

Identifying and quantifying entry points to bridge yield gaps in non-traditional wheat production environments in Southern Bangladesh

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Background

- ❑ Wheat is commonly grown in Bangladesh in rice–wheat systems during the dry or winter Rabi season: November to April
- ❑ The second most significant food security crop after rice
- ❑ Per capita wheat demand - 17.3 kg/year about 20% of rice consumption.



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- ❑ Wheat is commonly grown in Bangladesh in rice–wheat systems during the dry winter ‘rabi’ season from November through April following monsoon rice crop.
- ❑ It is the second most significant food security crop after rice
- ❑ Currently, per capita wheat demand is 17.3 kg/year about 20% of rice consumption.

Yearly production, harvest area, import and domestic consumption of wheat

Domestic consumption:

1970s : 0.1 million tons
2013-14 : 4.7 million tons

Wheat Import:

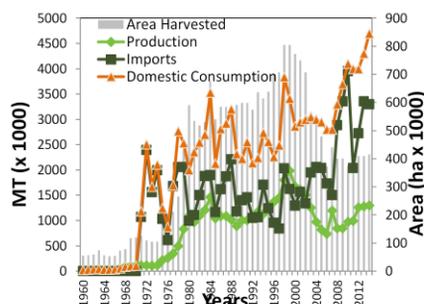
1999-2000 : 1.6 million tons
2013-2004 : 3.3 million tons

0.67 Billion US\$

Wheat Production:

1999-2000 : 1.7 million ha
2013-2004 : 0.74 million ha

Area declined: 50%

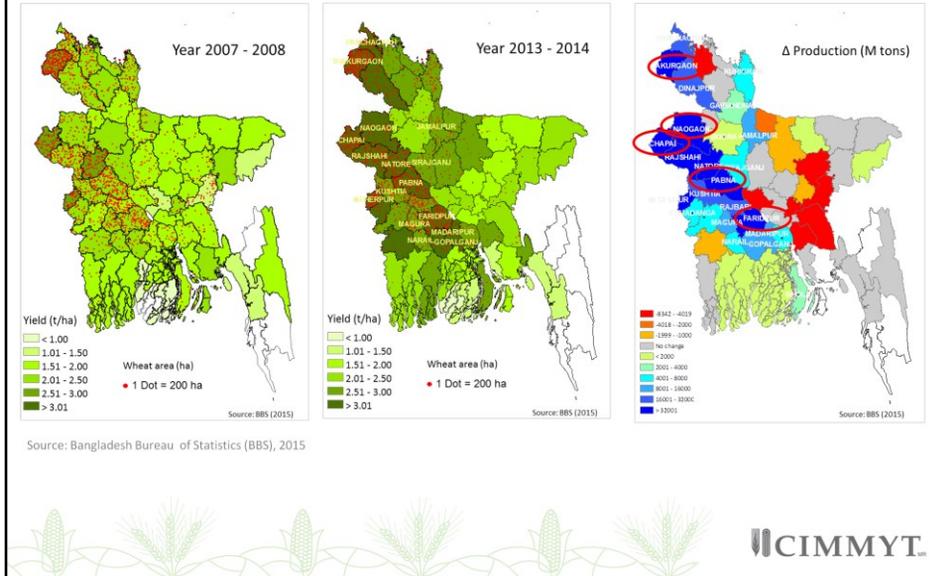


Source: <http://www.indexmundi.com/agriculture/?country=bd&commodity=wheat&graph=production> 27th September, 2015

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- ❑ Domestic consumption of wheat has been increased from 0.1 million tons in 1970s to 4.7 million tons in 2013-2014.
- ❑ Due to high domestic demand, wheat import has increased from 1.6 million tons in 1999-2000 to 3.3 million tons in 2013-2014 costing about \$0.67 billion in foreign currency reserves.
- ❑ Although, in the first half of the 1980s, domestic wheat production rose to more than 1 million tons, production has been declining from 1.7 million tons in 1999-2000 to 0.74 million tons in 2006-2007 with a 50 % decline of wheat area.
- ❑ In recent year, farmers are slowly returning to wheat cultivation, encouraged by higher yields with newly released wheat varieties and good market prices.

Distribution of wheat in Bangladesh



- ❑ Increased wheat production has mostly observed in north and central zones, where wheat has historically been grown and environmental stresses are limited.
- ❑ This higher wheat production is more associated with increase yield per unit area than increases area under wheat cultivation.

- ❑ In order to reduce wheat import, wheat production need to be increased by:
 - bridging yield gaps on currently wheat growing area
 - expanding cultivation to new land mostly in the fallow land in the southern Bangladesh which are estimated between 0.24 and 0.8 million ha

- ❑ Wheat production challenges in southern Bangladesh
 - terminal heat stress - at reproductive stage
 - late vacating monsoon floodwaters that delay planting
 - soil salinity
 - farmers' lack of knowledge with wheat cultivation



- ❑ In order to reduce wheat import, wheat production need to be increased by bridging yield gaps on currently wheat area or by expanding cultivation to new land, mostly in the fallow land in the southern Bangladesh which are estimated between 0.24 and 0.8 million ha.
- ❑ However, farmers in the south have numerous production challenges.
- ❑ The most common problem is terminal heat stress at reproductive stage
- ❑ It is usually happened when farmers grow long-duration local rice varieties monsoon season and late vacating flood waters.
- ❑ The both of which delay wheat sowing in this region
- ❑ It has been well documented that soil salinity at different growth stages contributed wheat yield reduction in the southern coastal area
- ❑ Farmers' lack of knowledge with wheat cultivation also affects yield.

- ❑ Bridging yield gaps is challenging in tropical environments, where yield is highly spatially and temporally variable, a result of environmental influences and farmers' management practices which remains poorly understood.
- ❑ A greater understanding of the factors influencing yield is important for advising farmers on how to close yield gaps in particular environments.
- ❑ Using crop cut and survey data from 160 farmers evenly distributed across three districts of Southern Bangladesh, we used Random Forest Regression Tree Models to identify the factors that controlling wheat yield in these regions, across which spatial variation in soil properties and farmers' management practices were considerable.



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Methods

Study area:

Fraidpur
Bhola
Satkhira

Number of Farmers:

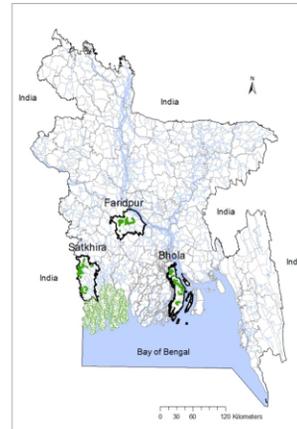
- Total 180 , 60 from each district

Crop cut for wheat yield:

- ~5 m² area in the center of each plot
- Grain yield was adjusted at 14% moisture content

Wheat crop management:

- wheat variety
- seed rate
- sowing date
- harvest date
- tillage operation
- fertilizer and organic matter management
- irrigation and weeding



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- ❑ We selected Fraidpur, a highly emerged wheat growing area, and Bhola and Satkhira, two non-traditional wheat growing districts.
- ❑ At the beginning of the wheat growing season in 2014-2015, a total 180 rice-wheat farmers, sixty from each district were selected.
- ❑ At physiological maturity, we did crop cut from ~5 m² area in the center of each farmer's plot for monitoring grain yield.
- ❑ Information on wheat crop management, such as wheat varieties, plot size, seed rates, sowing and harvest dates, tillage, fertilizer, irrigation and weeding was recorded.

Previous monsoon rice crops :

- reported grain yield
- rice variety name
- sowing
- harvest date
- Fertilizer management

Soil samples and analysis

- at time land wheat preparation
- soil depth 20 cm
- soil samples were analyzed for pH, soil OC, N, P, K, S, Zn, B and soil texture



- In addition to, information on various management related variables for previous monsoon rice crops was collected. This included, the reported grain yield, variety name, sowing and harvest date, fertilizer and organic matter management prior to wheat establishment.
- At the time of land preparation wheat, a composite soil samples were collected from 20 cm soil depth.
- Soil samples were analyzed for pH, soil OC, N, P, K, S, Zn, B and soil texture
- Wheat seeds were broadcast by all farmers after ploughing with two wheel power tiller and then applied flood irrigation.

Data analysis

- ❑ We used Random Forest regression (RF) models to identify important variables (variable importance) controlling wheat yield in our study
- ❑ We applied RF model selection approach for selecting the model with lower error component with optimum numbers of predictors.
- ❑ All analyses were done for all data as well as the date set for each district.
- ❑ The “*RandomForests*” (Liaw and Wiener, 2015) and “*rfUtilities*” (Evans and Murphy, 2015) packages in the R statistical computing environment (R ver. 3.2.1; R Core Team, 2015) was used for all statistical analysis.



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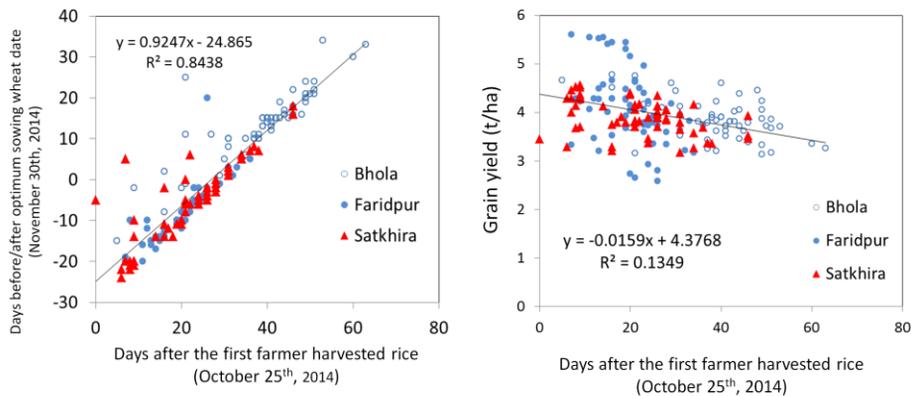
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Results



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Wheat grain yield vs Rice harvest date

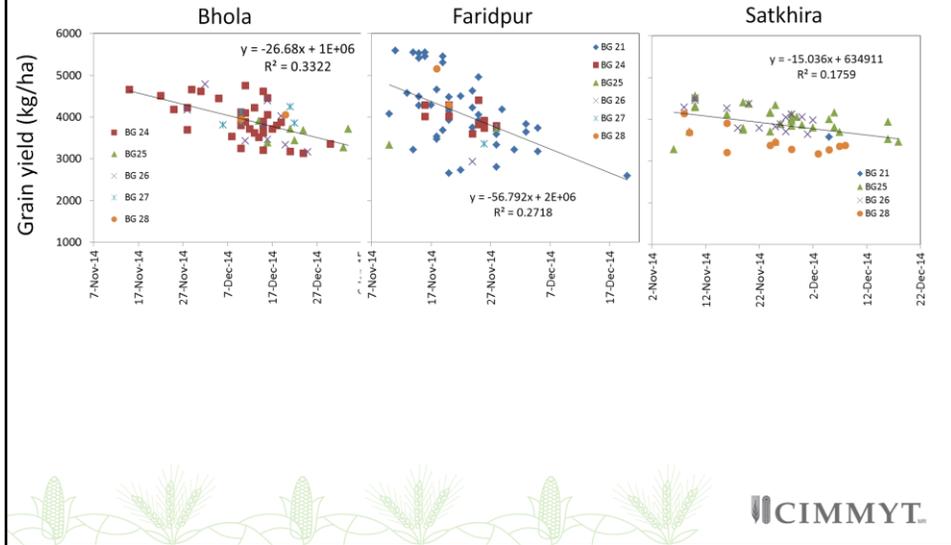


The earliest rice harvest date: October 25th in Satkhira and
 The latest : December 27th in Bhola district
 Optimum wheat sowing date: November 30th (Rawson et al., 2011)

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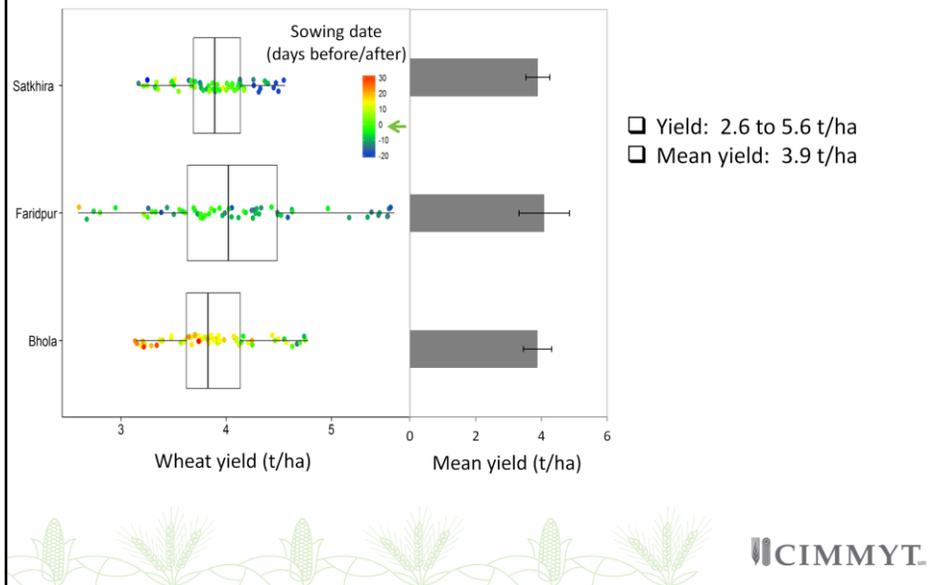
- ❑ In this field survey, we found that the earliest any farmers was able to rice harvest on October 25th in Satkhira District and the latest was on December 27th in Bhola district.
- ❑ The sowing day before or after November 30, the optimum sowing date linearly related to days after the earliest rice harvest date
- ❑ Wheat yields negatively related with rice harvest date but explained only 13 variability of wheat yield, respectively

Wheat Grain Yield vs Wheat Sowing Date



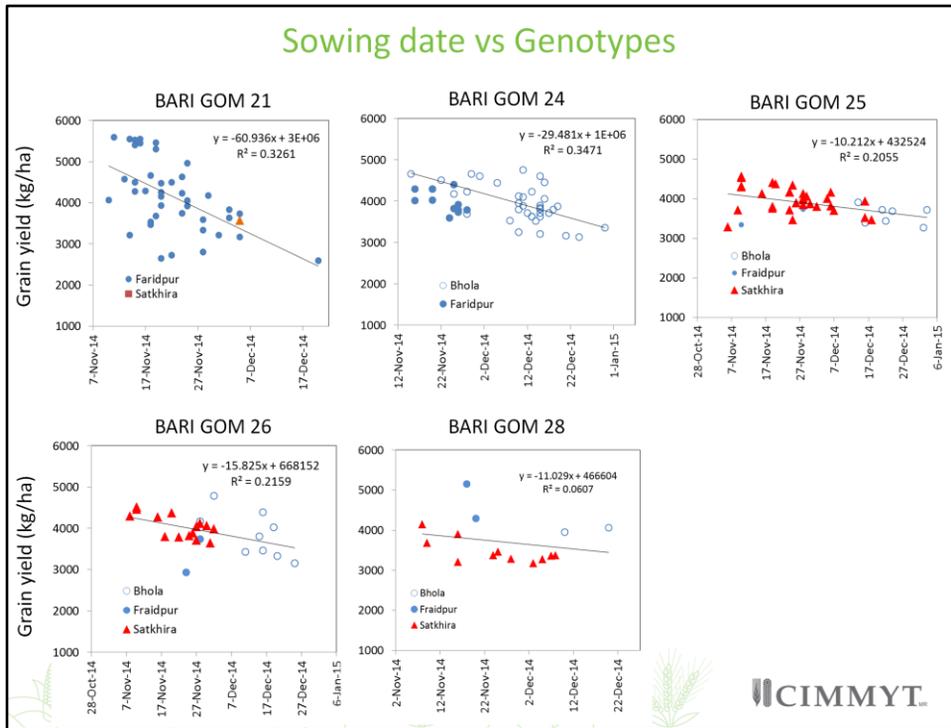
- When we regressed sowing date and yield for each district, we found that, yield reduction due to late sowing was the highest in Faridpur district with 57 kg lost per day delay from November 11th and the lowest in Satkhira districts 15 kg lost per day delay from November 6th.

Variability of Wheat Yield

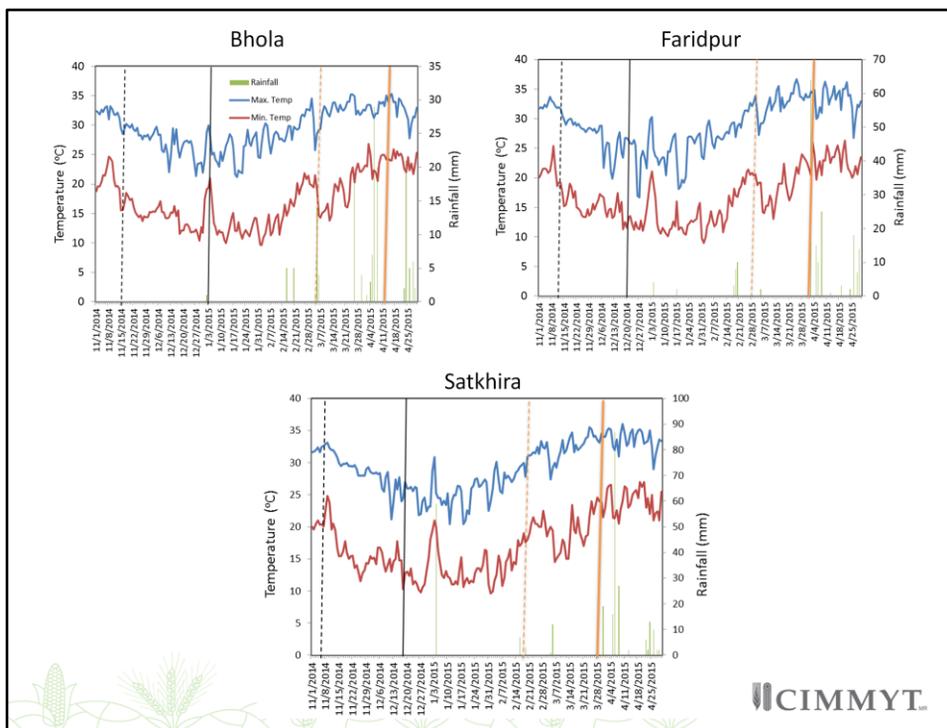


- ❑ The box - jitter plot shows the variability of wheat yield in relation to days before/after November 15, 2015, the optimum sowing date which is shown as a color palette in the figure where zero means sowing took place on November 30th and values toward the negative or positive values mean sowing of wheat was increasingly early or late, respectively
- ❑ The wheat yield in 180 surveyed farmers varied widely, ranging from 2.6 to 5.6 t/ha with a mean yield of 3.9 t/ha.
- ❑ Variability of yield was very high in Faridpur district despite early sowing

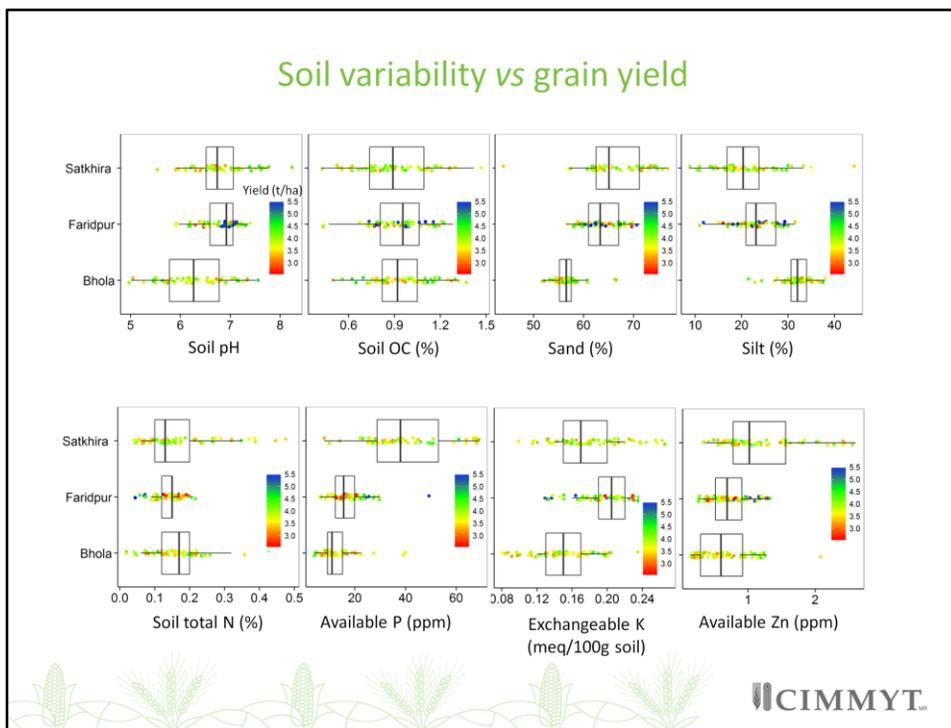
Sowing date vs Genotypes



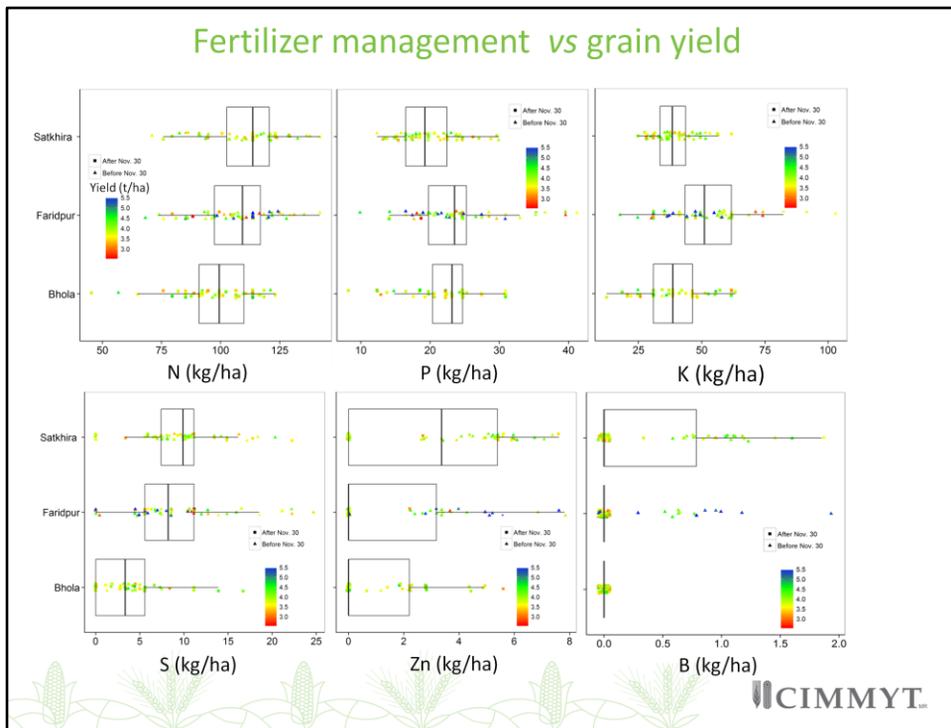
- Among the all varieties BG 21 was more sensitive to late sowing.
- The yield loss of this variety was 61 kg per day delay from November 10^h
- The BG 25 and 26, mostly grown in Satkhira district yield loss varied only from 10 to 15 kg per day delay.



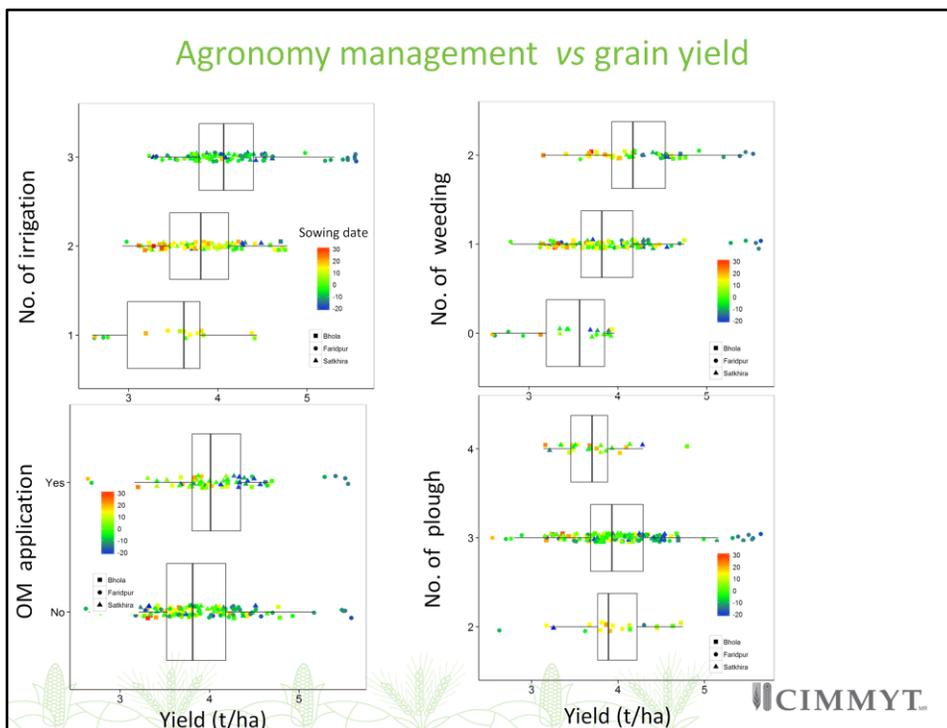
- ❑ Late sowing pushed wheat experienced higher minimum temperatures, resulting in terminal heat stress and lower yields.
- ❑ However, 2014-15, wheat experienced lower minimum temperature during the first two weeks in March in all three districts.
- ❑ So wheat yield was relative higher in this year.



- Initial soil properties varied widely both within and across districts
- Soil pH was generally lower in Bhola district compared to Faridpur and Satkhira districts.
- High SOC variability was observed in Satkhira district where high available P and Zn was observed.
- Wheat yield was related to none of the soil properties.

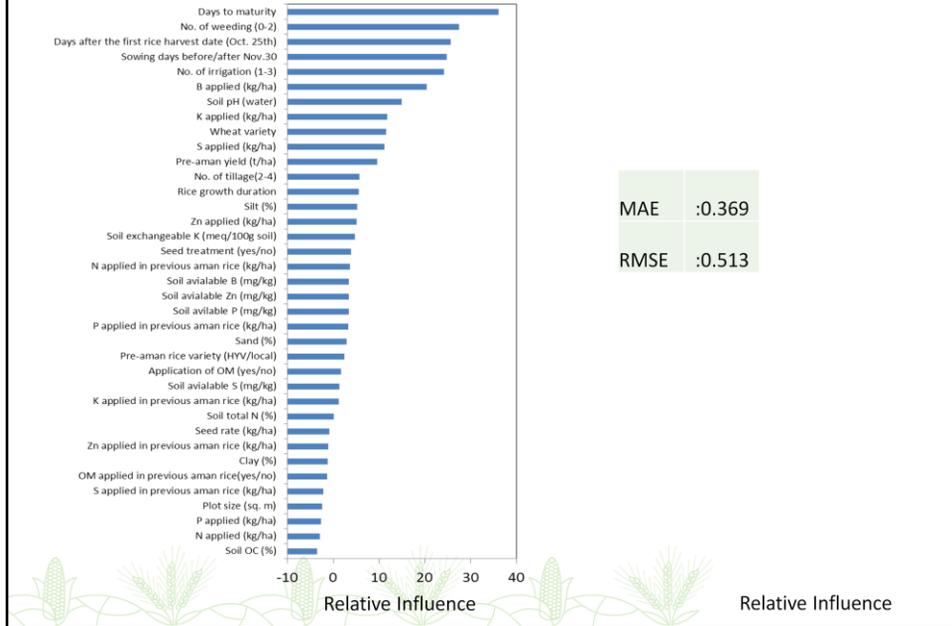


- ❑ All farmers applied N, P and K for wheat cultivation, but dose varied widely both within and across districts.
- ❑ The effect of these fertilizers on yield was not noticeable.
- ❑ In Faridpur district, some farmers harvested wheat with a very high yield with Zn and B fertilization.



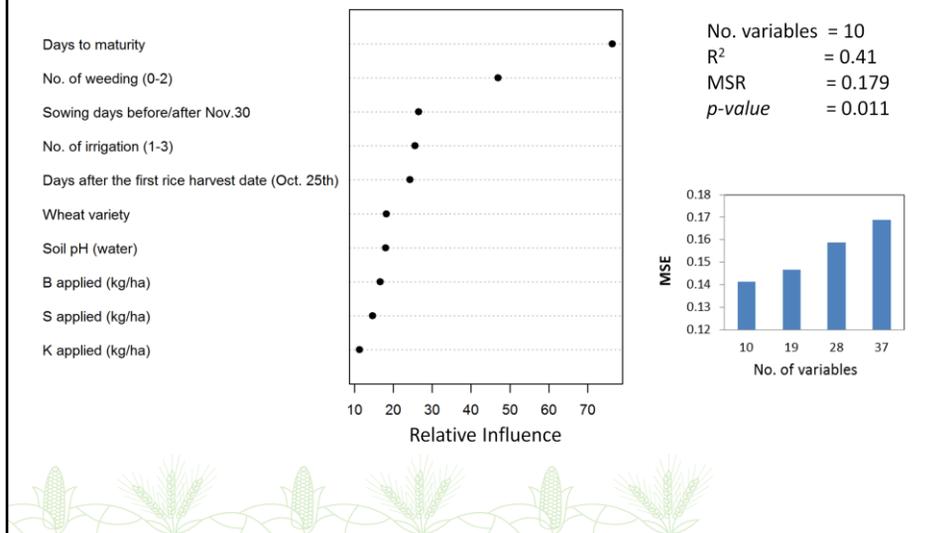
- ❑ Most of the early sowing farmers, mostly in Fardpur and Satkhira districts applied 3 irrigation, yield varied among these farmers from 3.2 to 5.6 t/ha with mean yield of 4.2 t/ha which was significantly higher than the mean yield with 1 or 2 irrigation.
- ❑ A Few farmers weeded one time.
- ❑ The mean yield with two weeding was higher than with one or no weeding.
- ❑ Neither OM application nor the number of ploughing showed effects on yield.

Variables Importance: Random Forest Regression Tree Model



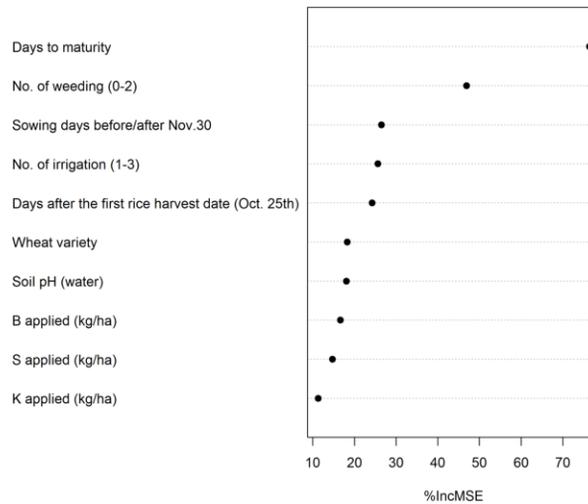
- The random forest regression with all 37 variables, identified days to maturity, weeding, variety, sowing date, rice harvest date, soil pH, K, B and S fertilizer application were the top most important variables for explaining wheat yield.

The best RF model: Variables Importance



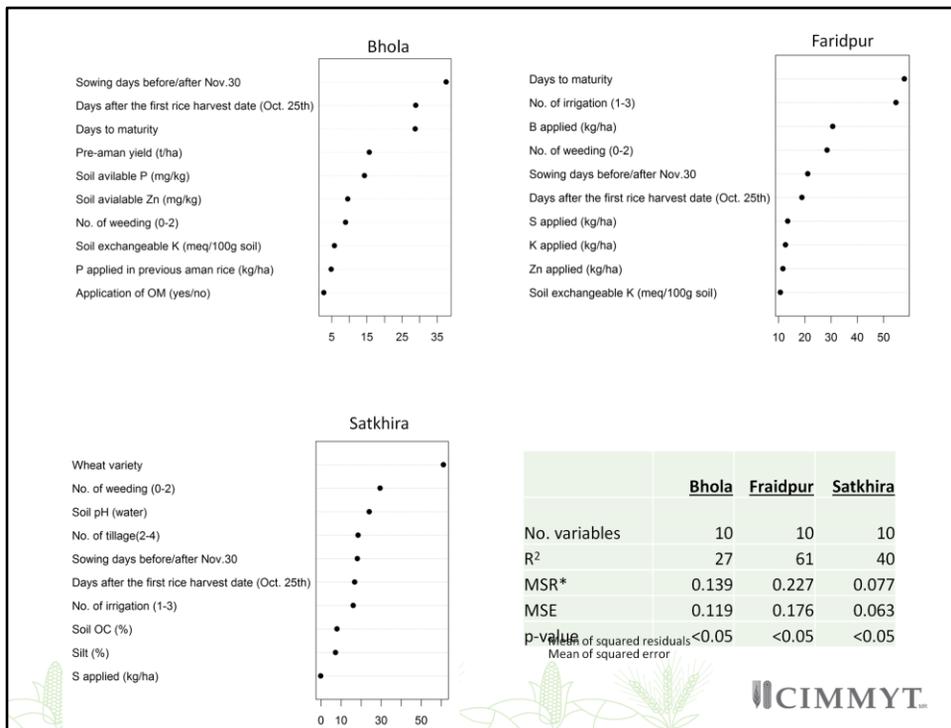
- ❑ When we applied a RF model variable selection approach, we found that the best RF model with 10 variables had the lowest MSE
- ❑ This model explained 41% of the variability of wheat yield.
- ❑ Days to maturity, weeding, variety, sowing date, number of irrigation, rice harvest date, wheat variety, soil pH, B, S and K fertilizer application were the most important variable explaining wheat yield.

Variable importance: yield > mean yield (3.9 t/ha)

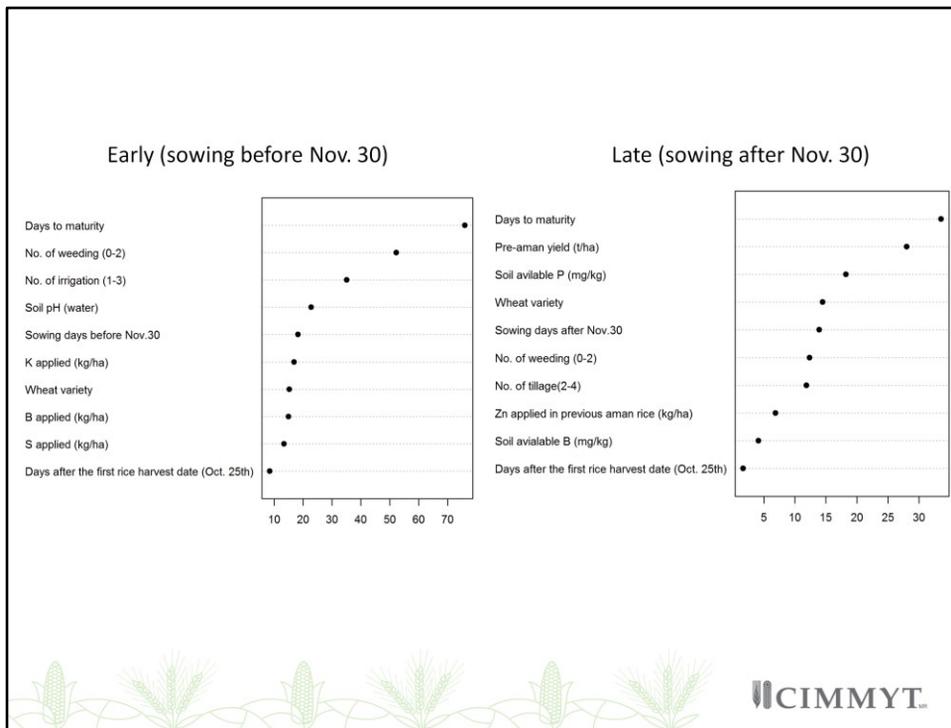


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- ❑ Random Forest identified same kind of variables and ranked similar way for the farmers those harvested wheat more than the average yield



- ❑ When applied RF model for each district, we found that the RF regression model explained the highest (61%) variability of wheat yield in Faridpur district and days to maturity, no of irrigation, boron fertilization was identified three most important variables.
- ❑ In Bhola district, the sowing date, rice harvest date, and days to maturity were the most important variables, but the model explained only 27% variability of wheat yield in this district.
- ❑ In Satkhira district, wheat variety identified as the most important variable. Others important variables for this district were weeding, soil and pH.



- ❑ Finally, we grouped the data as early (sowing done before November 30) and late sowing groups (sowing done after November 30).
- ❑ For the both sowing groups, RF identified days to maturity was the most important variable controlling wheat yield.
- ❑ For early sowing group, no of weeding and number of irrigation were 2nd and 3rd most important variables, though weeding and irrigation was not crucial for late-sowing farmers because the yield was already depressed due late planting.
- ❑ Others important variable for late sowing farmers were pre-aman rice yield, soil available P and wheat varieties.

Conclusions

- ❑ The most important factors controlling wheat in farmers' fields were:
 - sowing date which related to the monsoon rice harvest date
 - irrigation
 - weeding
 - application of B fertilizer
- ❑ In south, farmers' fields may not be available for wheat due to the late harvest of monsoon rice that prologs soil saturation and delays land preparation.
- ❑ Improve drainage facilities, growing short duration monsoon rice or growing heat tolerant wheat genotypes (BG 25 & BG 26) could help overcome this problem.
- ❑ Finally, scale-appropriate seeding machinery may be considered to accelerate sowing by reducing land preparation time.



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- ❑ The farmers who sown wheat early (before November 15) and managed their crops – such applied irrigations 2-3 times, 1-2 times weeding and applied Boron and Zinc fertilizers – were able to wheat harvest close to attainable yield (5 t/ha) and some cases, more than that.
- ❑ In south, farmers' fields may not be available for wheat due to the late harvest of monsoon rice that prologs soil saturation and delays land preparation.
- ❑ Improving drainage facilities, growing short duration monsoon rice or growing heat tolerant wheat genotypes (BG 25 & BG 26) could help overcome this problem.
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