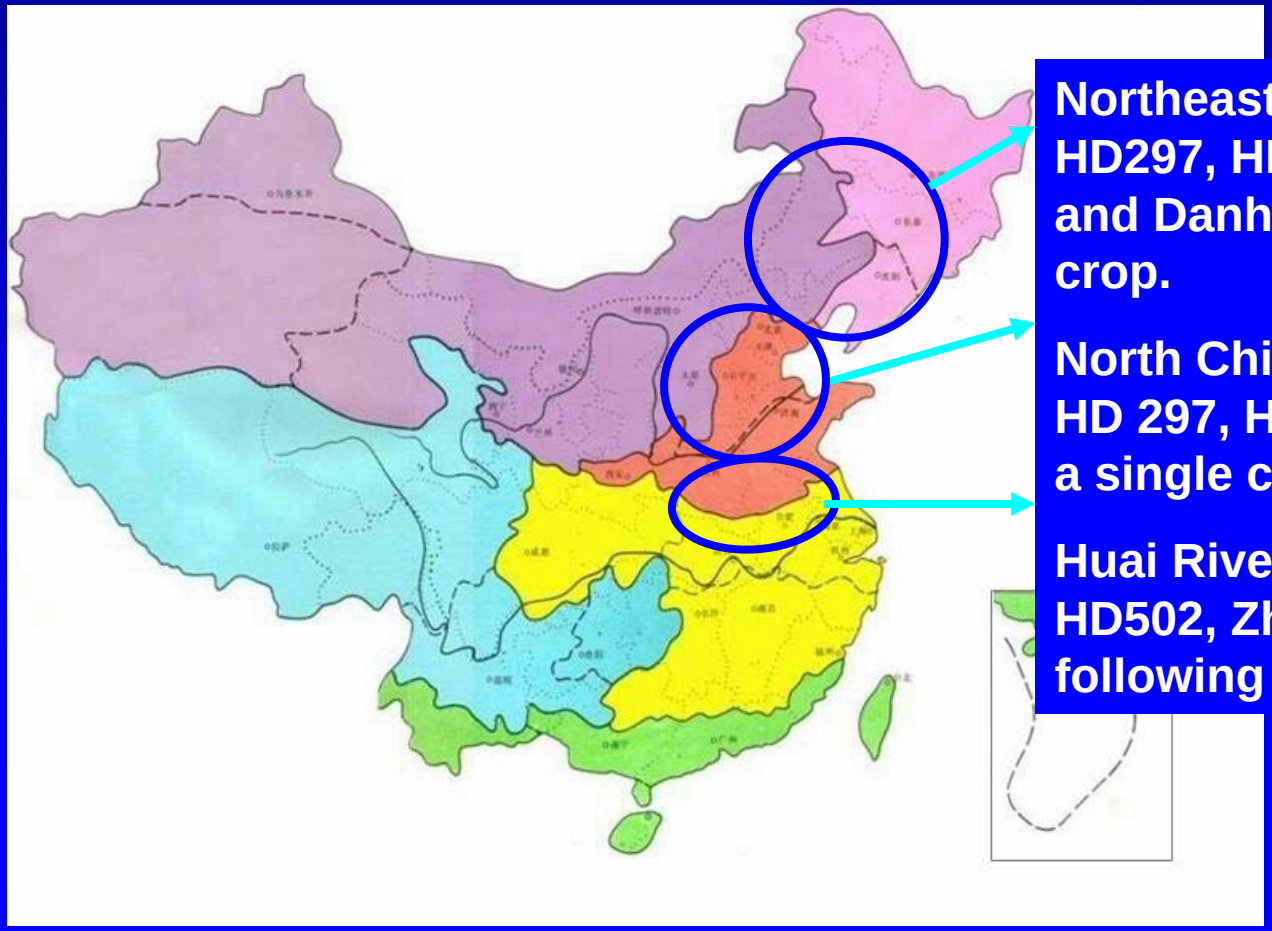
=> High-yielding aerobic varieties > 5 t ha^{-1} with high inputs

- State of Mato Grosso: 250,000 ha commercial production (sprinkler irrigated)


Aerobic rice, Mato Grosso, Brasil
Guimarães and Stone, 2000
Embrapa

Practical evidence: North China

High-yielding and good-quality aerobic rice varieties released since late 1990s.



Northeast China Plain: HD297, HD502, Dangeng 8, and Danhandao 1 a single crop.

North China Plain HD277, HD 297, HD65, Wushi HD as a single crop.

Huai River Plain HD277, HD502, Zhonghan 3 grown following winter wheat.

Practical evidence: North China

Tested by farmers on estimated 80,000 ha

- **In rainfed areas where rainfall is insufficient to sustain lowland rice production (diversification!)**
- **In irrigated areas where water is scarce/expensive**
- **In salt-affected areas**
- **In flood-prone areas**

Huanjia Chuan (Beijing)

Feng Tai (Anhui)


浙江柳林

China Agricultural University: developed ‘aerobic rice’ varieties since 1980’s

旱稻

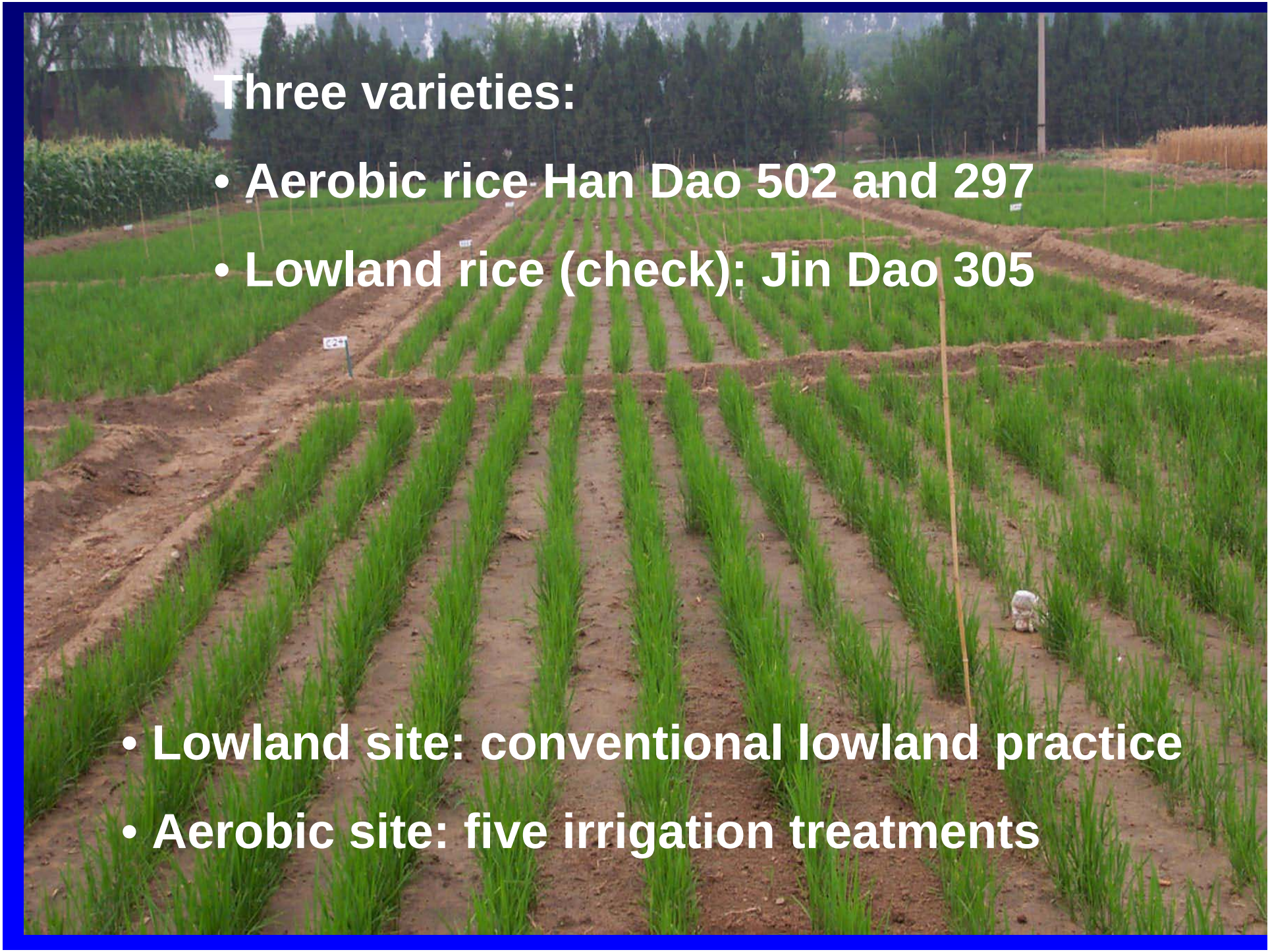
Questions……
Yield? Water use? Can stand flooding??
Management? Sustainability? ……

Results field experiments Beijing

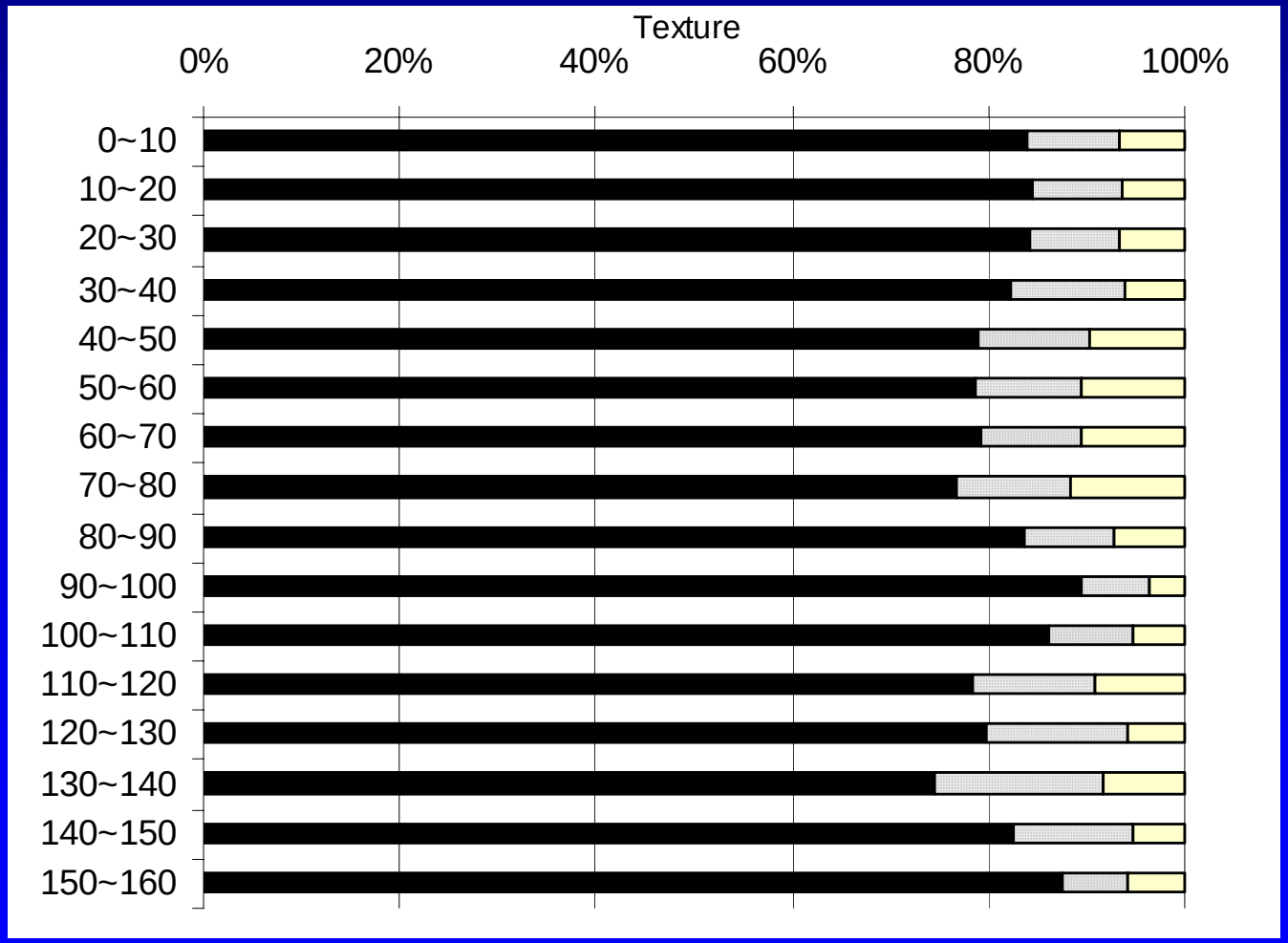
Checking the concept:

Hydrology field experiment Beijing

Explore aerobic rice yield and irrigation water use


Three varieties:
• Aerobic rice Han Dao 502 and 297
• Lowland rice (check): Jin Dao 305
• Lowland site: conventional lowland practice
• Aerobic site: five irrigation treatments

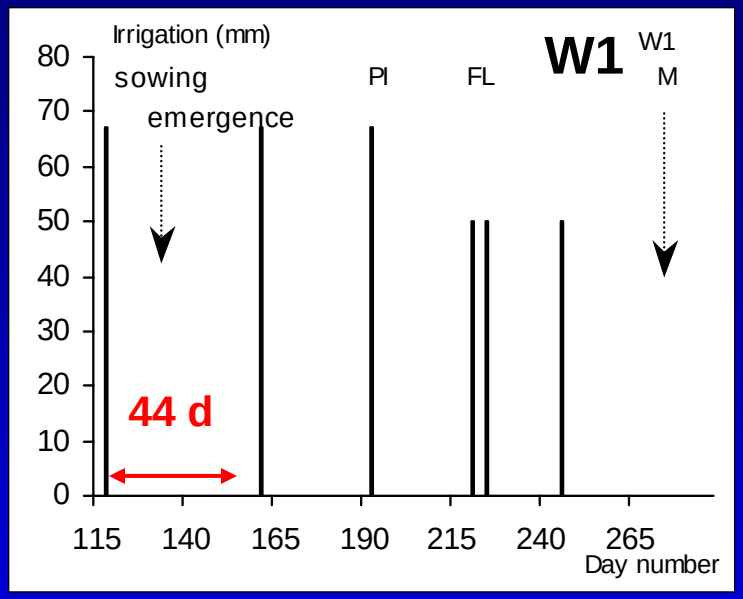
Aerobic site: sandy soil with > 20 m deep groundwater

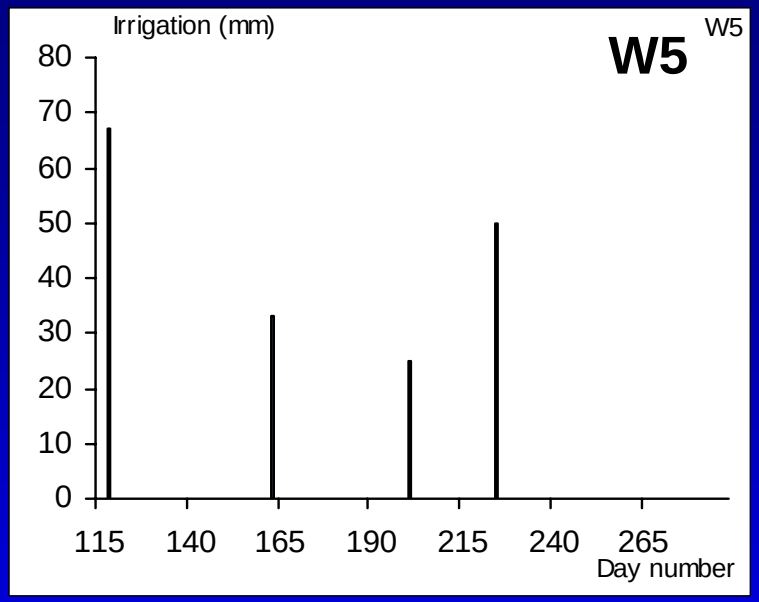


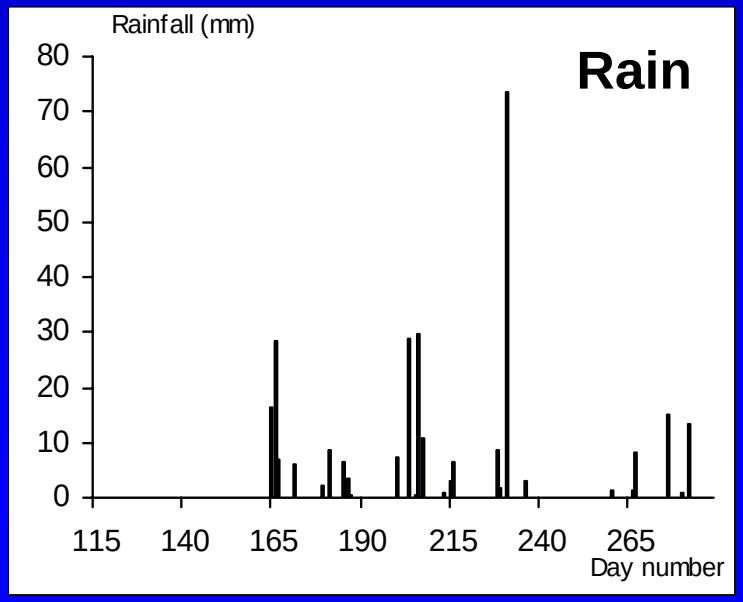
Bulk density	
2001	2002
1.41	1.23
1.31	1.35
1.49	1.36
1.55	1.35
1.44	1.29
-	1.32
-	1.31
-	1.34
-	1.36
-	1.39
-	1.38
-	1.36
-	1.52
-	1.52
-	1.53
-	1.48

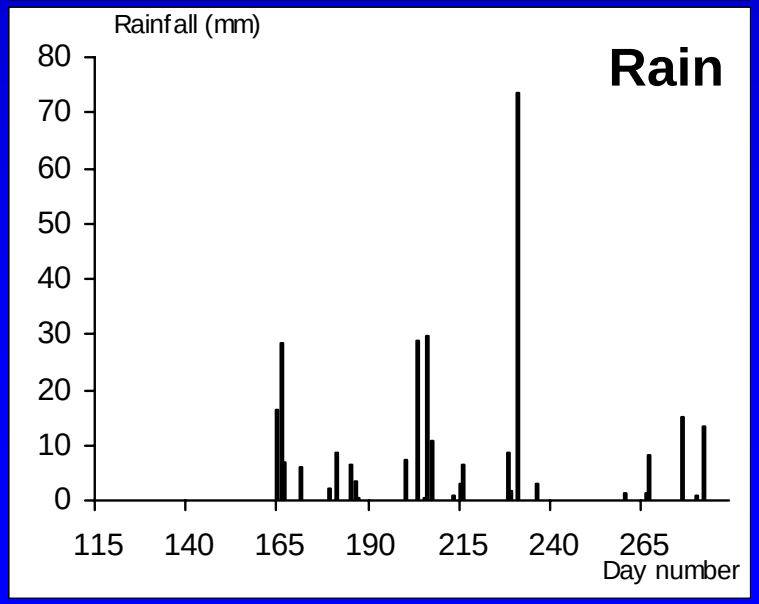
Sand **silt** **clay**

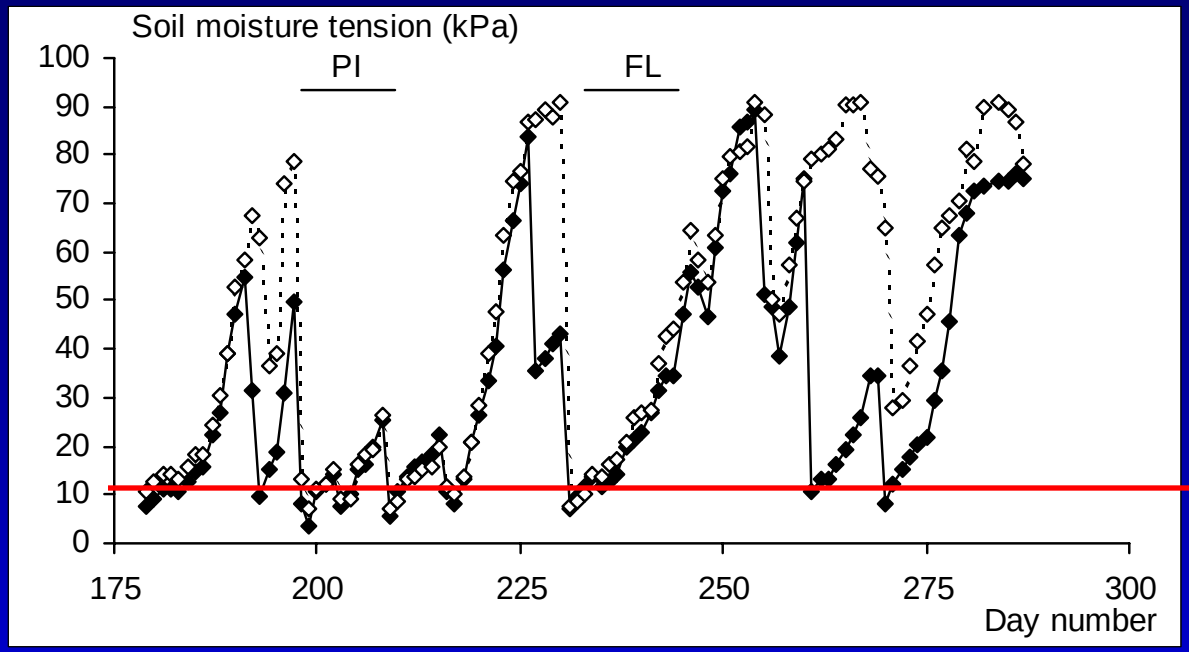
Aerobic: different amount and timing Irrigation







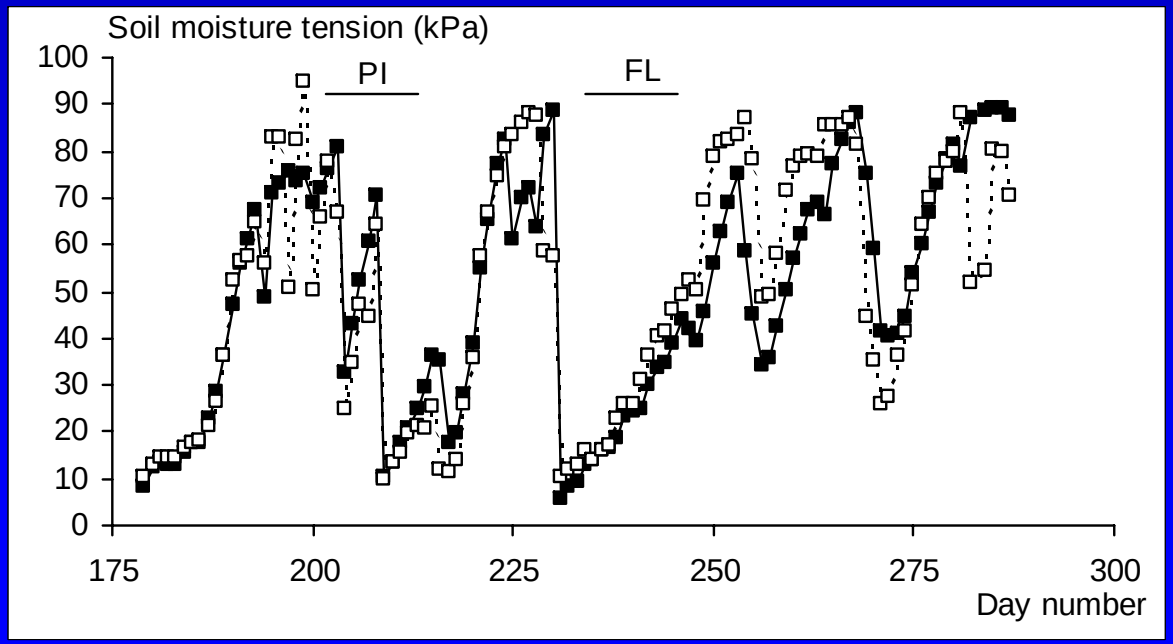




Soil moisture tension at 20 cm depth; 2001

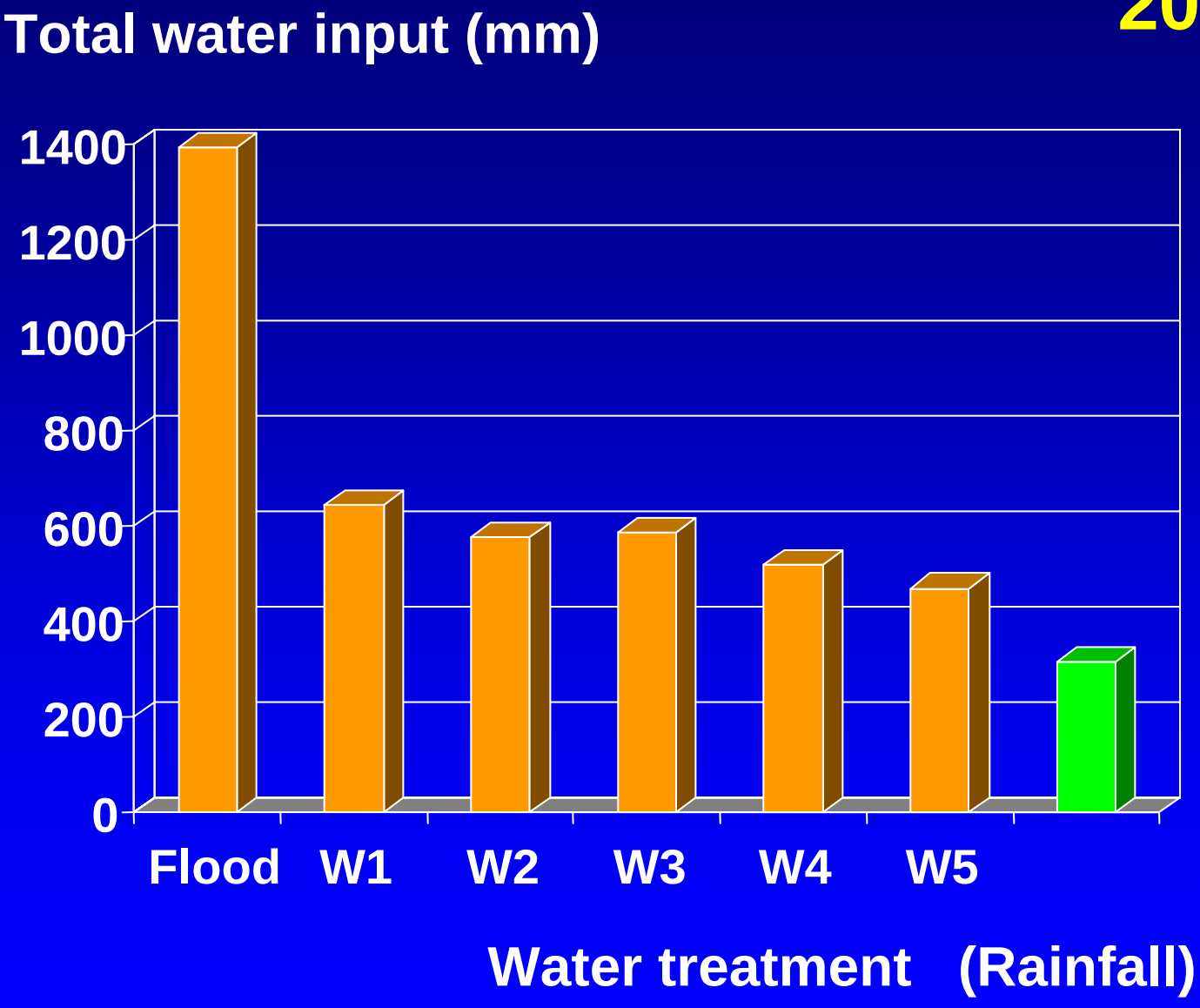
Field capacity

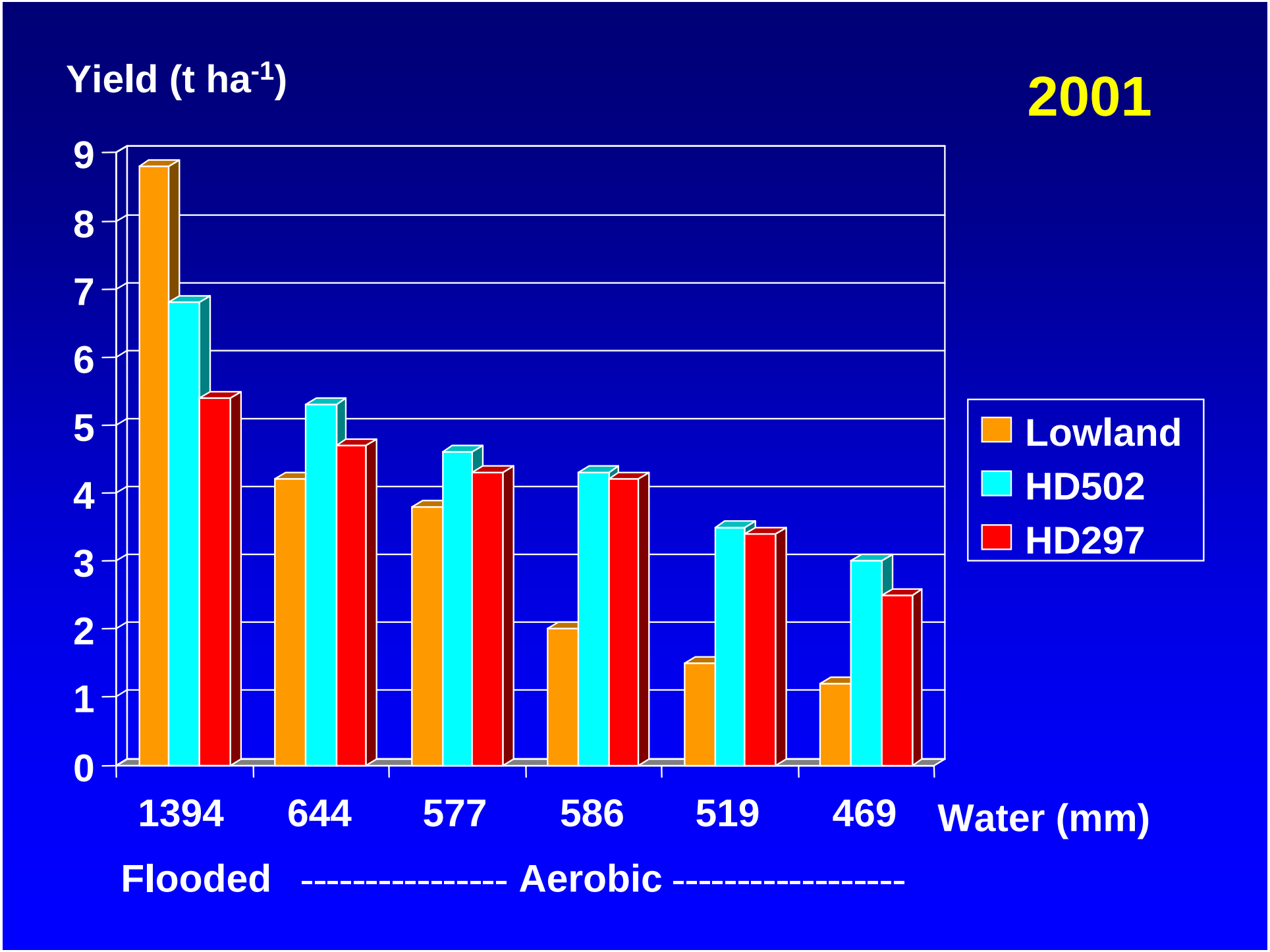
W1, W2



W3, W5

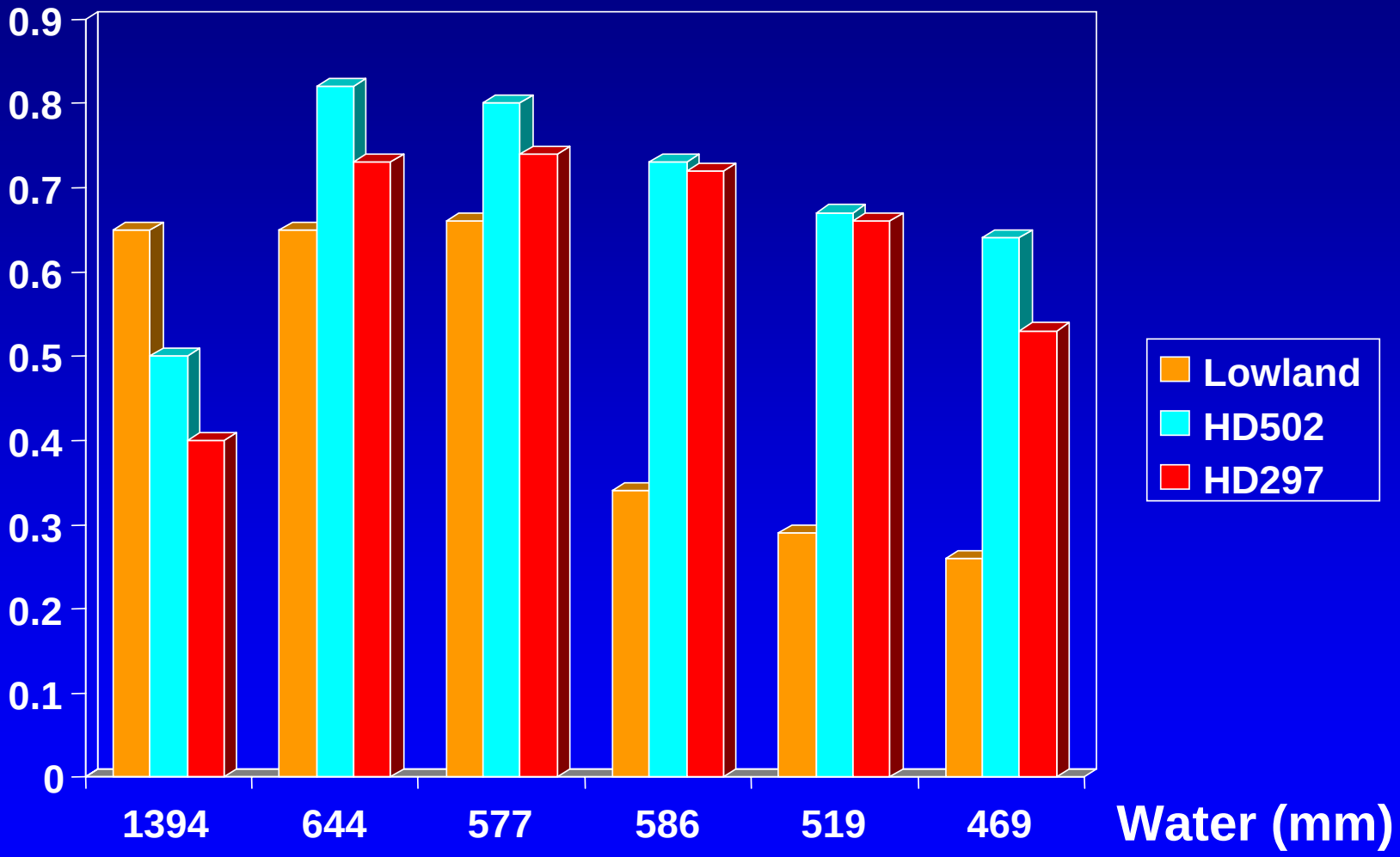
2001


Total water input (mm)
1400
1200
1000
800
600
400
200
0
Flood
W1
W2
W3
W4
W5
Water treatment (Rainfall)

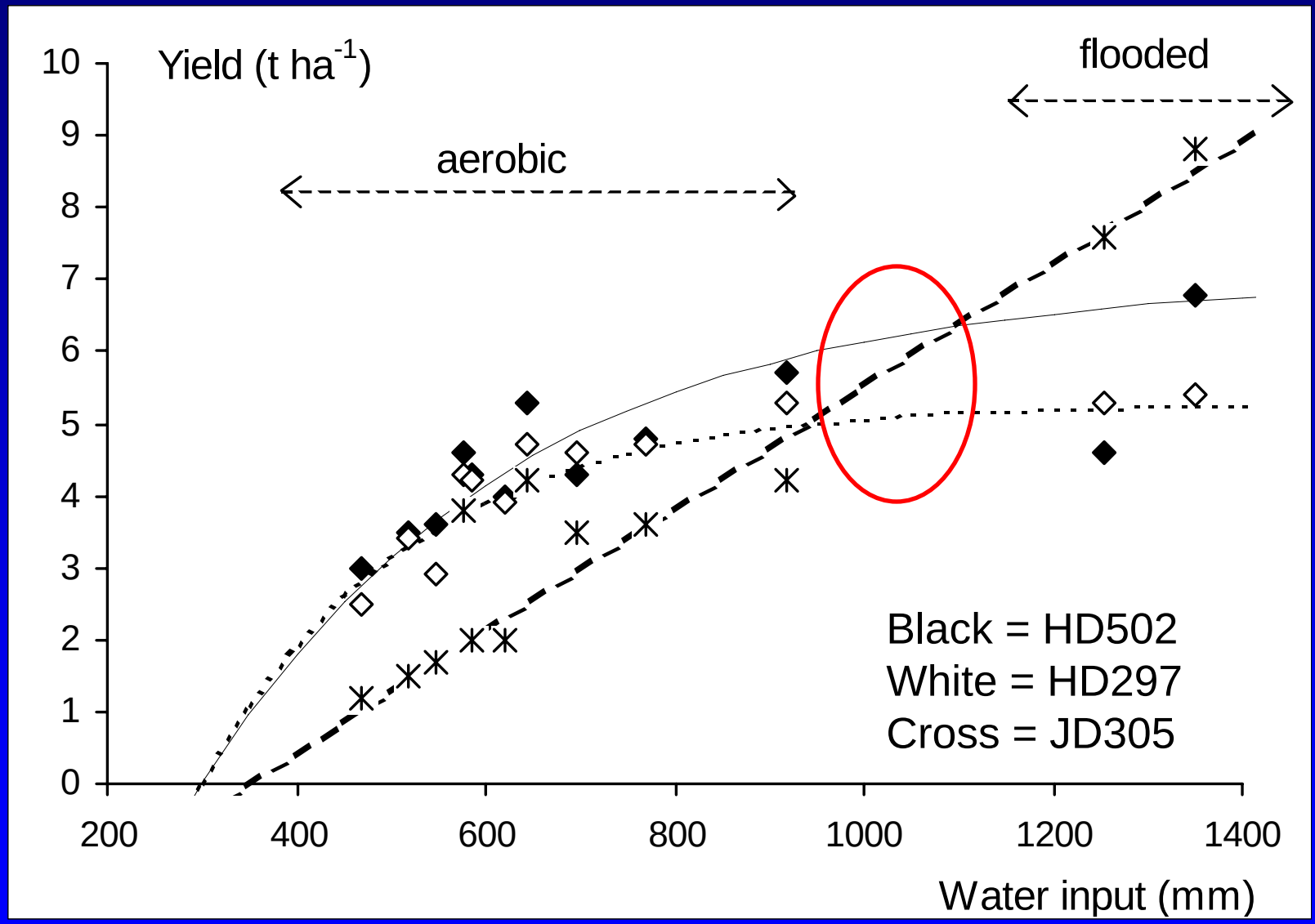

Yield (t ha-1)
2001
9
8
7
6
5
4
3
2
1
0
Lowland
HD502
HD297
1394
644
577
586
519
469
Water (mm)
Flooded ---------- Aerobic ----------

2001

Water productivity (g grain kg^{-1} total water input)

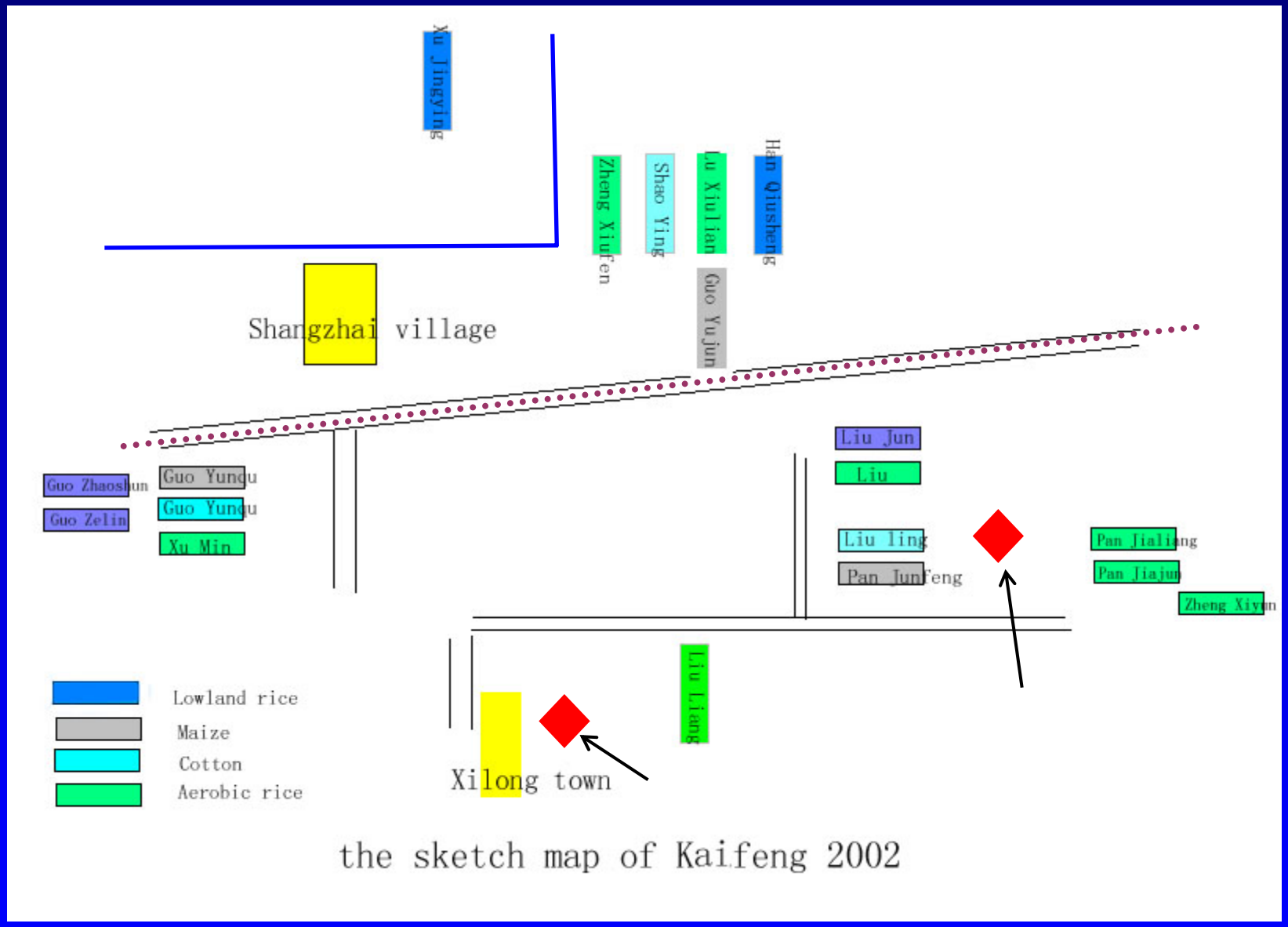


2001 and 200; all crops

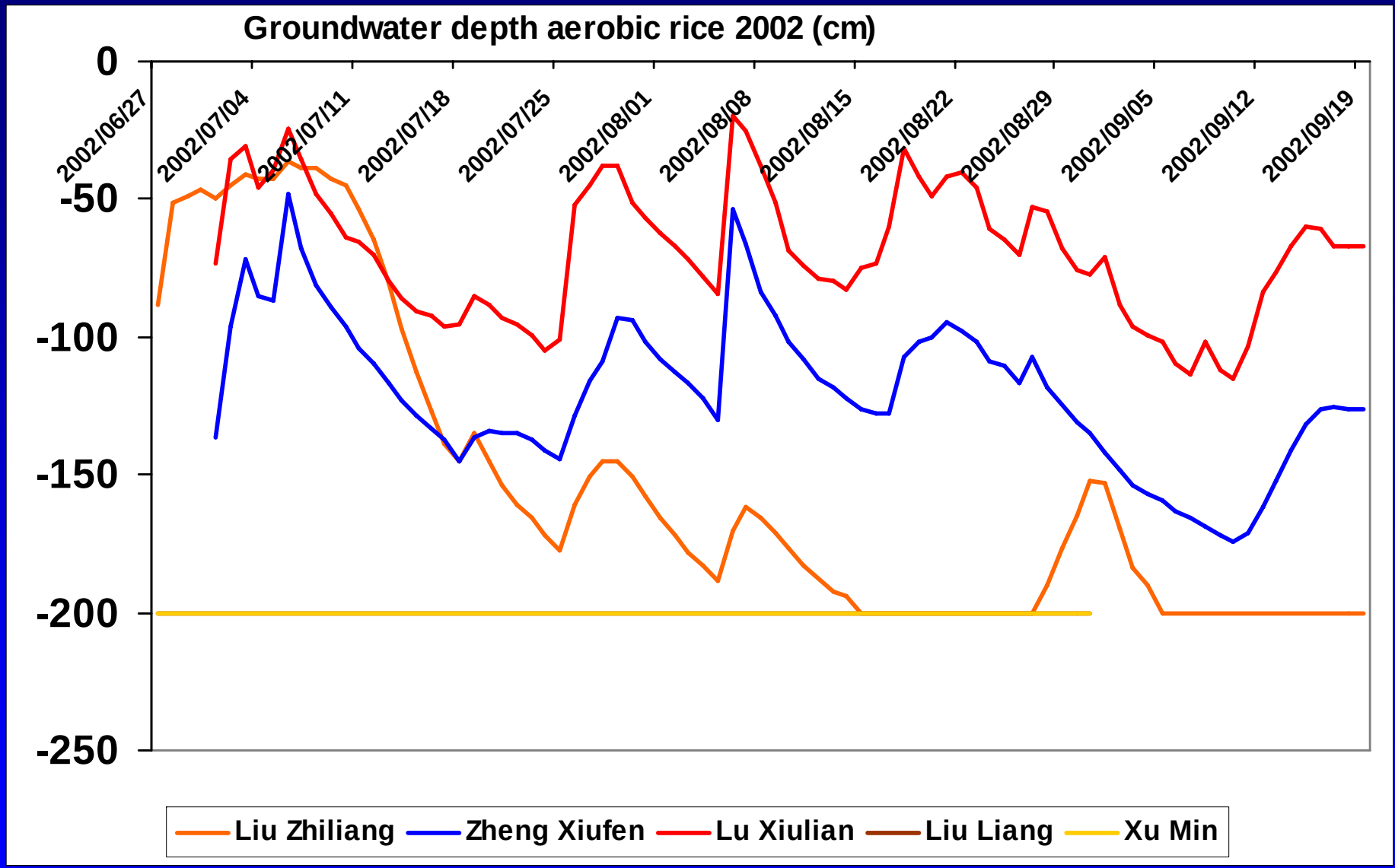


Results from farmers

Site location



the sketch map of Kaifeng 2002


Groundwater depth aerobic rice 2002 (cm)
0
-50
-100
-150
-200
-250
2002/06/27
2002/07/04
2002/07/11
2002/07/18
2002/07/25
2002/08/01
2002/08/08
2002/08/15
2002/08/22
2002/08/29
2002/09/05
2002/09/12
2002/09/19
Liu Zhiliang
Zheng Xiufen
Lu Xiulian
Liu Liang
Xu Min

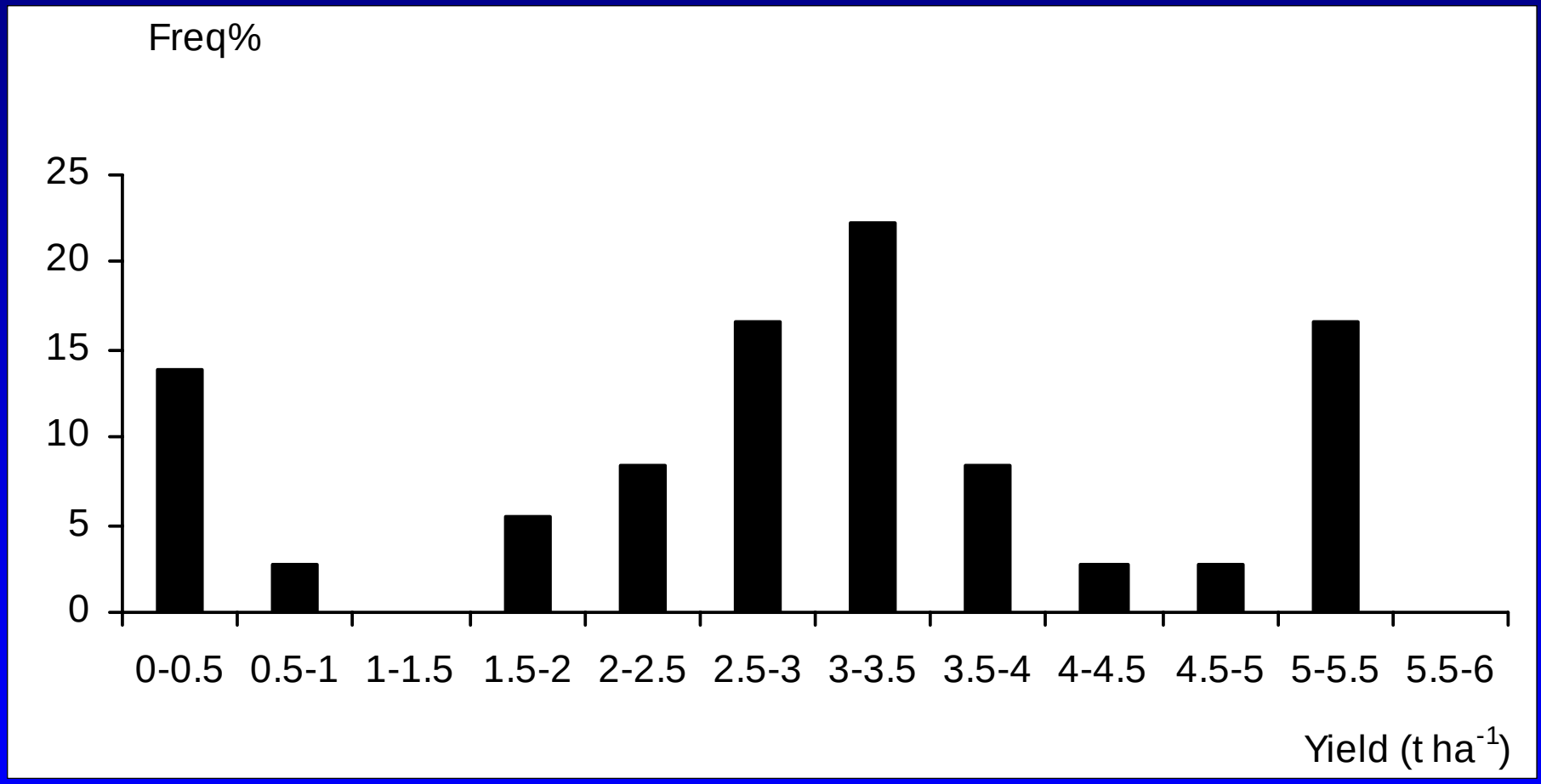
AEROBIC RICE 2002	Xu Min	Zheng Xiufen	Lu Xiulian	Pan Jiaqun	Pan Jialiang	Zheng Xiyun	Liu Liang
Field size (ha)	0.17	0.11	0.13	0.07	0.07	0.04	0.21
Grain yield (t/ha)	3.8	4.4	3.8	5.1	5.5	4.7	3.4
Irrigation (mm)	225	225	80	231	230	300	225
Rainfall (mm)	337	337	337	337	337	337	337
Total water (I + R; mm)	562	562	417	568	566	637	562
WP (g grain/ kg total water)	0.67	0.77	0.90	0.89	0.97	0.73	0.60
Input cost ($/ha)							
fertilizer	93	22	35	30	86	85	60
seeds	55	56	55	56	57	57	56
herbicide and pesticide	33	55	41	18	28	33	25
harvest	16	16	17	12	12	14	19
fuel (except irrigation)	37	37	37	36	37	38	38
irrigation (water, fuel)	21	34	10	36	32	39	37
Total input cost ($/ha)	255	221	195	189	251	265	235
Production value ($/ha)	609	707	609	826	890	756	546
Net income ($/ha)	355	562	415	637	638	492	311
Hired labor (d/ha)	4.1	4.1	4.4	9.1	9.2	9.5	3.2
Own labor (d/ha)	68	74	78	90	88	140	71
Net income, labor included	220	416	260	451	455	211	171

MEANS OF CROPS 2002	Lowland rice	Aerobic rice	Maize	Cotton
Field size (ha)	0.12	0.12	0.15	0.14
Grain yield (t/ha)	7.31	4.35	7.47	3.10
Irrigation (mm)	1407	217	77	79
Rainfall (mm)	337	337	337	337
Total water (I + R; mm)	1744	553	414	416
WP (g grain/ kg total water)	0.42	0.79	1.81	0.75
Input cost ($/ha)				
fertilizer	106	59	64	54
seeds	93	56	41	23
herbicide and pesticide	39	33	4	19
harvest	22	15	6	0
fuel (except irrigation)	25	37	11	0
irrigation (water, fuel)	94	30	13	11
Total input cost ($/ha)	379	230	140	106
Production value ($/ha)	1097	706	1071	1700
Net income ($/ha)	718	487	906	1594
Hired labor (d/ha)	0	6	0	0
Own labor (d/ha)	116	87	109	238
Net income, labor included	500	312	703	1147

Aerobic rice (2003)	Guo Erkui	Quan Yuliang	JiRuixiang	GuoGuangtian	QinFengying	Guo Guangshan
Field size (ha)	0.10	0.16	0.06	0.11	0.11	0.13
Grain yield (kg/ha)	1200	3825	2400	3750	3608	3038
Irrigation (mm)	156	159	145	169	146	162
Rainfall (mm)	674	674	674	674	674	674
Total water (I+R, mm)	830	833	818	842	820	836
Water productivity (g/kg)	0.14	0.46	0.29	0.45	0.44	0.36
Input costs ($/ha)						
Fertilizer	100	125	70	88	158	70
Seeds	33	28	14	30	30	31
Herbicide and pesticide	20	88	30	71	131	52
Hired labor	0	0	22	0	0	0
Harvest	6	19	4	12	5	9
Ploughing etc.	40	20	26	35	23	53
Irrigation (fuel, oil)	25	9	17	26	23	23
Total input costs ($/ha)	224	289	183	263	370	238
Production value ($/ha)	210	669	420	656	631	532
Net income ($/ha)	-14	381	237	394	262	293
Own labor (d/ha)	63	88	52	80	97	69
Net income (w lab) ($/ha)	-129	217	140	246	82	165

Crop means (2003)	Lowland	Aerobic	Maize	Cotton
Field size (ha)	0.11	0.11	0.56	0.16
Grain yield (kg/ha)	3675	2970	5705	1233
Irrigation (mm)	476	156	0	76
Rainfall (mm)	674	674	674	674
Total water (I+R, mm)	1149	830	674	749
Water productivity (g/kg)	0.32	0.36	0.85	0.16
Input costs ($/ha)				
Fertilizer	143	102	56	59
Seeds	37	28	27	65
Herbicide and pesticide	68	65	13	36
Hired labor	31	4	23	0
Harvest	20	9	4	0
Ploughing etc.	23	33	5	3
Irrigation (fuel, oil)	57	21	0	12
Total input costs ($/ha)	378	261	129	175
Production value ($/ha)	643	520	856	873
Net income ($/ha)	265	259	727	699
Own labor (d/ha)	162	75	41	173
Net income (w lab) ($/ha)	-34	120	651	379

Farmers' yield, Kaifeng 2006. N = 36



Destroyed cotton and maize fields by flooding, 2004

Destroyed sesame and maize fields by flooding, 2002

Farmers' feedback (Oct 2004)

- Yields 3-6 t ha^{-1}; should be 6 in 'normal year'
- Any yield good with flood years (failure in 2004 maize, cotton,..)
- Good quality
- Easy to manage
- Less labor requirement
- More extension and support needed on management
- Weed control important

Tropical aerobic rice
Results field experiments

IRRI, Philippines: long-term sustainability experiment (compare flooded-aerobic rice) Heavy clay soil (60% clay!)

Objectives:

1. **Quantify yield potential, water use and water productivity of rice varieties under aerobic conditions**
2. **Quantify long-term yield stability**

Three treatments:

- **Aerobic in dry season – aerobic in wet season**
- **Aerobic in dry season – flooded in wet season**
- **Flooded in dry season – flooded in wet season**

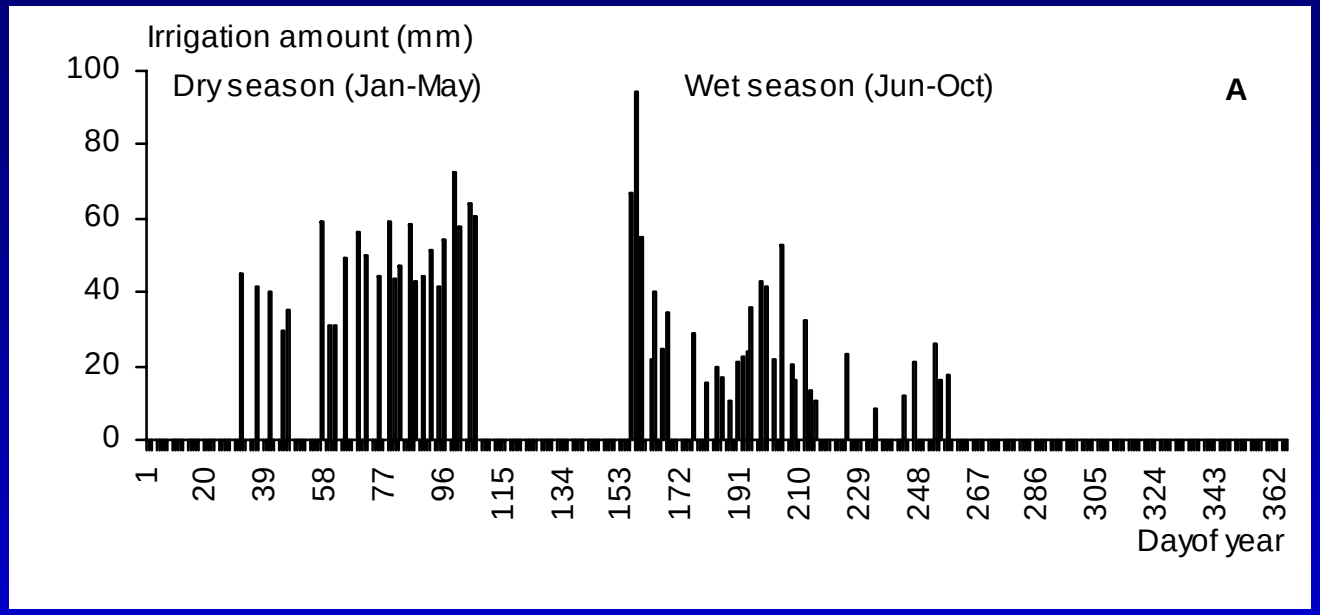
Varieties:

1. Apo under "full" N (120 kg ha^{-1}) and zero N

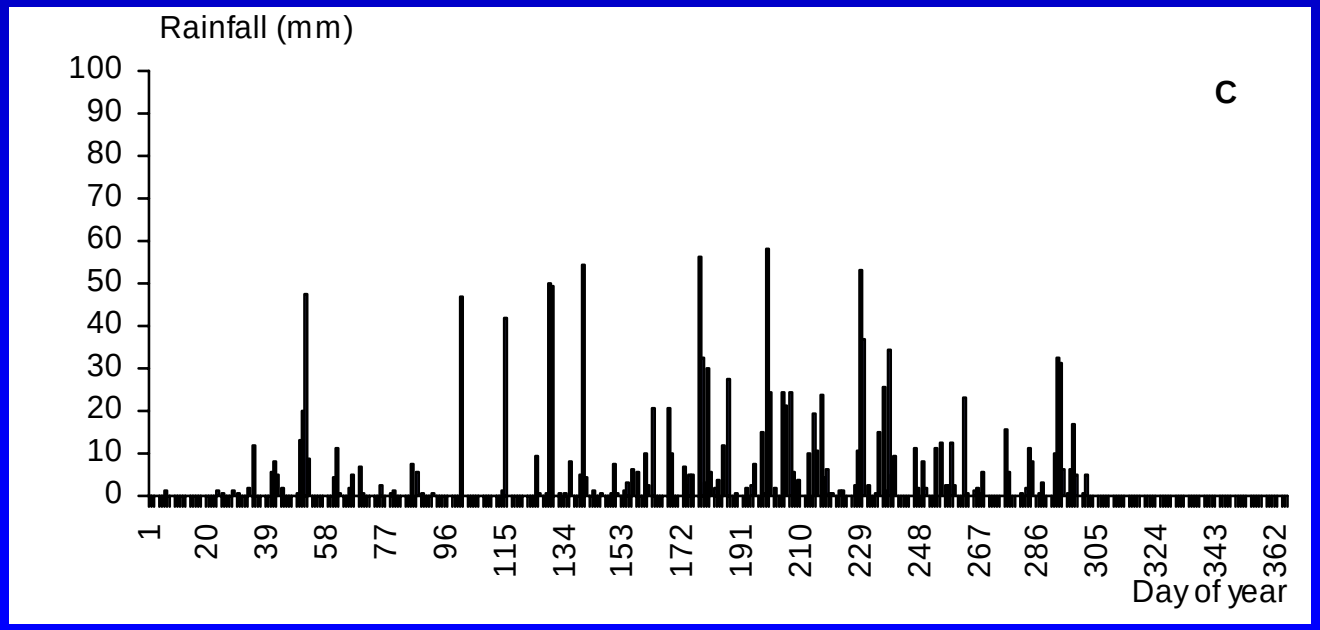
2. Different varieties under full N

Flooded 2001

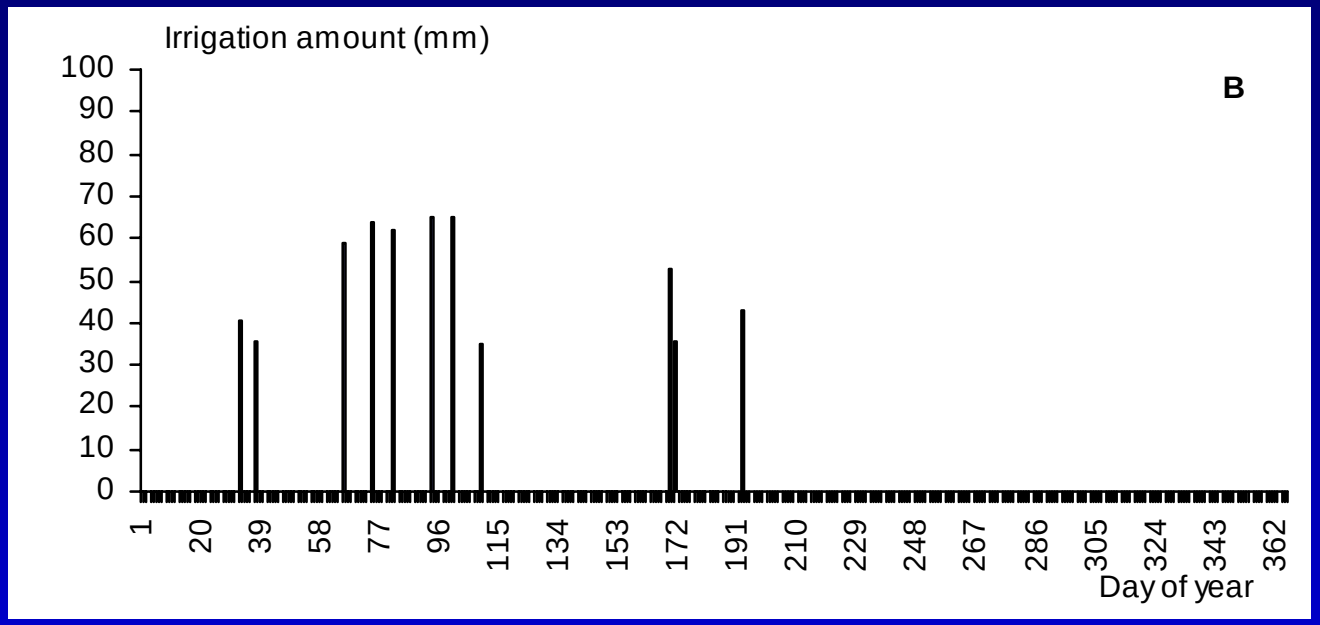
Irrigation



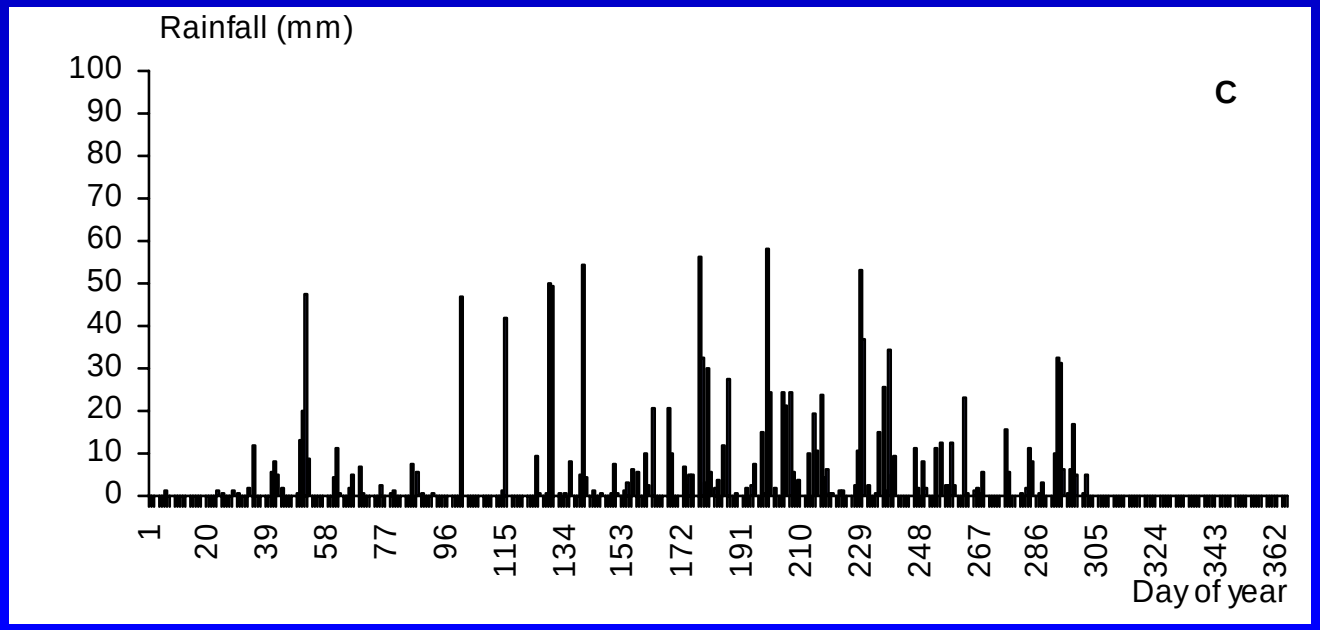
Rainfall



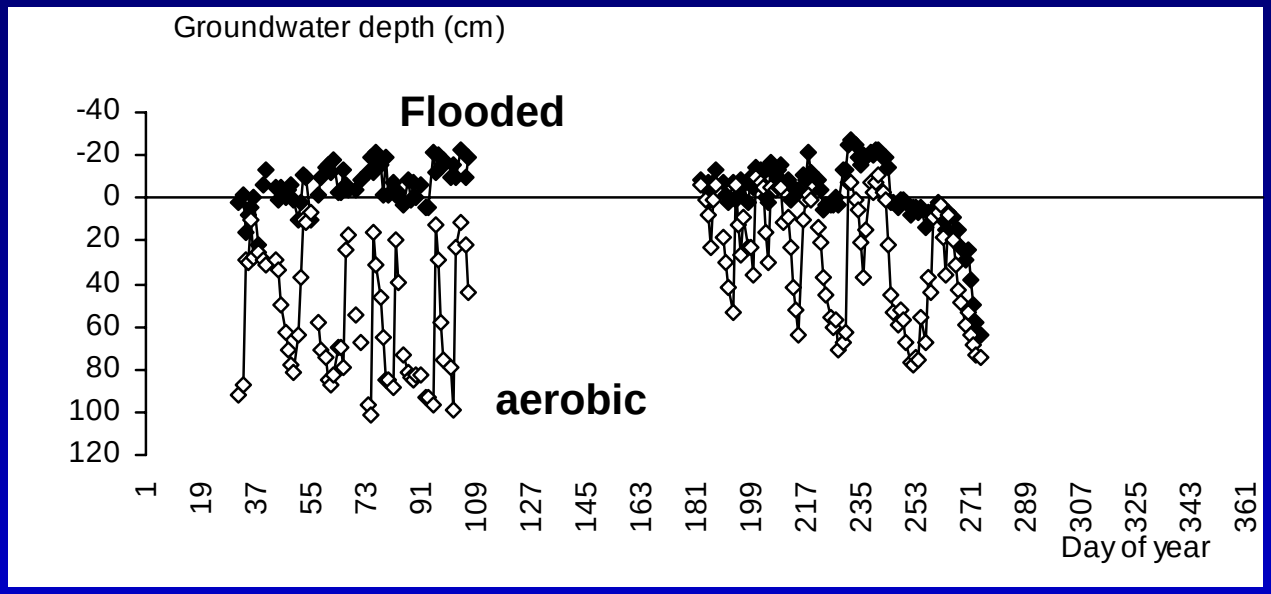
Aerobic 2001



Irrigation

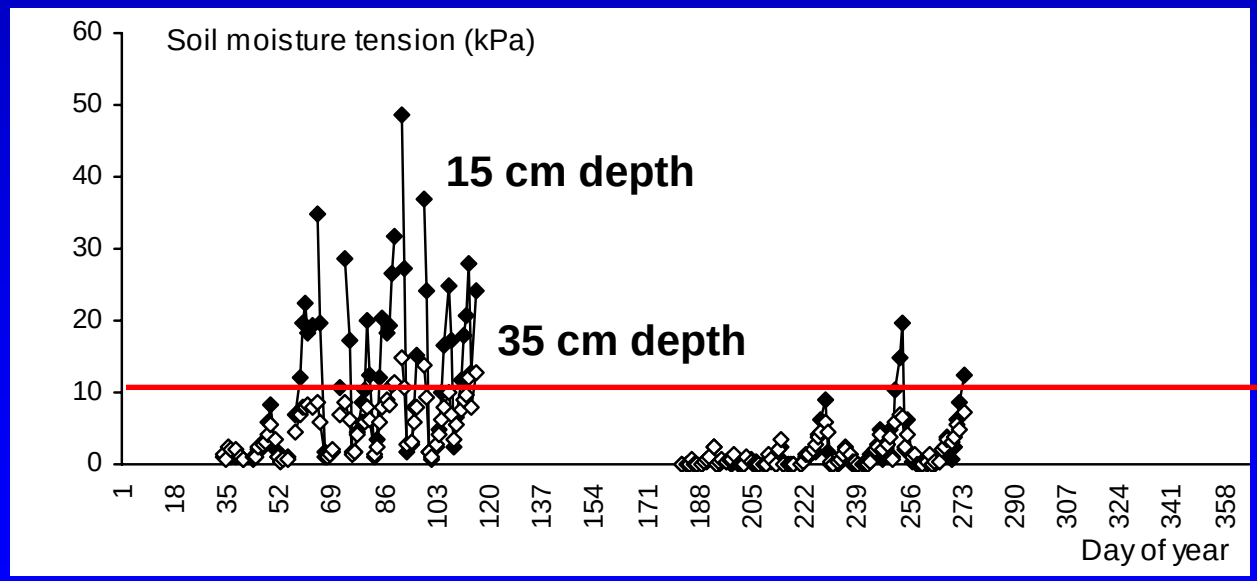


Rainfall



2001

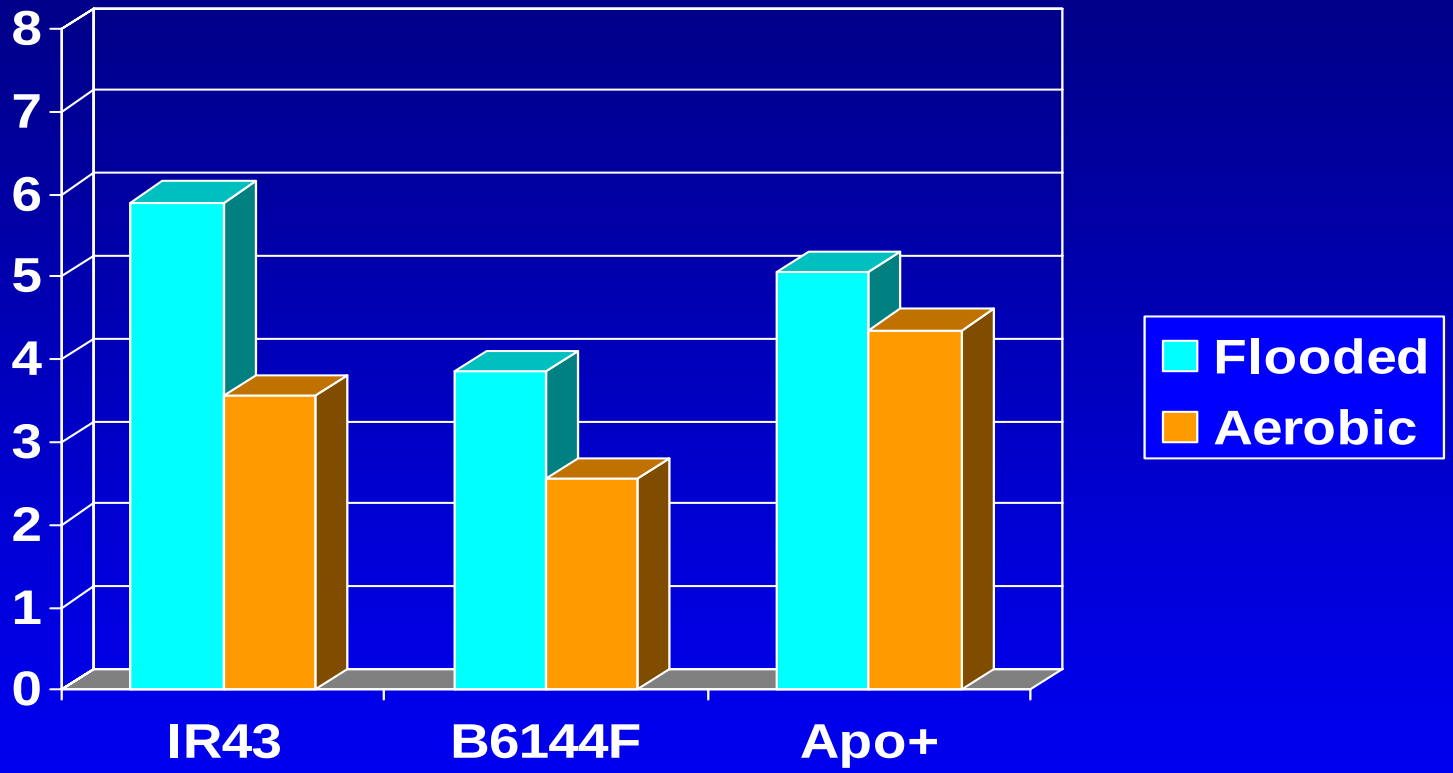
Groundwater



Soil moisture tension in Aerobic plots

Field capacity

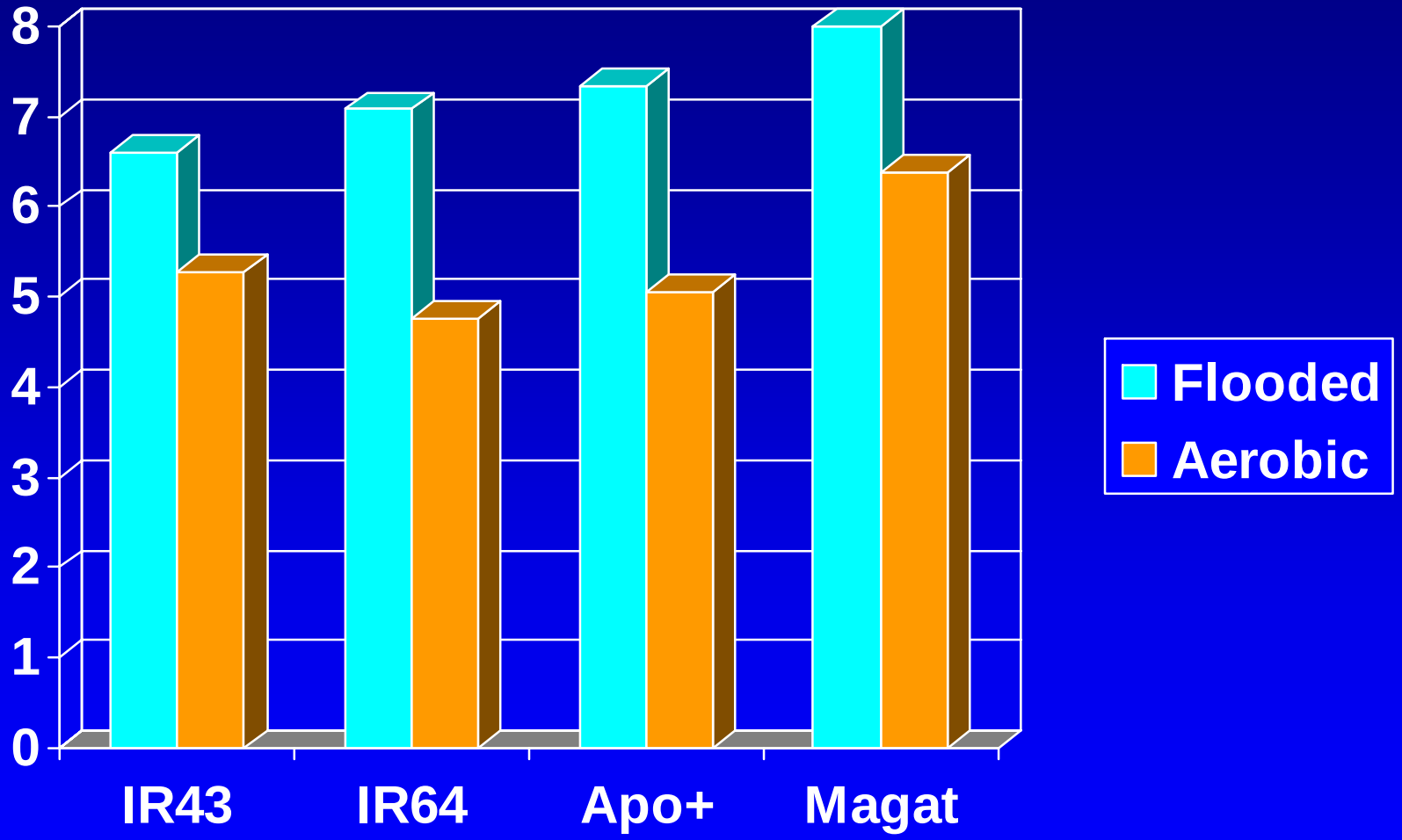
IRRI, 2001 DS: yield (t ha^{-1}) in K6/7



Fertilizer: 180-60-40 kg ha^{-1} NPK

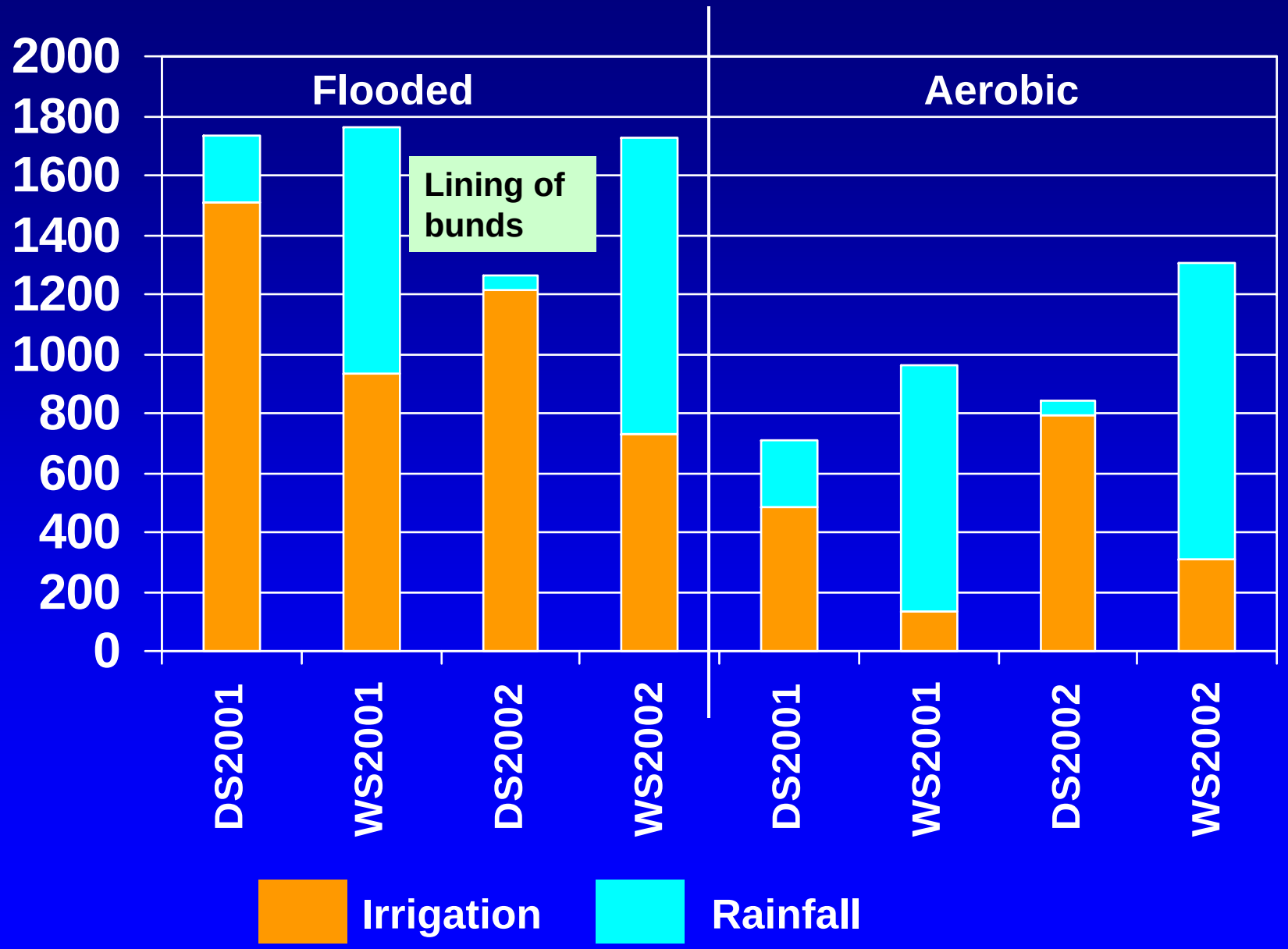
Pests and diseases: mole crickets (aerobic), stem borer, sheath blight; lodging in B6144F

IRRI, 2002 DS: yield (t ha^{-1}) in K6/7

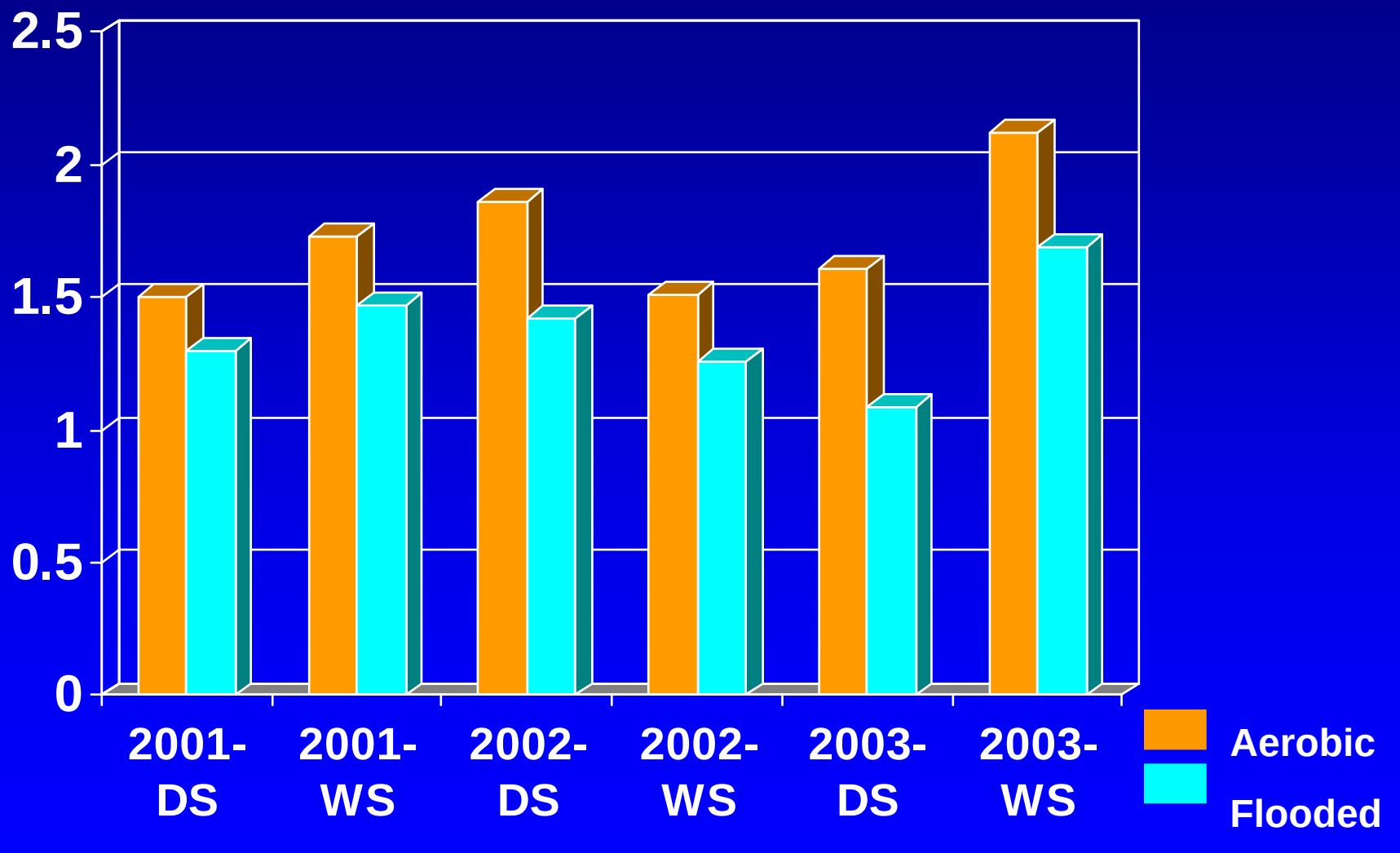


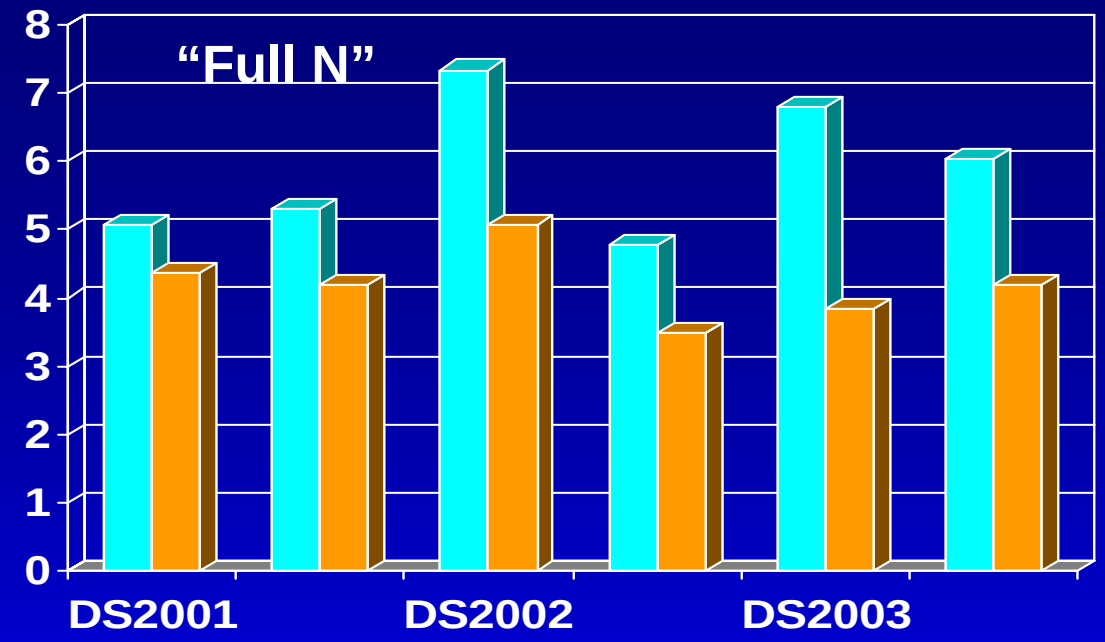
Fertilizer: 120-60-40 kg ha^{-1} NPK

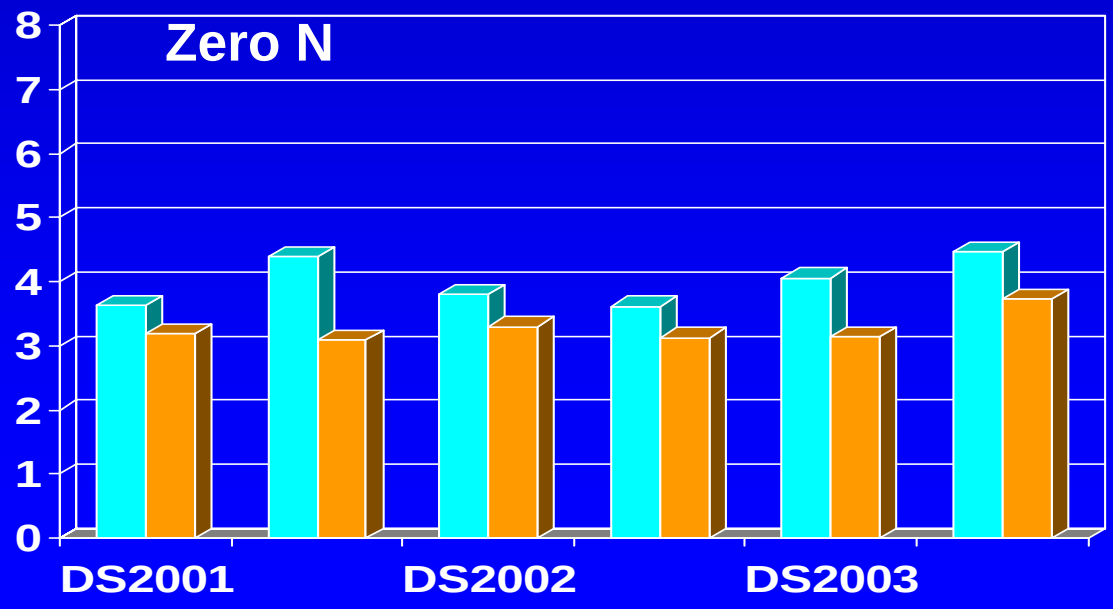
Water input, including land preparation (mm)



Water productivity Apo (g grain kg^{-1} water)







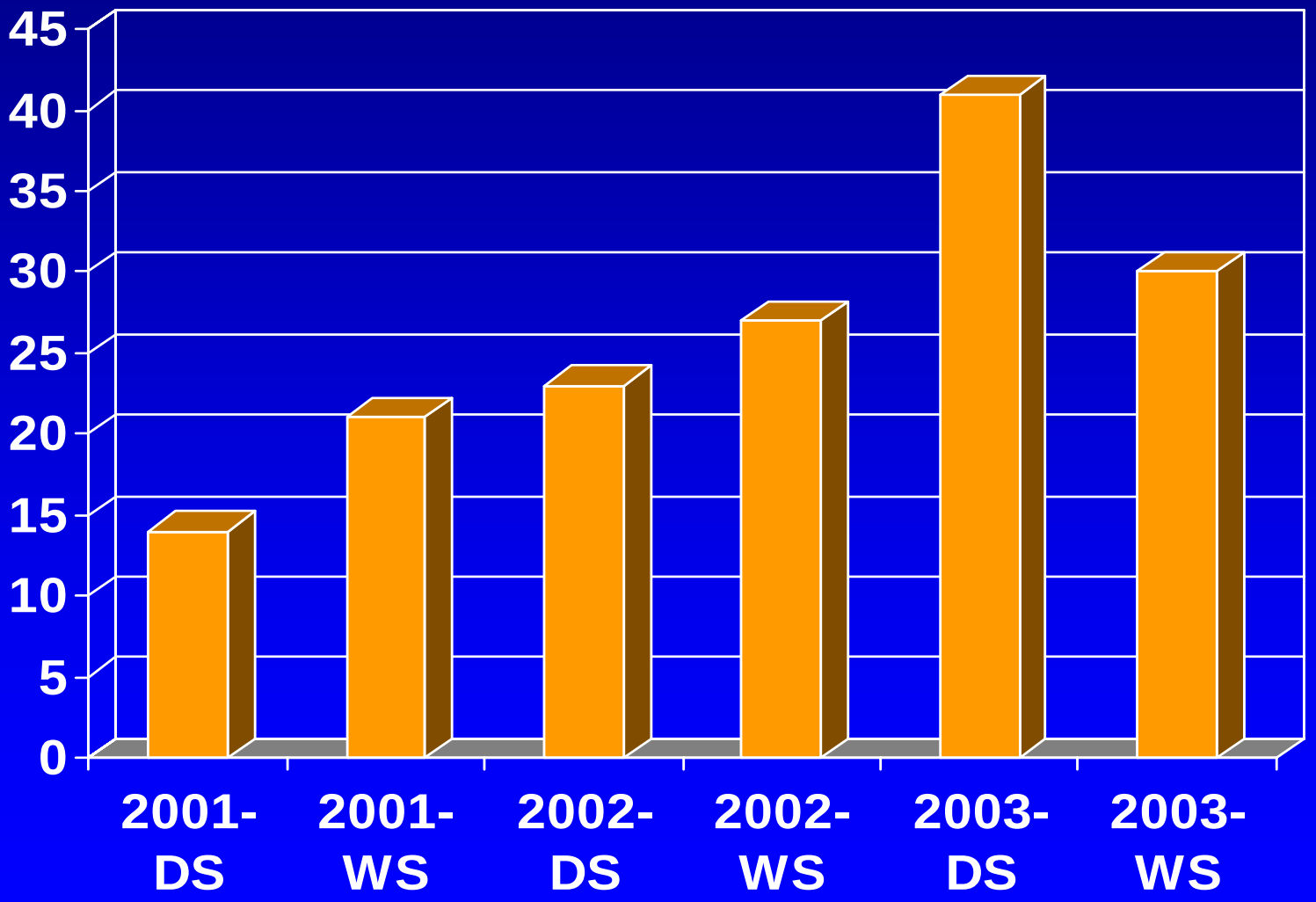
Yield stability

Apo (t ha^{-1})

Aerobic

Flooded

Aerobic yield stability % reduction from flooded



Results from farmers

Farmer-participatory R&D, central Luzon

1. Participatory variety Selection (PVS)

2. Crop establishment: traditional technology (Moldboard plough, Lithao, hand-dibbling)

3. Automated seeder with basal fertilizer application

- Labor saving
- Efficient fertilizer use?

4. Weed control: traditional technology (plough, Lithao,)

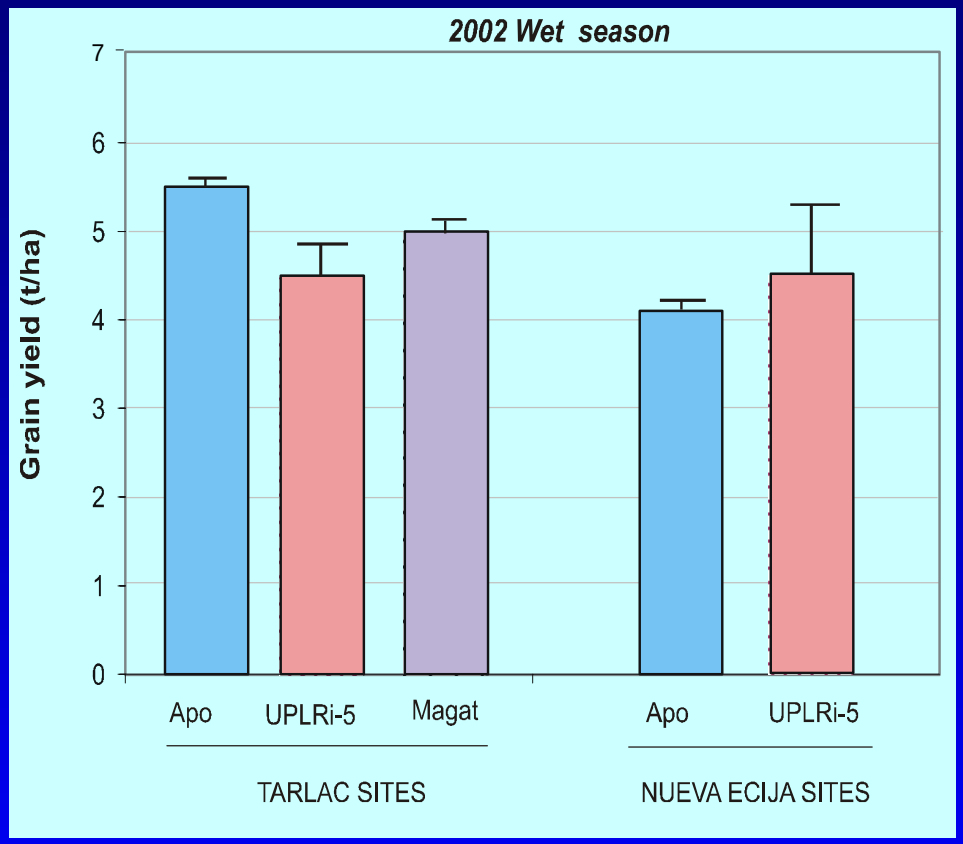
Farmer innovation

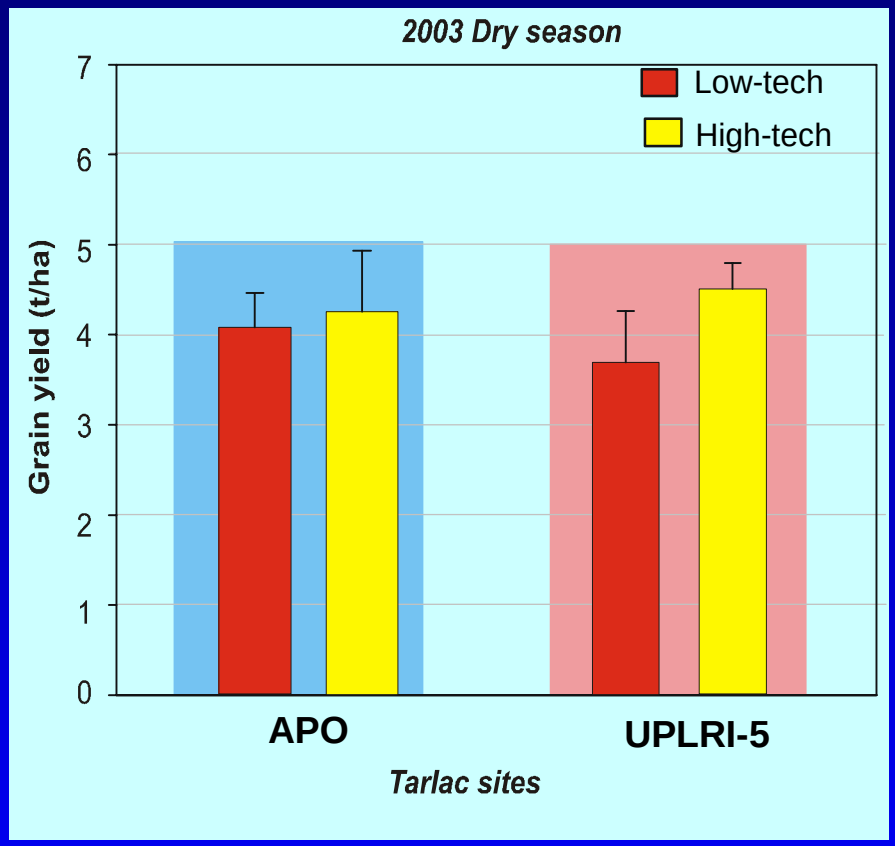
5. Irrigation and fertilizer management: amount and timing

Initial results

- Varieties with 5-6 t ha^{-1} yield potential
- Farmers can get 4-5 t ha^{-1} by farmers in wet season
- Some 30-50% less water than flooded rice
- Yield decline with continuous cropping
- Many problems in dry season: nematodes, micronutrients, soil-borne diseases, heat stress

Yield WS 2002 - DS 2003 (t ha^{-1}), Philippines





Yield range in WS:
APO : 4.1 - 5.9 t/ha
UPLRI-5 : 4.0 - 5.6 t/ha
Magat : 4.5 - 5.4 t/ha

Yield range in DS:
APO : 2.0 – 6.6 t/ha
UPLRI-5 : 2.2 – 5.3 t/ha


Some farmers results aerobic rice (DS 2003)

Nematodes….

Conclusions “aerobic rice”

1. Identified varieties with yield potential of 5-6 t ha^{-1}, using about half the water used in lowland rice (tropics: Apo, Magat, UPLRI5; China: HD502, HS297)
2. Chinese varieties more drought-resistant than Philippine varieties (dryer soil conditions!)
3. Initial management recommendations that can deliver 4.5-5.5 t ha^{-1} in farmers’ fields
4. Under water-short conditions, aerobic rice is attractive option: higher $ returns per unit water use than flooded lowland rice
5. Urgent to develop crop rotations (nematodes!) and good management practices (water, nutrients, weeds)