Groundwater Irrigated Rice : A Techno-Economic exploration of the possibilities of producing 'More Rice with Less Water'

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Expansion of Rice into Moisture Deficit Areas

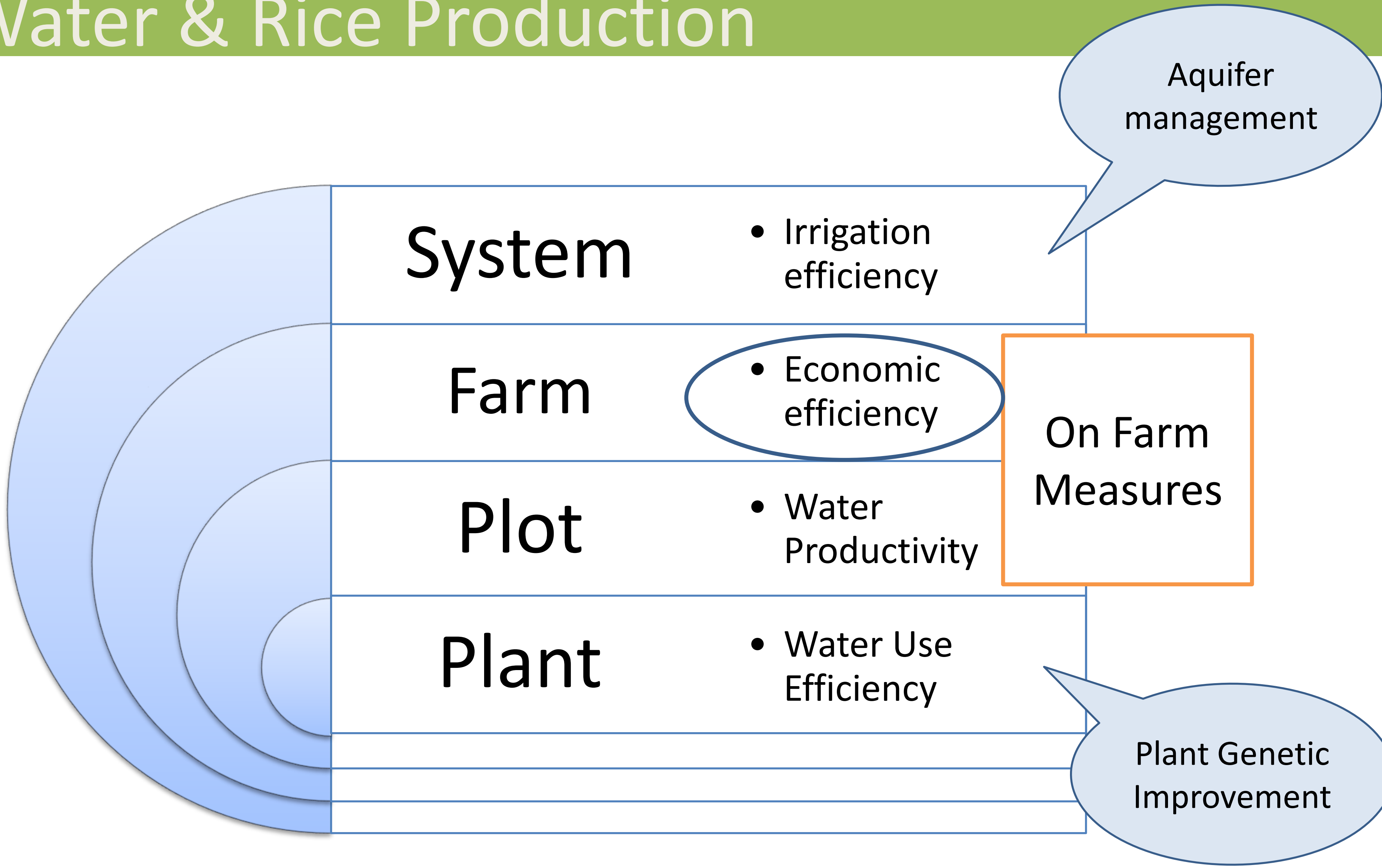
Distribution of rice area in the Agro-Climatic Zones in India (figures in percentage)		
Districts with predominantly →	**Rainfed Rice**	**Irrigated Rice**
Arid (Mi<=-66.7)	0.00	4.10
Dry Semi Arid (-66.6<=MI<=-50)	0.50	10.83
Wet Semi Arid (-49.9<=MI<=-33.4)	2.84	12.77
Dry Sub Humid (-33.3<=MI<=-0)	16.20	34.48
Sub Humid (0.1<=MI<=20)	1.56	3.28
Humid (20.1<=MI<=99.9)	3.55	2.85
Per Humid (MI>=100)	5.12	1.92
All ACZs	29.78	70.22
Source: computed from secondary sources		

- **No technological differentiation was made in rice production when rice expanded to moisture deficit areas or rice produced under scarce groundwater situations.**

Emerging Global Imperatives in Irrigated Rice Cultivation

- Several irrigated rice areas are already facing water scarcity and the problem is projected to result into physical and economic water scarcities (Tuong & Bouman 2003).
- 'Increase in rice production to be accomplished under increasing scarcity of water' (Bouman, Humphreys, et al. 2007) or
- 'producing **more rice with less water** in irrigated systems' becomes imperative (Guerra et al. 1998).

Water & Rice Production



- Increasing **Water Productivity may not imply economic efficiency;** increased water productivity with reduced economic efficiency can not incentivize farmers' uptake of technology. Dave (2005)

Response Options

- Preventing water losses (crack ploughing, bunds repair and other measures to prevent water losses).
- Water management during crop-growth stages
  - Saturated Soil Culture
  - **Alternate Wetting and Drying**
  - Aerobic Rice

Reducing water application during crop growth stages is an important first step to reduce water consumption in rice cultivation

System-Wide Initiative on Water Management (IWMI) concluded that 'continuous submergence is not essential for obtaining high rice yields' (Guerra et al. 1998)

Conventional recommendations 1: IRRI

- After crop establishment, **continuous ponding of water generally provides the best growth environment** for rice and will result in the highest yields. **Flooding also helps suppress weed growth**, **improves the efficiency** of use of nitrogen and, in some environments, helps protect the crop from fluctuations in temperatures.

- After transplanting, water levels should be **around 3 cm initially, and gradually increase to 5-10 cm with increasing plant height.** With direct wet seeding, the soil should be kept just at saturation from sowing to some 10 days after emergence, and then the depth of ponded water should gradually increase with increasing plant height.

Source : http://www.knowledgebank.irri.org/ *(emphasis added)*

Cautious recommendation on AWD : IRRI

- "**Under certain conditions**, allowing the soil to dry out for a few days before reflooding can be beneficial to crop growth. In certain soils high in organic matter, toxic substances can be formed during flooding that can be removed through intermittent soil drying. Intermittent soil drying promotes root growth which can help plants resist lodging better in case of strong winds later in the season. Intermittent soil drying can also help control certain pests or diseases that require standing water for their spread or survival, such as golden apple snail. In China and Japan, farmers often practice a period of 7-10 days "mid-season drainage" (during which the soil is left to dry out) during the active tillering stage. This practice should reduce the number of excess and nonproductive tillers, but these benefits are not always found. Intermittent soil drying is also used in the System of Rice Intensification (SRI) and is suggested to lead to improved soil health. Other research, however, shows that nonflooded soil promotes the occurrence of certain soils pests such as nematodes. **Farmers who want to experiment with intermittent soil drying can use the practice** of Safe Alternate Wetting and Drying as starting point".

Source : http://www.knowledgebank.irri.org/ *(emphasis added)*

Recommendations in India:

Tamil Nadu Agriculture University:

Stages of crop growth	Depth of submergence (cm)
At transplanting	2
After transplanting for 3 days	5
Three days after transplanting upto maximum tillering	2
Maximum tillering to panicle initiation	2
Panicle initiation to 21 days after flowering	5
Twenty one days after flowering	Withhold irrigation

Continuous land submergence for rice is, usually, practiced due to the associated major advantages of increase in availability of nutrients and less weed management problems.

Shallow submergence of water up to 5 cm depth throughout the crop period is optimum for high yield.

Source : www.tnau.ac.in

Recommendations of ANGRAU, PAU, HAU .. Follow the same pattern.

Yield response to water availability and soil conditions:

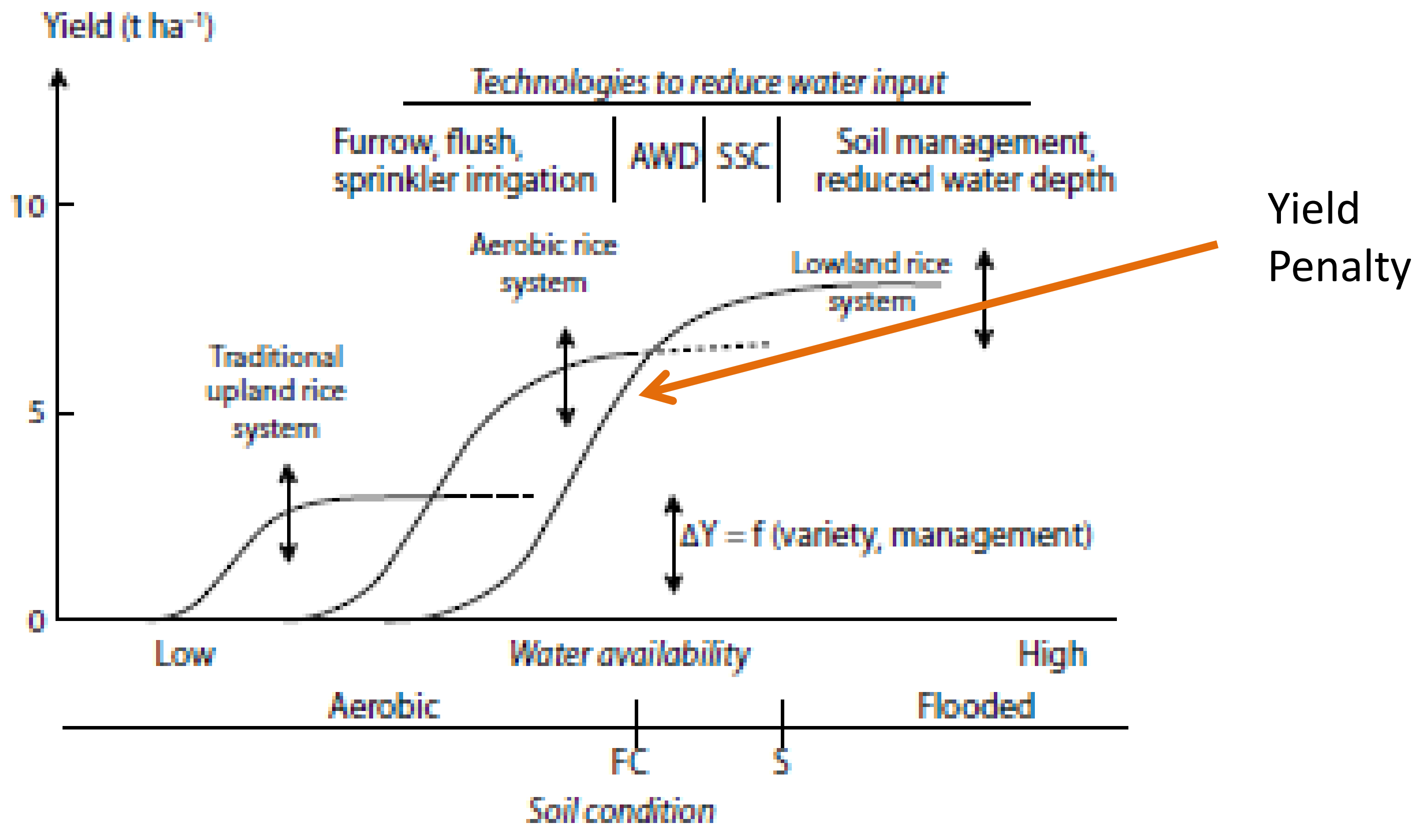
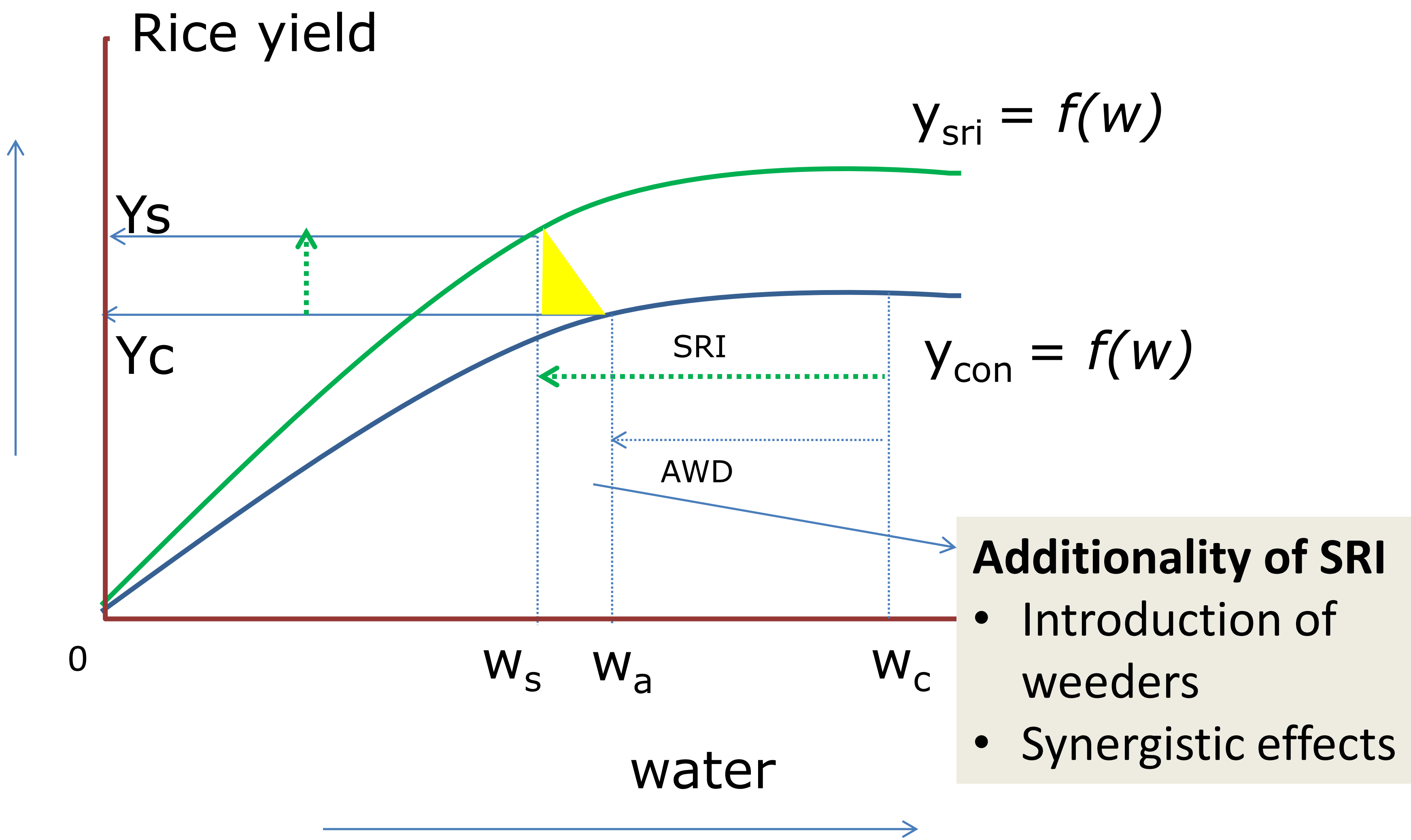


Fig. 3.6. Schematic presentation of yield responses to water availability and soil condition in different rice production systems and their respective technologies to reduce water inputs. AWD = alternate wetting and drying, SSC = saturated soil culture, FC = field capacity, S = saturation point, ΔY = change in yield. Adapted from Tuong et al (2005).

Source : Bouman BAM, Lampayan RM, Tuong TP. 2007. Water management in irrigated rice: coping with water scarcity. Los Baños (Philippines): International Rice Research Institute (as presented)

“More Rice With Less Water”



Three Minimal Conditions for Effective Farmers' Uptake of "Less Water Intensive Measures"

1. Reduction in water application
2. Increase in yields
3. Increased profitability

Central Research Question :

Is it possible to increase rice yields while reducing water use in water constrained groundwater irrigated rice cultivation in semi-arid areas?

Methodology

- Selected 7 villages in two districts of Telangana
- 41 paired plots of SRI and non-SRI (with minimal physical variation) in practicing farmers’ fields
- Season long measurement of water levels in ‘Field Water Tube’ installed in the plots
- Soil tests
- Borewell discharge
- yield measurements through crop-cutting
- supplemented by farmers’ survey.

"Field Water Tube" and Standardisation of AWD by IRRI

- A tool for famers to look into the sub-surface water levels
- Safe AWD : up to 15 cm below the surface i.e. 35 cm depth measured from the top – safe for several situations (no yield penalty)
- Farmers can experiment as per their situations and find appropriate depth

Methodology ..

- Water measurements:
  - Mean Daily Inundation Index :

  =($(n * 20 - \sum Xi)/n$)

  20= ground level (saturation level)

  -ve value = below ground level (less than saturation)

  +ve value = inundation
- Reduced the soils data using PCA
- Cluster Analysis
- Regression

Does SRI as practiced differ from the local conventional?

Practice	SRI	Conven-Tional	Total
Age of the Seedlings (Days)			
Minimum	13	16	13
Mean*	**18.66**	**22.59**	**20.57**
Maximum	25	29	29
N	41	39	80
Std. Deviation	3.12	2.47	3.412

Number of hills per sq m			
Minimum	15.67	20.33	15.67
Mean*	**18.04**	**29.18**	**23.71**
Maximum	24.33	46.67	46.67
N	26	27	53
Std. Deviation	2.38	7.43	7.87

Significant differences in perceptions in irrigation water use – after transplantation and during flowering stages

Transplantation Method (Frequency)			
	SRI	**Conv**	**Total**
Random	0	40	40
	0	**-97.6**	
Single Row	24	1	25
	-58.5	-2.4	
Square Planting	17	0	17
	-41.5	0	
Total	41	41	82
	-100	-100	
Figures in brackets are percentages			
Method of doing first weeding (Frequency)			
Hand	18	41	59
	-43.9	-100	
Using a rotary Weeder	15	0	15
	-36.6		
Both hand and rotary Weeder	8	0	8
	-19.5		
Total	41	41	82
	-100	-100	

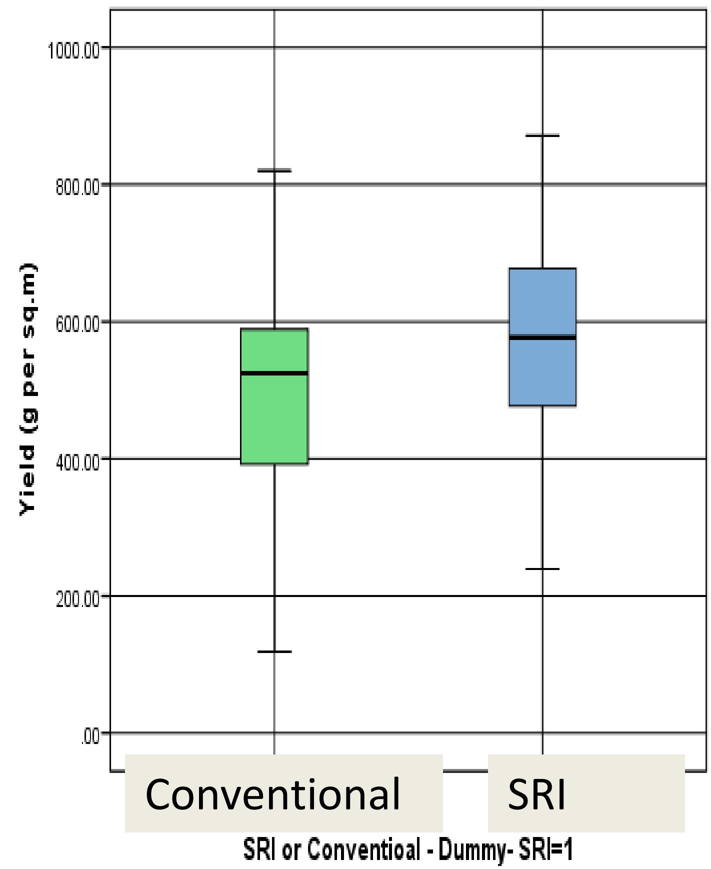
MORE RICE….?

DOES SRI INCREASE YIELD?

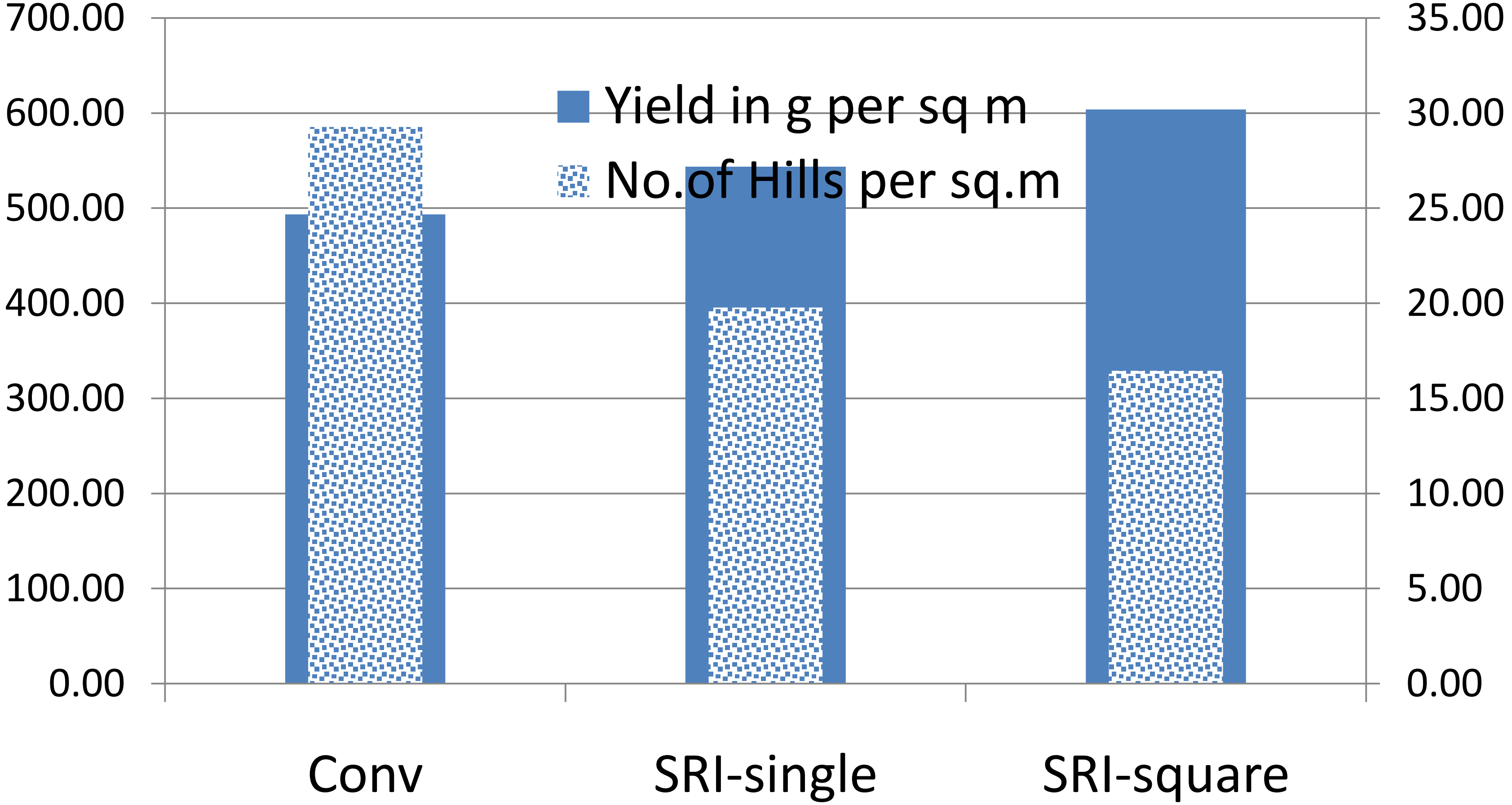
Paired Mean yield differences between SRI and Local Conventional Method

From field measurement		Mean
Yield (gm/sq.m) (p=0.01) N=32 pairs	Conventional	486.84 (167.77)
	SRI	546.91 (146.41)
	Difference	60.07
% Yield advantage over conventional		(12.34%)
From farmers' survey:		
Yield (Q per Ha) (p=0.01) N=41 pairs	Conventional	56.42 (16.27)
	SRI	62.78 (16.31)
	Difference % over conventional	6.37 (12.28%)
(Fig in parenthesis - std deviation of the mean)		

- Correlation coefficient between the two measures of yield is 0.422; significant at >95% confidence level; p=0.000.



Yield vs Planting Density



… WITH LESS WATER?

IS THERE POTENTIAL TO REDUCE WATER APPLICATION?

Recommendations in India:

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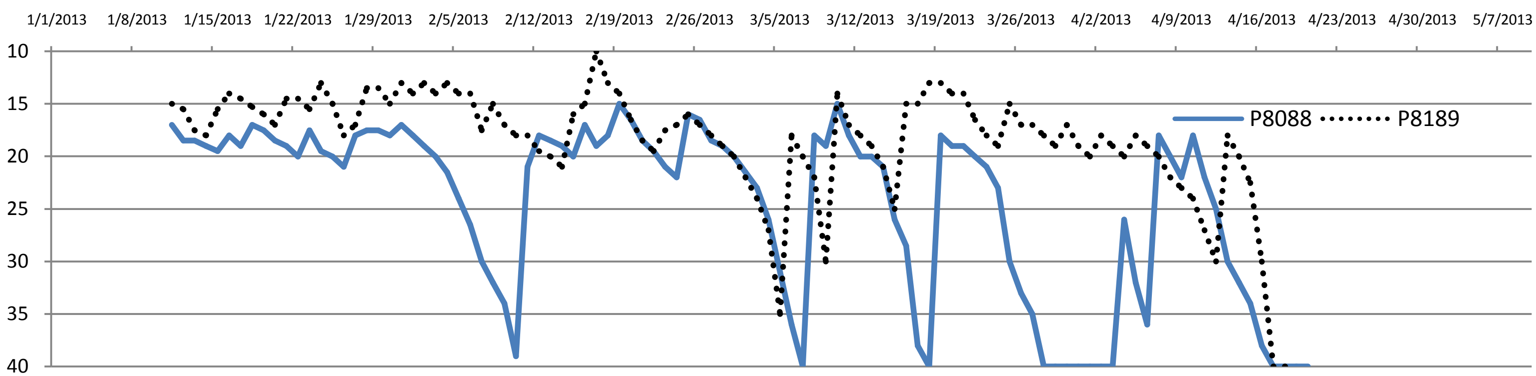
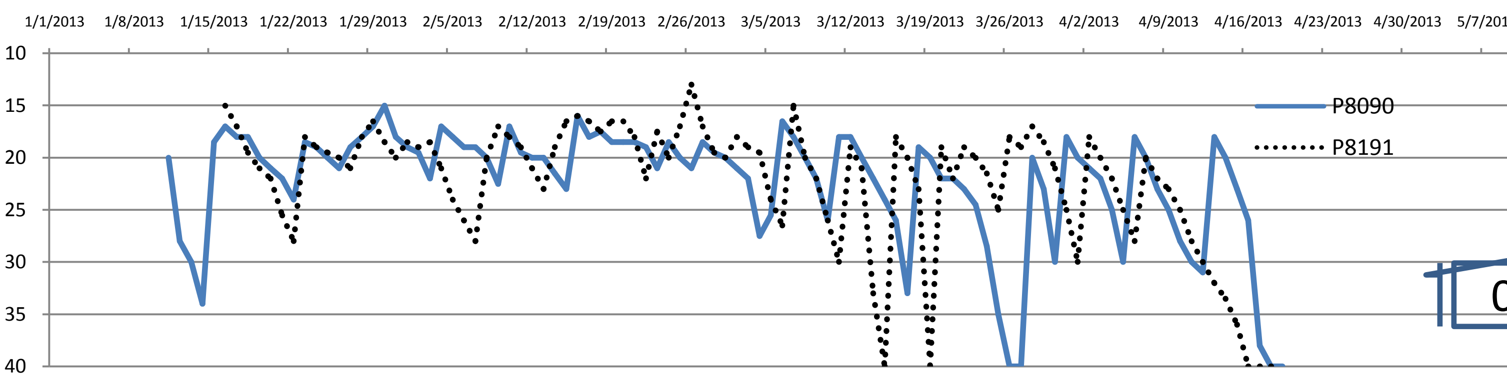
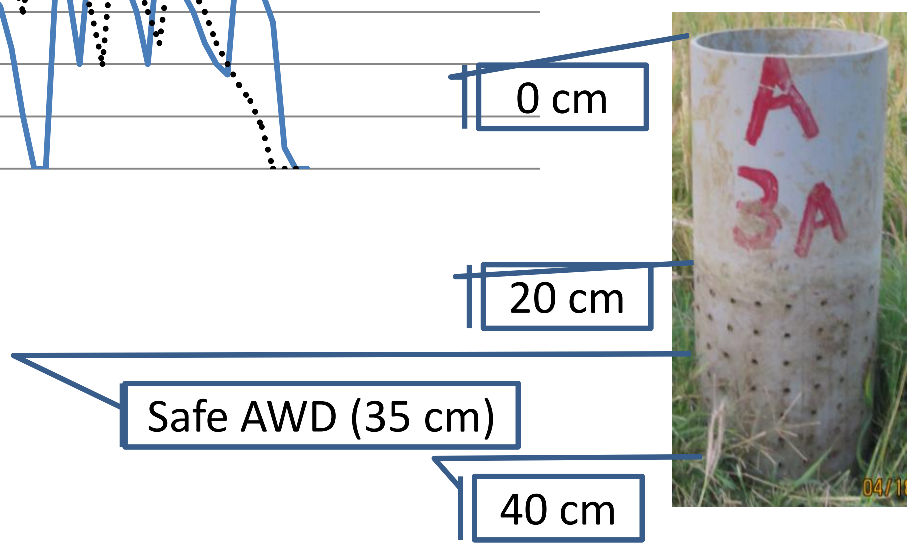
Farmers' Perceptions on Irrigation :	irrigated and drained	Irrigated and left to infiltrate	Thin film of water	Kept Inundated	TOTAL
	%	%	%	%	%
1. Vegetative Stage					
Conventional	4.9%	12.2%	43.9%	39.0%	100%
SRI	17.1%	12.2%	46.3%	24.4%	100%
TOTAL	11.0%	12.2%	45.1%	31.7%	100%
Pearson Chi-Square =4.189; p=0.242					
2. Reproductive stage*					
Conventional	0.0%	0.0%	26.8%	73.2%	100%
SRI	2.4%	9.8%	39.0%	48.8%	100%
TOTAL	1.2%	4.9%	32.9%	61.0%	100%
Pearson Chi-Square =7.926; p=0.048					
3. Ripening stage					
Conventional	0.0%		12.2%	87.8%	100%
SRI	7.3%		7.3%	85.4%	100%
TOTAL	3.7%		9.8%	86.6%	100%

Daily water levels (cm) in the FMT

- (solid line SRI, dotted one - conventional)







Mean Daily Inundation Index (cm)

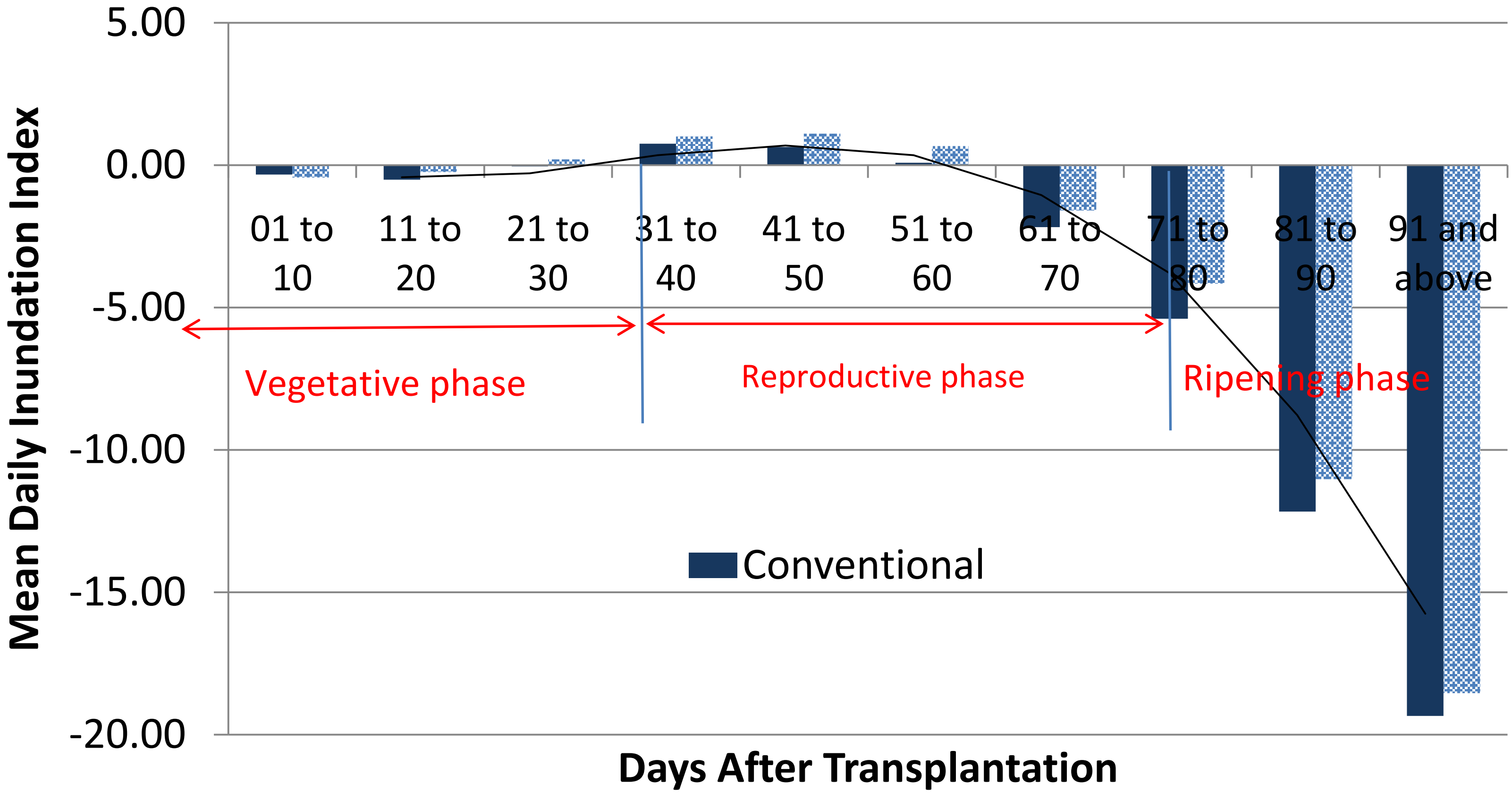


Table : Means of daily FMT measurements and MDI Index values at 10 days intervals (figures in cm)

Period / Phase		Water level in FMT (cm)		MDI Index (cm)		Extent of deviation + in cm	
Days after transplantation		Conv	SRI	Conv	SRI	Conv	SRI
1 to 10	Vegetative	20.33 (-3.09)	20.44 (-1.90)	-0.33	-0.44	**-4.67**	**-4.56**
11 to 20	Vegetative	20.51 (-3.18)	20.24 (-2.22)	-0.51	-0.24	**-4.49**	**-4.76**
21 to 30	Vegetative	20.04 (-2.65)	19.80 (-2.78)	-0.04	0.20	**-4.96**	**-5.2**
31 to 40	Vegetative / Reproductive	19.25 (-2.14)	18.98 (-2.51)	0.75	1.02	**-5.75**	**-6.02**
41 to 50	Reproductive	19.36 (-3.31)	18.89 (-3.79)	0.64	1.11	**-5.64**	**-6.11**
51 to 60	Reproductive	19.92 (-3.37)	19.33 (-3.67)	0.08	0.67	**-5.08**	**-5.67**
61 to 70	Reproductive	22.18 (-5.45)	21.59 (-5.18)	-2.18	-1.59	**-2.82**	**-3.41**
71 to 80	Ripening	25.39 (-6.24)	24.16 (-6.76)	-5.39	-4.16	0.39	-0.84
81 to 90	Ripening	32.16 (-5.55)	31.03 (-5.71)	-12.16	-11.03	7.16	6.03
91 to 100	Ripening	39.34 (-1.74)	38.55 (-2.39)	-19.34	-18.55	na	na

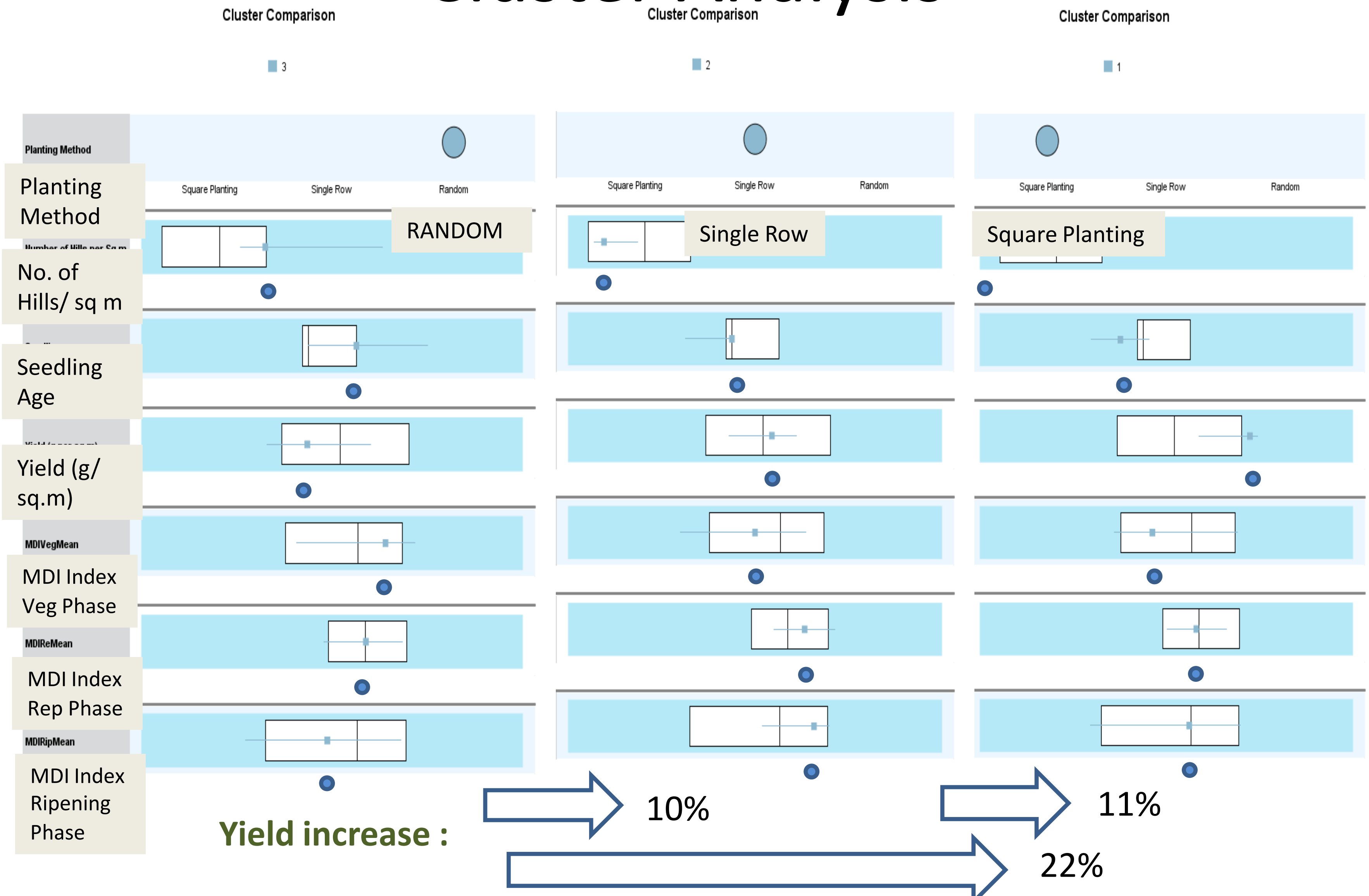
Figures in brackets are standard deviation of the mean

+ extent of deviation from (-5.0 cm) i.e. the average of 5 cm inundation and (-15cm) of safe AWD depth.

Water (Electricity) Saving using Safe-AWD benchmark

SNO	Details	Calculation	Quantity	Unit
1	Water column (in soil to be saved)	from data	-366.87	Cm
2	conversion in to actual water- factor	assumption	12%	
3	water column to be saved	1 x 2	-44.0242	Cm
4	water column to be saved	1 x 2 / 100	-0.44024	M
5	Square meters per ha area		10000	Sq m
6	total volume of water to be saved	4 x 5	-4402.42	Cu m
7	Average discharge per 5 HP borewell	from data	10740.15	lt/hr
8	Discharge in cu.m	7/1000	10.74015	cu.m/hr
9	No. of hrs of pumping required for the water quantity saved	6/ 8	-409.903	Hrs
10	pump rating	data	5.00	Hp
11	electricity consumption pr hour/ hp		746.00	watts=1 hp
12	electricity consumption per hr/ hp/		3730.00	watts
13	1 hr of 5 hp pump consumes power		3.73	kwh
14	total electricity saving/ha	13 x 9	-1528.94	kwh
15	subsidy on electricity *	**	4.8	rs/ kwh
16	**total electricity subsidy (saving) Rs./ha**	**calculated**	**-7338.9**	**Rs/ ha**
	** From Annexure K5, APERC Tariff order dated 30/3/2013			

More Rice with Less Water ..? Cluster Analysis



Descriptive statistics of the Clusters

Two-Step Cluster Number		Cluster 1		Cluster 2		Cluster 3		Total	
Cluster Description →		SRI with square		Sri- Single row		Conventional			
	p value	Mean	std	Mean	std	Mean	std	Mean	std
Number of Hills per Sq.m*	.000	16.45	1.17	19.78	3.14	29.27	7.72	22.95	7.86
Seedling_age*	.000	18.82	3.07	18.80	1.93	22.28	2.91	20.33	3.20
Yield (g per sq.m)**	.096	603.76	162.80	543.58	131.49	493.43	164.68	538.39	160.10
Borewell discharge lt / hr	.338	11576	7320	13938	4507	10931	5800	11939	6031
Area in acres	.840	1.21	0.69	1.18	0.86	1.31	0.75	1.25	0.75
MDIVegMean	.440	0.29	1.96	-0.49	1.96	0.46	2.66	0.16	2.29
MDIReMean	.600	0.60	2.01	1.25	2.18	0.65	1.99	0.79	2.03
MDIRipMean	.302	-9.26	4.54	-6.84	3.82	-7.72	4.44	-8.01	4.35
Age of farmer	.699	43.00	6.78	40.57	12.82	42.75	5.83	42.22	8.48
Number of family labour	.787	2.94	0.93	2.64	1.15	2.86	1.39	2.82	1.18
Total fertilizer costs per ha	.669	6983	1840	7335	3222	6668	1785	6930	2214

Does variation in MDI explain yield variation?

Model : Dependent variable : Yield (g/ sq m)	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	293.202	272.195		1.077	.286
Method Dummy; SRI =1	89.262	38.081	.285	2.344	**.023**
District Dummy Karimnagar =1	122.708	73.707	.384	1.665	**.101**
Veg Mean	3.451	10.118	.050	.341	.734
Rep Mean	8.437	10.230	.138	.825	.413
Veg Coeff of var in %	-2.162	2.919	-.091	-.741	.462
Rep CV in %	-3.378	2.703	-.207	-1.250	.216
Soil Factor 1	7.318	28.929	.048	.253	.801
Soil Factor 2	-48.327	24.709	-.316	-1.956	**.055**
Soil Factor 3	15.647	20.062	.095	.780	.439
R-square =0.22	p=0.079		n=67		

Conclusions

1. Significant differences in the method of cultivation with SRI (low planting density, lower age of seedlings, mechanical weeding)
2. **Plots practicing variants of SRI method have shown higher yields over the conventional**
   - **Over all : non-SRI to SRI (mix of row and square plantation) →12% (about 6 q/ha) :**
   - **Non-SRI to square Planting → 22%**
3. Though traces of AWD is seen in SRI farmers' perceptions, in practice there is no difference in the practice of irrigation between SRI and non-SRI.
4. **Lack of substantial variation in water use across SRI and non-SRI farmers in the sample prevents us from analysing whether 'more rice' is achieved with 'less water' under SRI.**
5. Substantial scope for reducing water use – using Safe-AWD as a bench mark; estimated savings in electricity subsidy is around Rs.7000 per ha along with a saving of 4400 cu.m of water per ha.
6. **Absence of water pricing and 'free electricity to farmer' makes water not to enter into economic decision making of farmers. (MVP becomes infinite)**