Rwanda | 2014A-2017B | Maize Variety Trials & Adoption

Farmers First

PHASE:	(1) Research Station	(2) 50 – 500 farmers	(3) 500 – 20,000 farmers	(4) Full Scale

Introduction

Maize is the most widely cultivated crop among TUBURA clients every A season (Aug-Oct planting), with around 78% maize farmers and 11.3 ares per maize farmer in 2016A[i]. This is lower for non-clients in the same regions at 53% cultivating the crop and 7.6 ares per maize cultivator, but still is one of the most important crops in Rwanda. It is a top priority crop in many local governments' production plans and increasing yields is a major national priority, with subsidy money supporting both fertilizer and seed for maize. Yet maize yields in Rwanda, averaging 3.5 tons/ha, are only at 70% of the economic optimum.[ii]

One major lever for increasing yields is varietal improvement. Working together with the Government of Rwanda over the past several years, TUBURA has trialed many different improved, hybrid maize varieties, then has sold the best varieties to our clients at scale. We have seen big increases in hybrid seed adoption over time, and we have also gathered a great deal of useful maize harvest data which can be analyzed to determine the top varieties and their relative impact on maize yields versus other factors.

The purpose of this report is to summarize all the key maize variety work done by TUBURA from 2014A-2017B. This includes farmer-field-level (Phase 2) trials, adoption of varieties sold in the core program (Phase 4) and estimated outcomes of how those varieties have performed at scale, through M&E survey and demonstration parcel data. Our goals are:

- To compile and summarize the key features and learnings about each variety tested
- To update and improve our list of varietal suggestions, including refining the appropriate geographic unit for making variety recommendations
- To quantify the relative importance of variety versus other key factors which affect maize yields
- To analyze hybrid maize adoption drivers and farmer knowledge and attitudes about maize
- To generate updated, more accurate impact figures for TUBURA's hybrid maize sales
- To make suggestions on new at-scale interventions and trials TUBURA should consider in the future based on these results

852	Number of farmer fields enrolled in Phase 2 trials between 14A and 17A	5.9 & 9.9	Kg/are yield increase for Hybrid vs. OPV maize in multiple regression with M&E and Phase 2 data, respectively
59%	% Adoption of hybrid maize seed among TUBURA clients, in 2017A	**$11-$29**	Impact/adopter of optimal hybrid maize seed variety in A season (AEZ range)

Phase 2 Trial Results & Varietal Recommendations

- Phase 2 variety trials were conducted in the seasons 2014A, 2014B, 2015A, 2015B, 2016A and 2017A
- The methodology of these trials was generally:
    - Recruit farmer volunteers in targeted cells representing the agro-ecological zones of interest

- Identify 300 m^2 of land per farmer and divide into 3-6 identical sections to plant varieties side-by-side under the same conditions (field history, soil type, slope)
- Provide free seed and fertilizer inputs for the trials
- Have Innovation Officer plant the fields with the farmer, do follow-up visits each week, and then harvest the parcels with the farmer to ensure conditions are identical across treatments and to collect data on all aspects of growth
- Collect fresh (on the cob) weights on harvest day, then dry and degrain a sub-sample of maize to find the fresh-to-dry grain conversion ratio and use that to calculate dry yield for all the data

- The conversion ratio issue has been a tricky one, since there are several different possible ways to calculate it and it's unclear which is most accurate:
    - Prior to 2015A we applied a single average conversion ratio for all maize varieties and zones to all the data; this generally was around 0.4, though it varied by season.
    - In 2015A we tried to take sub-samples in each zone and for each variety, calculate an average and apply it per AEZ-variety pairing. However, this produced some strange results wherein OPV seed seemed to have higher yields than hybrid, and the field team assured us this was not accurate.
    - In 2016A and then in 2017A we had the Innovation Officers take a sub-sample of 5 kg of maize from every single treatment and farmer field and do the drying and de-graining to get a personalized conversion ratio.
        - The dry weights for those seasons come directly from that plot-level individual conversion that was done
        - For other seasons and for the M&E data, we took the average conversion ratio from 2016A-2017A per AEZ and applied it retroactively to all that past data
        - We had decided to do this rather than apply a treatment + AEZ specific ratio because when looking at the data we saw very little variation between varieties within the same AEZ and much higher variation across the AEZs
- Each season we looked at the dry grain yields, estimated revenues and profits, and farmer preference rankings per variety per AEZ and used this to create and then update the list of maize varieties we would sell at scale.
- Full reports on the results of each individual season can be found here
- The datasets on which those reports are based can be found here
- We compiled the data for 15A-17A to create a summary table and rankings by variety
- Rankings were mostly based on a "special average yield" calculated from the Phase 2 data using the following procedure:
    - Take the ZM 607 average across the full period 14A-17A for which there is data in the AEZ
    - For each individual season, calculate the difference between the varieties tested and the ZM 607 control in that season
    - In the trials without a ZM 607 control—Pool 9A in one season in Congo Nile and M 101 in several AEZs in 2016A—we took the average difference between ZM 607 and that OPV control variety from other years and used it to adjust the hybrid varieties to create a proxy for their difference from ZM 607
    - Where varieties were tested in more than one season, average the differences between that variety and ZM 607 for each tested season, then add that value to the baseline ZM 607 value to get an average value for that variety and AEZ
    - Where a variety was only tested one time, so it's difference from ZM 607 might be biased upward or downward due to climatic idiosyncrasies in that one season, we did an adjustment wherein the average difference from ZM 607 for a hybrid tested 3-5 seasons (like PAN 4M21 or ZM 607) was taken and adjusted by the difference between the given treatment variety and that variety in the single season it was tested; then this adjusted "difference from ZM 607" value was added to the baseline ZM 607 yield to get the yield measure for this variety
- In the detailed chart we looked not only at this adjusted yield value but also at the coefficient from a multiple regression done on variety and other factors using these data, the size of the sample per season and the number of seasons tested

- We made a general note of our level of confidence in the data for each variety and AEZ.
  - Where a variety was tested across many seasons and had a significant regression coefficient we had high confidence in the data; where it was tested only 1-2 seasons and/or had an insignificant coefficient we were less confident.
  - In some cases the average yield for one variety was higher than another but our level of confidence in the data was low, so we gave a variety with lower average yield but higher confidence a higher ranking
- In addition to the Phase 2 data we also looked at the key Ihuriro demonstration parcel outcomes for the varieties that had been tested in these parcels. This is noted in the full chart linked below, but for more detailed information you can also refer to the Ihuriro parcel report and data in this folder
- The first ranking list, by AEZ, is shown below. To see the details behind how these rankings were, follow this link to the full Maize Variety Chart
- In addition to this ranking chart by AEZ, the full document also includes:
  - The priority list of AEZs to which each variety should be allocated in situations of limited supply
  - A ranking of TUBURA districts by order of priority to get maize seed in the case of limited supply
- Note in the table below that we have divided the Central Plateau AEZ into two sections—cells with average altitude 1800 m+ and those below 1800 m.
  - We chose to do this because we had some unique data from one cell in the Central Plateau for 17A (Ngeli, in Nyaruguru district, which has average 1800 m altitude) which showed very high yields with high-altitude varieties like H 629, PAN 691, etc.
  - We have never tested these varieties in lower-altitude parts of the Central Plateau, and we do not believe that they would succeed there.
  - In future seasons there should be a concerted effort to test cells of different altitudes within the same AEZ to see if there are varietal performance differences like this one; with the existing data this is the only major split that we found necessary

Maize Variety Choice Rankings by AEZ, from Phase 2 Data 15A-17A

Agro-Ecological Zone	Bugarama	Central Plateau 1800 m+	Central Plateau below 1800 m	Congo Nile	Cyangugu	Eastern Ridges	Eastern Savannah	Lake Kivu	Mayaga-Bugesera
Choice 1	PAN 53	SC 637	PAN 4M21	SC 637	PAN 4M21	PAN 4M21	PAN 4M21	SC 637	SC 403
Choice 2	PAN 4M21	H 628	SC 403	PAN 4M21	SC 637	PAN 53	DH 04??	PAN 53	PAN 4M21
Choice 3	SC 403	H 629	PAN 53	H 628	PAN 53	SC 403	M 101	PAN 4M21	PAN 53
Choice 4	DH 04??	PAN 691	SC 637	H 629	SC 719	SC 513	SC 403	H 629	SC 637
Choice 5	M101	PAN 4M21	DH 04??	PAN 691	PAN 691	ZM 607	PAN 53	H 628	PAN 67
Choice 6	PAN 67	SC 719	M 101	SC 719	PAN 67	M 101	SC 513	M 101	M 101
Choice 7	SC 513	PAN 53	ZM 607	ZM 607	SC 403	DH 04??	M 101	ZM 607	ZM 607
Choice 8	ZM 607	ZM 607			SC 513		ZM 607		
Varieties that are not acceptable; avoid selling	Pool 9A	SC 403	Pool 9A	Pool 9A	Pool 9A	Pool 9A	Pool 9A	DH 04	Pool 9A
	SC 719	SC 513	PAN 67	M 101	DH 04	SC 719	SC 719	SC 403	PAN 691
	SC 637	DH 04	SC 719	DH 04	H 629	SC 637	SC 637	Pool 9A	SC 719
	PAN 691	M 101	PAN 691	SC 403	H 628	PAN 691	PAN 691	SC 513	H 629
	H 629	PAN 67	H 629	PAN 53	M 101	H 629	H 629	PAN 691	H 628
	H 628	PAN 63	H 628	PAN 63	ZM 607	H 628	H 628	PAN 63	PAN 63
	PAN 63	Pool 9A	SC 513	PAN 67	PAN 63	PAN 63	PAN 63	SC 719	SC 513
			PAN 63	ZM 607		PAN 67	PAN67	PAN 67	DH 04

Maize Seed Adoption & Farmer Knowledge

- This section summarizes some facts about TUBURA maize seed sales from 2015A-2017B

- Documents here show the varieties sold and trainings delivered to Field Ops to share with farmers each season
- We sold seed for the first time in 2015A, when the government opened up the market to private companies
  - All seed was delivered in 2 kg bags, which is approximately enough to cover 6 ares of land
  - PAN 4M21 was offered as the hybrid variety and ZM 607 as the OPV for all cells with average altitude below 1800 m
  - PAN 691 was the hybrid variety and Pool 9A the OPV variety for all cells with average altitude 1800 m or above
  - The seed was sold under the Government subsidy program, with 300 FRw/kg set as the OPV price and 475 FRw/kg set as the hybrid seed price.
    - Actually there were also some hybrid varieties set at 570 FRw/kg, but TUBURA paid the difference and just charged 475 FRw/kg for all
  - There were some challenges this first season, with some varieties being mixed up by Logistics and delivered to the wrong cells, and farmers in mid-altitude areas complaining about PAN 4M21 due to its short stature, before they observed harvests. Some reimbursements were granted in areas with high complaints
- In 2015B we again only gave 1 single hybrid and OPV option to each cell:
  - PAN 4M21 and ZM 607 were again offered in all cells below 1800 m
  - SC 637 and Pool 9A were offered in all cells above 1800 m; this shift was made because we worried that PAN 691 had a maturity periods too long to succeed in B season
  - We had complaints about ZM 607 from some districts this season and sent out partial replacement seed to deal with the issue.
- In 2016A we shifted from only one hybrid and OPV per cell to offering farmers a catalog of several different suitable varieties
  - We again sold maize in 2 kg bags under the government subsidy program, though prices per variety changed this season; some hybrids were actually given the same price as OPVs in order to promote them. The full list of prices can be found here.
  - We created 4 different catalogs, switching to AEZ rather than altitude as our main criterion and lumping together some AEZs with similar altitude and rainfall patterns:
    - M1: For all cells in the Congo Nile AEZ
    - M2: For cells in the Cyangugu and Lake Kivu AEZs
    - M3: For cells in the Central Plateau and Mayaga-Bugesera AEZs
    - M4: For cells in the Eastern Ridges, Eastern Savannah and Bugarama AEZs
  - In each catalog ZM 607 was an option, plus 2-4 other acceptable varieties based on our Phase 2 results.
  - In the catalog we ranked the varieties in order of expected yield and we included information like expected yield level, general expected maturity time, height, and special features (i.e. drought tolerance, disease tolerance)
  - Farmers were allowed to purchase up to 3 different varieties of maize
  - In this season we pushed SC 719 was the top choice in the Congo Nile and many farmers ordered it but later complained of poor cob development and low yields; when we investigated the results were mixed but there was some evidence to suggest that several bags of seed were impure and contained SC 403. Because of this mistake we reimbursed all SC 719 adopters.
- In 2016B we again offered catalogs, but we shifted the varieties available slightly, eliminating those with the longest maturity periods and adding a few new options,for example PAN 4M21 in the Congo Nile AEZ
- In 2017A we again marketed maize using catalogs M1-M4 with several options
  - Prices matched the government subsidy prices set per variety, which can be found here.
  - Unfortunately there were major supply problems and we were unable to get the varieties which we had intended to sell in the quantities which were ordered in the Roster

        - We had to tell farmers that they would not get the variety which they specifically requested but that if they ordered OPV we would give them ZM 607 and if they ordered any type of hybrid then we would select a suitable hybrid for them amongst varieties that we were able to get access to
        - In the end we distributed much more H 629 and SC 403 than we would have done under the farmer-choice model, and we also distributed SC 513 in many areas even though it was not in our original catalog of options at all
        - The Systems group used a ranking list (best varieties, acceptable varieties, unacceptable varieties per AEZ) provided by Innovations to look at the varieties and quantities available and allocate them to specific cells as the seed arrived and was ready to distribute
    - In 2017B we worried about supply reliability and decided not to offer a catalog at all but just to tell farmers to sign up if they wanted hybrid maize and we would deliver a suitable variety
        - The Systems groups again used a ranking list from Innovations to compare to the actual varieties and quantities as they became available to TUBURA and to make the judgement call close to the last minute of what variety to deliver where
        - We deliberately avoided H 629 in this season because of A season complaints and the fact that its maturity period is not ideal for B season
    - In 2018A we are generally planning to do the same thing as in 2017B, with Systems using the new variety rankings provided in this report to make the variety per cell decisions as seed becomes available
- The graphs below show some key summary statistics on TUBURA maize seed adoption throughout this period

Summary of TUBURA Client Maize Seed Adoption, 15A-17A

Season	15A	15B	16A	16B	17A	17B	Change 15A >17A	Change 15B > 16B
% Maize adoption	34%	21%	46%	21%	59%	24%	76%	16%
kg/client	0.9	0.6	1.5	0.6	1.96	0.72	107%	29%
kg/adopter	2.8	2.7	3.27	2.96	3.32	3.00	18%	11%
% Maize that was hybrid	75%	65%	97%	88%	98%	100%	31%	36%

Percent TUBURA Clients Adopting Maize Seed by District

District	15A	15B	16A	16B	17A	17B	Change 15A >17A	Change 15B > 17B
Bugarama	37%	10%	50%	6%	60%	5%	61%	-46%
Gatsibo	59%	22%	43%	17%	71%	72%	19%	232%
Giheke	18%	3%	47%	6%	62%	6%	250%	106%
Gisagara	35%	20%	61%	27%	57%	57%	61%	188%
Huye	26%	27%	31%	23%	50%	35%	95%	28%
Karongi	64%	46%	76%	30%	86%	27%	36%	-43%
Kayonza	Not yet part of TUBURA				63%	55%	n/a	n/a
Kibogora	26%	5%	20%	3%	27%	0%	5%	-96%
LWH East	Maize not sold		38%	8%	60%	38%	n/a	n/a
LWH West	not sold	21%	30%	22%	36%	32%	n/a	56%
Mugonero	49%	9%	58%	8%	71%	1%	45%	-87%
Ngoma	Not part of TUBURA		63%	7%	86%	48%	n/a	n/a
Ngororero	Not part of TUBURA		76%	17%	46%	44%	n/a	n/a
Nyagatare	Not yet part of TUBURA				65%	58%	n/a	n/a
Nyamagabe	71%	8%	75%	2%	74%	3%	4%	-67%
Nyamasheke	26%	5%	18%	7%	27%	6%	5%	27%
Nyanza	32%	58%	50%	69%	75%	68%	135%	18%

Nyaruguru	16%	7%	30%	6%	47%	5%	192%	-25%
Rubengera	64%	46%	54%	40%	65%	31%	1%	-34%
Rusizi	9%	3%	18%	4%	25%	3%	180%	21%
Rutsiro	22%	53%	37%	55%	55%	31%	152%	-41%
Grand Total	**34%**	**21%**	**46%**	**21%**	**59%**	**24%**	**76%**	**16%**

- Orders in terms of kg/client have increased by about 107%; this is driven partially by an increase in kg/adopter but mostly by an increase in % of clients adopting any maize seed
- The proportion of TUBURA clients who ordered maize seed has increased steadily each A season, from 34% to 46% then to 59%, an overall 79% increase.
- This increase has been most substantial in Giheke, Rusizi, Nyaruguru, Rutsiro and Nyanza where it more than doubled over the period; this seems to be because adoption of the seed started at a low level in the beginning and then farmers were convinced of the impact of the hybrid seed and increased demand in the second and third years
- The level of adoption is especially high in certain districts (86% in Karongi and Ngoma in 2017A, for example) while it is fairly low in others (25-27% in Kibogora, Nyamasheke and Rusizi in 2017A).
- B season adoption is generally much lower than A season adoption, at 21-24%, and this has not changed from 2015B-2017B overall.
  - In some districts, notably Kibogora, Mugonero and Nyamagabe, the adoption of maize seed has actually decreased from 2015B to 2017B
  - Because there is high disease pressure and overall lower yields for maize in B season this is probably appropriate, and the decrease in maize in these areas might represent an increase in knowledge about maize
  - During our marketing campaigns each B season TUBURA offers maize seed but warns farmers of the risks of growing it in B season and advises them not to plant maize if they expect high disease or pest pressure
- The percentage of maize ordered that was hybrid, versus OPV, has changed dramatically throughout the period:
  - From 15A-17A we saw a continual increase from 75% to 97% to 95%. In each of these seasons OPV was still an option for clients to buy.
  - Generally when OPV was still an option in B season (so 15B and 16B) a higher portion of farmers chose to buy it compared to A season
  - The fact that 100% of farmers ordered hybrid in 17B is due to the fact that we did not offer OPV for sale that season, as it was no longer being produced in Rwanda

TUBURA Client Maize Seed Adoption by AEZ, 17A-17B

AEZ	2017A Maize Adoption			2017B Maize Adoption		
	% adopters	kg/adopter	kg/client	% adopters	kg/adopter	kg/client
Bugarama	67%	2.01	1.35	8%	2.55	0.21
Central Plateau	52%	3.37	1.74	42%	2.59	1.08
Congo Nile	65%	3.26	2.12	8%	2.75	0.21
Cyangugu	43%	2.79	1.20	4%	2.39	0.10
Eastern Ridges	70%	3.53	2.48	53%	3.29	1.73
Eastern Savannah	67%	3.56	2.37	65%	3.73	2.43
Lake Kivu	56%	3.38	1.90	21%	3.32	0.68
Mayaga-Bugesera	60%	4.26	2.56	60%	2.99	1.78
TOTAL	**59%**	**3.32**	**1.96**	**24%**	**3.00**	**0.72**

- If summarized by AEZ in the most recent two seasons, 2017A-B, we see that:

- % Adoption is highest in Eastern Ridges, Eastern Savannah and Bugarama and lowest in Cyangugu, Central Plateau and Lake Kivu
- There is also substantial variation in kg/adopter, with the lowest level in Bugarama and the highest in Mayaga-Bugesera
- We will use these numbers in our overall impact calculations in the following section

Hybrid Maize Seed Impact Model

- We used average Phase 2 yield data from 14A-17A and maize seed adoption data from 17A-B to generate an Impact Model for maize seed sales in both seasons
- The model uses the following assumptions:
  - The impact is based on the "special average yields" for ZM 607 versus other tested varieties from Phase 2 trials, calculated using the procures outlined in the Phase 2 section above
    - The averages shown in the "A season" tab actually cover all data from both A and B season, because this seemed more accurate given our failure to test varieties consistently in both A and B, and because this helped us to maximize sample size
    - For the B season averages we took the % differences in each treatment from ZM 607 from the "A season" tab as well as the B season ZM 607 average yield for each AEZ and adjusted each variety up by from this baseline level by the % increase from A season
    - In future, once there is more data for all varieties of interest from both A and B season trials, then these could be calculated separately. For now we didn't feel this was accurate, particularly for B season impact calculations, given the small sample size in B season
  - Though the overall magnitude of yields will be different for Phase 2 versus as scale, we still use these yield differences because we don't have good variety-level data at scale and because we assume that the relative differences between varieties will remain generally the same
  - We used conversions from fresh into dry grain using the same AEZ-level conversion ratios for 16A-17A from Phase 2 before calculating average yields
  - We assume the value of the harvest is that dry grain multiplied by the price of grain on the market; we use the annual average farmer maize grain price across all AEZ, which is 216 FRw/kg
  - To calculate profits per are we subtract out the cost of DAP (assuming 1 kg/are and the 17A government price), Urea (assuming 0.5 kg/are and the 17A government price) and compost (using the average compost used in M&E data for 15A-17A by AEZ and the average compost price across all AEZs from FO survey data)
  - We use only a one-season model, since seed should be purchased again every season
  - Though there is a sales price for ZM 607, we assume the cost is zero because we want to compare purchased improved seed to saved OPV seed
  - We start by calculating yields and profits per are and kg of maize seed adopted, then use the actual 2017A or 2017B adoption data to calculate the impact per average adopter, the impact per client in the AEZ and the total impact made by TUBURA in that season
  - We try to calculate the cost to TUBURA of buying, storing and transporting the seed, as well as a penalty for the potential risk we face that there will be a problem with the seed and farmers will complain and we will need to reimburse them
- To look at the effect of maize sales on SROI we look at the baseline total impact and deficit which Finance has noted down for 2017A for TUBURA with changes included in both based on if we sell different varieties of maize in 2018A or beyond
- We chose to focus these calculations on:
  - A non-ideal but suitable hybrid, to show the impact if we have supply problems and have to offer one of the lowest choices on our list
  - The ideal hybrid currently being sold, to show the impact if we are able to supply what we believe to be the best variety in the zone currently available
  - A new hybrid (non-released or released but never before sold in this AEZ), to show the impact if we are able to do more trials and the impacts still stay this is high, and/or if we then work with the Government to release and sell the new variety

- The results of the overall impact calculations for these three highlighted varieties per AEZ are shown below for A season.

AEZ	Variety type	Variety	Impact/kg adopted	Impact/ adopter	Expected adoption %	Total adopters expected	Total kg seed	Total impact	New SROI (vs. 4.77 baseline)
Congo Nile	Sub-optimal	PAN 691	$6.17	$20.11	65%	33,722	109,918	$678,132	4.87
	Optimal	SC 637	$11.05	$36.03				$1,214,913	5.03
	New	DK 777	$22.35	$72.85				$2,456,596	5.40
Lake Kivu	Sub-optimal	H 629	$5.36	$18.11	56%	12,420	41,933	$224,897	4.80
	Optimal	SC 637	$16.29	$54.98				$682,897	4.94
	New	SC 727	$14.60	$49.29				$612,219	4.92
Cyangugu	Sub-optimal	H 629	$0.60	$1.68	43%	9,102	25,436	$15,332	4.76
	Optimal	PAN 4M21	$20.10	$56.17				$511,254	4.91
	New	DK 777	$26.48	$74.00				$673,567	4.95
Central Plateau	Sub-optimal	SC 513	$11.93	$40.15	52%	23,958	80,638	$961,871	5.02
	Optimal	PAN 4M21	$28.82	$97.01				$2,324,160	5.42
	New	SC 608	$26.28	$88.45				$2,119,138	5.33
Mayaga-Bugesera	Sub-optimal	PAN 4M21	$18.54	$78.99	60%	3,676	15,657	$290,339	4.85
	Optimal	SC 403	$25.09	$106.87				$392,833	4.88
	New	DK 777	$28.98	$123.45				$453,797	4.89
Eastern Savannah	Sub-optimal	SC 403	$8.59	$30.55	67%	7,851	27,915	$239,867	4.83
	Optimal	PAN 4M21	$20.51	$72.91				$572,433	4.93
	New	SC 608	$26.72	$95.01				$745,959	4.97
Eastern Ridges	Sub-optimal	SC 513	$5.93	$20.95	70%	18,970	67,014	$397,435	4.86
	Optimal	PAN 4M21	$23.41	$82.71				$1,568,947	5.20
	New	SC 608	$36.62	$129.35				$2,453,768	5.44
Bugarama	Sub-optimal	SC 513	$4.98	$10.04	67%	3,747	7,546	$37,614	4.78
	Optimal	PAN 53	$22.52	$45.35				$169,927	4.82
	New	WE 1101	$21.73	$43.75				$163,966	4.82

- Some key results coming out of this Impact Model analysis:
    - **Congo Nile:**
        - Ensuring supply of SC 637 versus a sub-optimal variety like PAN 691 should boost SROI by 0.16, while pushing for release of the new variety DK 777 might boost it further by 0.37.
        - Clearly more research on DK 777 in this AEZ is a big priority.
    - **Lake Kivu:**
        - Here, getting the optimal variety, which is also SC 637, is the top priority. It should boost SROI by 0.14, whereas the new alternative varieties do not seem as good as SC 637 and would boost SROI by slightly less.
        - It is still worth trialing SC 727 and other new varieties further, but our bigger priority here should be to work with SeedCo to ensure good SC 637 supplies.
    - **Cyangugu:**

    - Ensuring access to the optimal variety, PAN 4M21, should boost SROI by 0.15, compared to a potential further boost of 0.04 if we get DK 777 released and sell it.
    - We should work on both, but put the first priority on PAN 4M21 supplies.
  - **Central Plateau:**
    - The biggest result to come out of our Phase 2 analysis was a suggested split between the high altitude (1800 m+) and low altitude parts of this AEZ. High-altitude varieties like SC 637, H 628 and PAN 691 are among the top choices in the 1800 m+ areas but not in other parts of the AEZ
    - The numbers shown in the chart are for the lower altitude areas, since they make up the majority of this AEZ
    - We see that using the optimal variety, PAN 4M21, will boost SROI by 0.40 versus using a sub-optimal variety like SC 513 whereas the most promising new variety, SC 608, performs worse than PAN 4M21
    - This suggest the top priorities for this AEZ are to push on more reliable PAN 4M21 supplies and also to further trial the issue of the altitude-level split to 100% refine the recommendations for the two different parts of this AEZ. We might find that SC 637 or another high-altitude
    - We also see that SROI is highest in this AEZ when compared to others, so it should be prioritized for maize seed supplies and trial capacity allocation
  - **Mayaga-Bugesera:**
    - We see that there is not a big difference between the optimal variety, the alternative varieties suitable for this AEZ, and the new varieties (SROI range is only 4.85-4.89)
    - Also luckily, the optimal variety in this zone is SC 403, which often has less competition than other varieties, so it should be easier to ensure supply of this variety.
    - We simply need to focus on getting supply of one suitable variety for this AEZ and can de-prioritize it for any varieties in short supply or for trial bandwidth, if needed
  - **Eastern Savannah:**
    - Offering the optimal variety, PAN 4M21, should boost SROI by 0.10, while offering the best new variety, SC 608, should boost it further by 0.07.
    - Although this is sizeable, it is dwarfed by the results found in the Eastern Ridges, so if case of budgetary or supply constraints Eastern Ridges should get higher priority for both seed supplies and trials
  - **Eastern Ridges:**
    - This AEZ has the second-highest SROI levels and is this also among the highest priority level areas for getting maize seed if there are limited supplies
    - Supplying farmers with the optimal variety (PAN 4M21) over the least-optimal suitable option (SC 513) boosts SROI by a very large 0.34. Then pushing for the best new variety, SC 608, might boost it by an additional 0.24.
    - Clearly we need to both prioritize PAN 4M21 allocation to this region but also continue to do more trials and push for release of new varieties in this zone.
  - **Bugarama:**
    - The optimal variety here is PAN 53, unlike all other AEZs, and offering it instead of a less-optimal variety should boost SROI by 0.04. From research so far there are not any alternative new varieties that should increase production and SROI significantly above this
    - It would still be a good idea to do more trials here to confirm these results, but in the meantime the priority is to ensure PAN 53 supplies to this AEZ.
    - The expected change for switching variety and the overall SROI level is low enough, however, that Bugarama should not be a top priority AEZ when compared to Eastern Ridges, Central Plateau or some of the others

Checking Maize Seed Impact at Scale with M&E Data

- The goal of this section is to look at maize seed impact at scale from M&E data, to check our estimates of impact
- For many years the M&E team has collected maize harvest data (along with data for 3 other key crops) every season from the field of 4 different groups selected randomly from their Crop Mix survey data:
    - Non-clients who are not using fertilizer
    - Non-clients who are using fertilizer
    - TUBURA clients who are not using fertilizer
    - TUBURA clients who are using fertilizer
- Since 2015A when TUBURA began to sell maize seed at scale the M&E team has asked farmers in this survey about the source and variety of their maize
- Combined M&E maize harvest data for 2015A-2017A can be found here
- Unfortunately, these data are not set up well to calculate the impact of maize variety at scale, for several reasons:
    - No stratification is done to select a balanced sample of OPV vs. Hybrid or any of the specific hybrid varieties, across the full sample or within the four major farmer groups listed above
        - Thus, we lack adequate sample size for some varieties to check their averages
        - For the varieties on which we do have yield data, they cannot be properly compared because other factors like fertilizer use, location, etc. differ dramatically for different maize types
        - There are some inherent biases in the data which would make stratification difficult even if we tried to do it; for example, TUBURA farmers are more likely to have hybrid rather than OPV seed, and farmers who buy hybrid seed are more likely to use fertilizer and plant in rows
    - Many farmers are unable to properly identify the maize variety that they planted
        - We could use TUBURA ID to look up the variety for the TUBURA clients, but we have no way to check it for non-clients and even the TUBURA clients in some cases have ordered 2-3 varieties and it's difficult to verify which was actually harvested for the survey
    - Many other factors affecting yield are also not stratified and controlled for, including planting date, planting spacing, compost use, etc.
        - Data on these factors is collected in the M&E databases, however, so we can attempt to control for them statistically
    - The conversion from fresh maize to dry grain presents complications in the data
        - Before 2017A the M&E team never collected data on dry weight conversions themselves, instead they applied average conversions supplied to them by the Phase 2 team
        - In all Impact reports through 2015B a uniform conversion ratio of 0.4 was applied on all maize in all AEZs
        - After the Phase 2 team determined AEZ-level conversion ratios in 2016A those averages by AEZ were applied to the M&E data for the 2016A-B analyses
        - Starting with 2017A M&E will begin collecting dry weight conversions for every individual harvested maize field, but those data are not yet available
- The table below shows the OPV and Hybrid average yields in the different AEZs for A season (2015A, 2016A and 2017A) and B season (2015B, 2016B).
    - When these data were combined we applied a single set of AEZ-level conversion ratios to the fresh maize yield to get a more consistent measure of dry grain yield.

AEZ	Conversion ratio (from 16A-17A average, Phase 2)
Congo Nile	0.45
Cyangugu	0.45
Lake Kivu	0.48
Central Plateau	0.50

Eastern Savannah	0.65
Eastern Ridges	0.65
Bugarama	0.51
Mayaga-Bugesera	0.60

- These ratios are drawn from the 2016A Phase 2 averages except for Eastern Ridges and Eastern Savannah, since their 2016A ratios (at 0.88 and 0.74, respectively) gave unrealistically high maize yields. We instead moderated the level to 0.65, which comes from Phase 2 2017A trial data for Eastern Ridges.
- We see that overall, hybrid seed seemed to boost yields in A season by 21% and in B season by 37%
- We must take these results with a grain of salt, however, based on the weaknesses mentioned above
- It is clear from the table that the OPV and Hybrid samples are not balanced in terms of size, and though not visible here they are certainly not balanced in terms of % fertilized, etc.

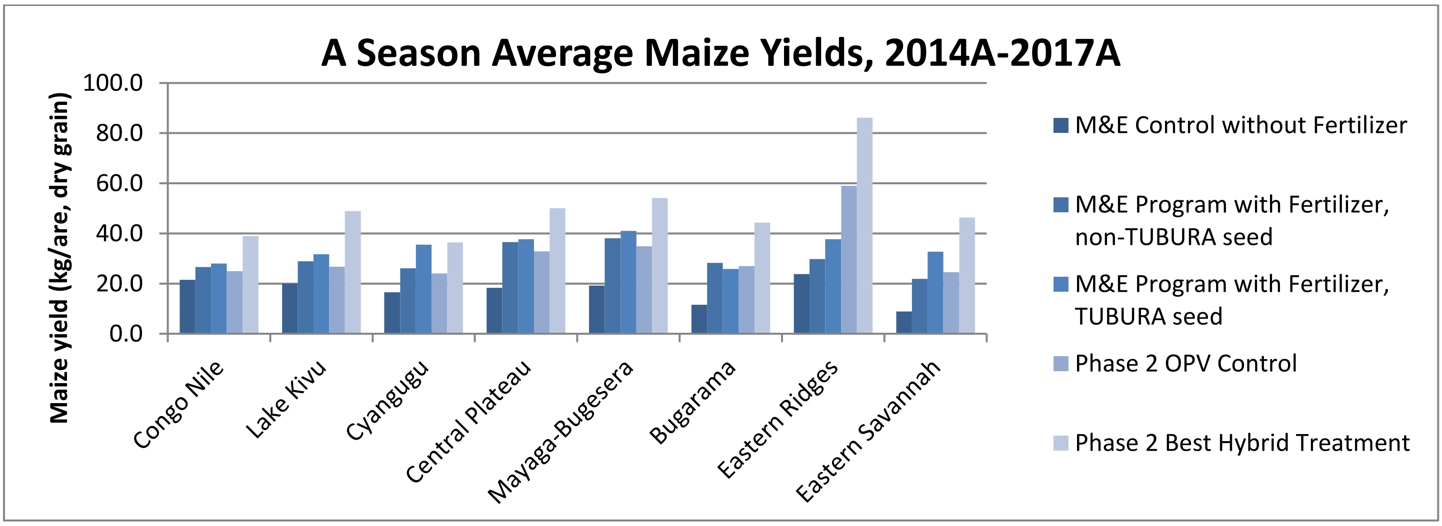
- Later in this report we will do a regression analysis to try to parse out the impact of Hybrid vs. OPV at scale more accurately, but controlling for these other factors in the data

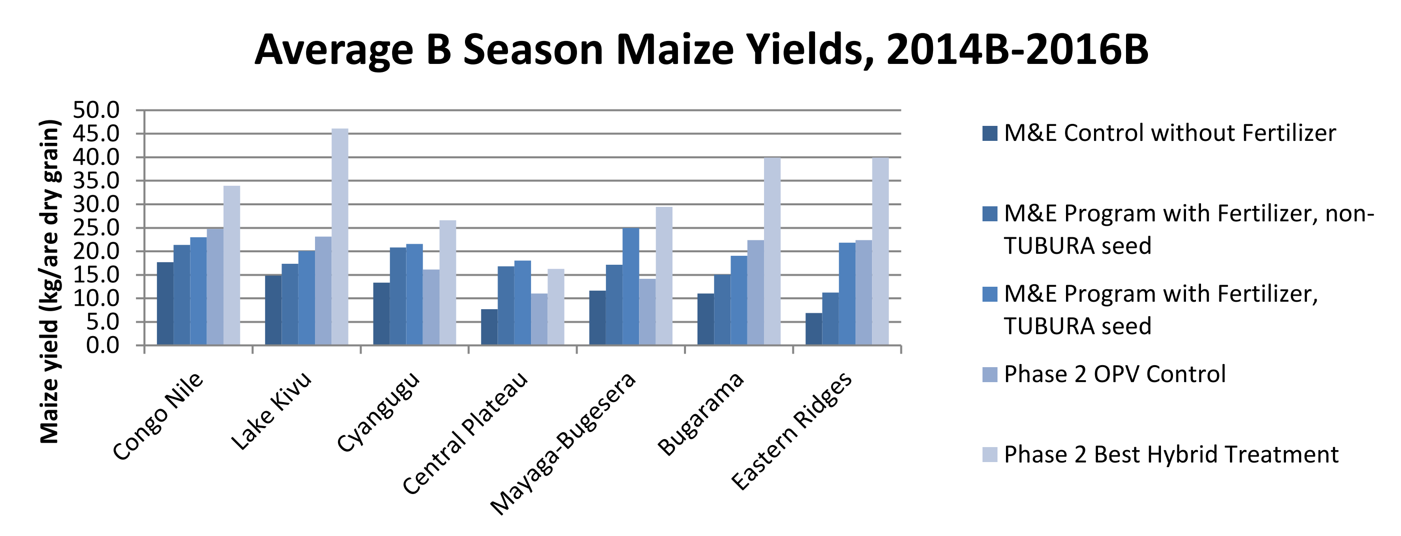
M&E Average Maize Harvest Data by Type, 2015A-2017A

AEZ	Season	OPV sample size	Hybrid sample size	OPV Yield	Hybrid Yield	% Difference
Bugarama	A	10	25	32.9	44.5	35%
	B	4	21	17.6	30.6	74%
Central Plateau	A	74	145	32	38.4	20%
	B	63	110	37.6	45.6	21%
Congo Nile	A	221	384	31.9	37.1	16%
	B	84	57	23.6	30.7	30%
Cyangugu	A	123	89	34	40.4	19%
	B	11	9	31.7	32.6	3%
Eastern Ridges	A	87	415	35.7	44.1	24%
	B	4	28	27.4	33.6	23%
Eastern Savanah	A	29	204	42.3	46.4	10%
	B	11	7	25.9	26.3	2%
Lake Kivu	A	94	204	29.9	33.1	11%
	B	26	66	27.3	45.5	67%
Mayaga-Bugesera	A	3	23	47.1	64	36%
	B	no data				
TOTAL	**A**	**641**	**1,358**	**33.1**	**40.1**	**21%**
	B	**203**	**299**	**29**	**39.7**	**37%**

- We have also done an analysis, shown in the table on the next page, comparing M&E yield and Phase 2 yields to one another.
- The tables include the following maize “treatments” compared side by side:
  - M&E Control without Fertilizer: non-clients, unfertilized maize fields
  - M&E Program with Fertilizer, Non-TUBURA seed: TUBURA clients who used fertilizer but reported using local seed, not seed purchased from TUBURA
  - M&E Program with fertilizer, TUBURA Seed: TUBURA clients who purchased TUBURA seed (mostly hybrid) and planted with fertilizer.
  - Phase 2 OPV Control: The average ZM 607 yield for the given AEZ and season type in the Phase 2 farmer field trials.
  - Phase 2 Best Hybrid Treatment: The average yield of the top released hybrid variety in each season, grouped by season type and AEZ. This represents the best possible yield we think will be obtained in each AEZ.

- Looking at the results in the tables, we see that A season yields are much higher than B season yields across all AEZs and maize "treatments"
- Eastern Ridges has the highest maize yields of all the AEZs in A season, though the geographic differences are lower in B season.
- The different maize treatments generally see a progression of increasing yields as you move through them in order with some notable exceptions:
    - OPV at Phase 2 has lower yields than hybrid at scale for Cyangugu in season A and B, Mayaga-Bugesera in season A and B, Congo Nile in season A, Lake Kivu in season A, Central Plateau in season A and Eastern Savannah in season A
    - The average best hybrid yields in the Phase 2 trials was actually lower than that at scale in Central Plateau in B season
- We see that the yield gap between fertilizer vs. non-fertilizer is larger than that for non-TUBURA seed vs. TUBURA seed in the M&E data at scale
    - This is in contrast to the much larger yield gap between OPV vs. the best hybrid in the Phase 2 data
    - This could be due to several factors:
        - Our M&E data does not accurately capture OPV vs. hybrid because some non-TUBURA seed is hybrid and vice-versa, and farmers do not always know their source or type of maize
        - TUBURA was not selling the best hybrid variety in some seasons and AEZs
        - Even where TUBURA was selling the best hybrid, farmers did not always buy it
        - Hybrids might be particularly responsive to fertilizer and good planting methods which they get at Phase 2 but often do not get at scale
- The biggest effect of TUBURA seed at scale seems to be in the Cyangugu, Eastern Ridges and Eastern Savannah AEZs
- There seems to be the biggest room for improvement between at-scale current yields and what could be obtained based on the Phase 2 results in Lake Kivu, Eastern Ridges and Bugarama AEZs
- We did not have enough data for Eastern Savannah in B season to include that zone in this chart; this shows the importance of getting more comprehensive data by AEZ from both M&E and Phase 2 data in the future





Yield Driver Analysis

- In this section we have analyzed both the compiled M&E variety harvest data and Phase 2 compiled variety trial data for the full periods available and run two different linear regression analyses to determine the relative importance of variety compared to other factors on yields
- A few notes on methodology:
  - In both the M&E and Phase 2 regressions we have taken fresh maize yields in kg/are from the original data, no matter what the year collected, and retroactively applied the AEZ conversion ratios from the Phase 2 trials in 16A-17A (shown in the table earlier in this report)
  - We had only a few factor variables available to us in the M&E data which were collected consistently across all seasons from 2015A-2017A, so there are fewer variables than in the Phase 2 regression
  - In the Phase 2 data we have specific detailed variety information, so specific variety type is included in the regression as the key variable of interest
  - In the M&E data we did not have accurate or balanced data by specific variety, so instead we just look at hybrid vs. OPV
  - In the Phase 2 data we cannot compare fertilizer use to any of the other factors because all repetitions of all treatments included fertilizer; however, since the M&E survey specifically selects maize farmers who did not use fertilizer we are able to quantify the relative effect of fertilizer on maize yields in that regression

Linear Regression on Maize Yield from M&E Data (kg/are dry grain, with AEZ conversion)		
Factor variable	**Coefficient**	**p-value**
Used fertilizer	7.1	0.001***
TUBURA client	3.1	0.001***
Used hybrid seed	5.9	0.001***
Applied compost	4.6	0.001***
Days planted after reference date (avg. planting date in the AEZ)	-0.2	0.001***
A season (vs. B season)	1.8	0.084*

AEZs vs. baseline of Lake Kivu		
Bugarama	2.1	0.442 NS
Central Plateau	4.8	0.001***
Congo Nile	-0.2	0.854 NS
Cyangugu	1.9	0.256 NS
Eastern Ridges	7.2	0.001***
Eastern Savannah	9.5	0.001***
Mayaga-Bugesera	23.6	0.001***
Sample size: 2,372		
R-squared: 0.130		

- Results from M&E Harvest Data regression:
  - We see that all included factor variables are highly significant
  - In order of the size of their effect on yield, the most important variables are:
    - Using fertilizer: this increases yields by 7. 1 kg/are on average
    - Ag zone location: Depending on the AEZ in question there was a 4.8-23.6 kg/are increase in yields when compared to Lake Kivu
    - Using hybrid seed: this increases yields by 5.9 kg/are compared to OPV
    - Using compost: increase yields by 4.6 kg/are
    - Being a TUBURA client: program clients had 3.1 kg/are higher yields, perhaps because of better planting practices
    - Season: Yield in A season were 1.8 kg/are higher than A season on average
    - Date of planting: Planting 1 day later than the average planting date for the AEZ resulting in a loss of 0.2 kg/are. So a farmer who planted 2 weeks later than average would be expected to see a 1.4 kg/are decrease in yields.
  - Overall this suggests that maize seed variety is a major factor affecting yields at scale, so by increasing hybrid adoption we are definitely making a positive impact.

Linear regression on Maize Yields from Phase 2 (kg/are dry grain, with AEZ conversion)		
Factor variable	Coefficient	p-value
Hybrid (vs. OPV)	9.9	0.001***
Number of days planted after Sept 15 or Feb 15	-0.31	0.001***
Applied compost	-3.3	0.07*
Soil fertility (1 = poor, 2 = medium, 3 = good)	3.8	0.001***
germination rate	0.34	0.001***
Days from planting to topdress	-0.01	0.410 NS
Drought problem at flowering	-3.3	0.001***
severe disease problem	-12.9	0.001***
A season (vs. B)	14.7	0.001***
Avg cell pH	13.2	0.001***
Avg cell altitude	-0.01	0.001***
All AEZs compared to baseline of Lake Kivu		
Bugarama	-16.7	0.001***
Burebuka highlands	1.4	0.588 NS
Central Plateau	8.5	0.001***
Congo Nile	-2.5	0.025**
Cyangugu	-11.8	0.001***
Eastern Ridges	35.5	0.001***
Eastern Savannah	13.8	0.001***
Mayaga-Bugesera	8.3	0.001***
Volcanic cones	-20	0.001***
Sample size: 4,476		
R-squared: 0.467		

- Phase 2 Maize Yield Regressions:
  - We conducted several different kinds of regressions
    - Regressions by individual AEZ that included individual, specific variety to estimate the relative impact of each over ZM 607 when controlling for other factors
      - These regressions are complicated and have very long results so they are not displayed here, but they can be found in this document
      - These results were used in the Maize Variety Chart and Rankings to help determine the impact of each variety per ag zone
      - The Stata file in which the regressions were run can also be found in this folder
    - A combined regression looking at all AEZs and seasons put together, in which variety was simplified into OPV vs. hybrid rather than specific variety types
      - The results of this regression are shown above
      - We drop out some the factor variables included in the long regression including "pest problem" and "drought at planting" because these variables had significant coefficients that were a counter-intuitive sign (positive), so we suspect there might have been some type of error with the data
      - Note that in both this regression and the more complicated Phase 2 regressions we use different planting reference dates than in the M&E regression—instead of average per AEZ we use Feb 15 for B season and Sept 15 for A season in all years
      - Note that this regression shows results for two new AEZs only tested in 17A—Buberuka highland and Volcanic cones in the North.
        - These were added in 17A so that we could begin to gather data to help guide sales choices if and when TUBURA expands to that region
        - Since there is only one season of data, not yet fully conclusive, and since as of 18A TUBRUA does not yet plan to move to the North these AEZs were not yet included in the list of variety rankings

  - Results show that there are many factor variables which significantly influence yields. In order of importance:
    - **AEZ**: the difference ranges from +35.5 kg/are for Eastern Ridges to -16.7 kg/are for Bugarama, compared to the Lake Kivu zone.
    - **Season:** A season has on average 14.7 kg/are higher yields than B season
      - This is dramatically higher than the 1.8 kg/are difference found in the M&E regression.
      - This could be because the Phase 2 data includes 2014B when we saw very large MLND losses whereas the M&E data does not
    - **Cell pH:** every increase in a point on the pH scale for the average soil in the cell increases yields by 13.2 kg/are
    - **Disease:** field which suffered a severe disease problem (primarily MLND or a component virus, followed by MSV) has 12.9 kg/are lower yields
    - **Altitude:** For every 1 m increase in altitude the yield dropped by -0.01, so moving from a cell of average altitude 1700 m to one of 1800 m would decrease yields by 10 kg/are
    - **Hybrid maize seed:** planting any hybrid (not just the best varieties) led to 9.9 kg/are higher yields versus all OPV varieties
      - This is higher than the 5.9 kg/are found in the M&E regression, as we would expect
    - **Planting date:** Every day planted after the reference date decreased yields by -0.31. So a farmer in A season who planted on Sept 30 instead of Sept 15 would be expected to see a loss of around 4.7 kg/are
      - This is similar to the -0.2 kg/day from the M&E regression

        - **Soil fertility:** Moving up a level in soil fertility rating from poor to average or average to good increased yields by 3.8 kg/are
        - **Drought at flowering:** Those fields with reported drought issues at flowering time saw yields 3.3 kg/are lower than those without a problem
        - **Germination rate:** If seed germinated at a 1% higher rate (due to seed quality or climate conditions) then this increased yields by 0.34 kg/are. So if germination was90% instead of 80% this would be expected to increase yields by 3.4 kg/are
        - **Compost:** Contrary to our hypotheses and what we saw in the M&E survey, applying compost correlated with a significant decrease of -3.3 kg/are in yields. On further reflection and investigation, however, this makes sense:
            - The farmers in these trials were all expected and heavily encouraged to use compost, and in fact 95% of them did so (versus 85% in the M&E sample)
            - The small minority of farmers who insisted on using no compost probably had very fertile fields and were able to convince our Innovation Officers that compost was not necessary
            - This means that the higher yields found for those not using compost can be attributed to soil fertility more than the practice of using compost, which we still know to be a crucial practice in the average field
    - The timing of top-dress application did not have a significant impact on yields, though perhaps this is because:
        - The major variation in top-dress timing that we would see at scale is farmer knowledge and choice, but in these trials the top-dress timing is mostly controlled by our Innovation officers and done according to the best recommendations (at V6 stage)
        - Given that, the timing should actually vary mostly by AEZ, given temperature differences, so and the effects that might have on yields are captured by the AEZ variables

- **Detailed Investigation:** Drought Issues & ASI
    - The results of this basic regression suggest that drought at flowering causes a large decline in yields
        - This supports the theoretical hypothesis; when there is drought stress during planting and flowering there are problems with pollination and cobs can be underdeveloped or have missing kernels
        - One concept that is closely related to this issue is "Anthesis-Silking Interval" (ASI)
            - This is the period of days between opening of the male flower, when pollen is released, and emergence of the female flowers or silks which receive the pollen
            - Pollen shed happens over a 5-8 day period and silks are viable to receive pollen released 7-10 days earlier, so they do not need to happen exactly at the same time, but a smaller gap of time increases the rate of successful pollination and thus yields
            - 2-7 days is the ideal recommended ASI length to get successful pollination
            - Drought stress lengthens the ASI window and thus decreases the successful rate of pollination and can decrease yields
    - The chart below shows the ASI levels by season type and AEZ
        - It looks like ASI is longer in B season when where is more drought stress
        - Overall it looks like our maize has longer than ideal ASI periods, of 8.6 days in A season and 10.3 days in B season, which could be the source of production problems
        - Congo Nile, Cyangugu, Lake Kivu and Buberuka AEZs have the longest ASI periods; it seems that ASI is lengthened not only by drought stress but also by colder temperatures and lower respiration

AEZ	A Season		B Season	
	ASI	Drought problem at flowering reported	ASI	Drought problem at flowering reported
Bugarama	3.5	50%	11.9	0%

Burebuka highlands	11.9	94%	n/a	
Central Plateau	7.3	30%	12.4	65%
Congo Nile	10.4	23%	10.3	34%
Cyangugu	13.4	1%	11.0	0%
Eastern Ridges	2.0	1%	not collected	100%
Eastern Savannah	2.8	20%	7.0	96%
Lake Kivu	10.1	33%	8.7	57%
Mayaga-Bugesera	8.2	13%	not collected	100%
Volcanic cones	8.3	93%	n/a	
TOTAL	**8.6**	**26%**	**10.3**	**51%**

- To probe more into this we looked at the correlation between ASI and yields in our Phase 2 data
  - We only collected ASI information for 2015B, 2016A and 2017A, so the sample size is reduced to 2,373 when include this variable in the previous regression model
  - The coefficient on ASI is -0.30 with a 99% level of significance, showing that this does indeed correlate with lower yields
- We then did correlation analysis to determine which factors might be affecting ASI
  - AEZ dramatically affects it, with warmer areas like the East and Bugarama showing shorter ASI periods (around 5 days less than Lake Kivu) and the colder areas of Cyangugu and Congo Nile having longer periods (around 2-4 days more)
  - Drought at planting and drought during flowering both increased the ASI period,
  - Some varieties seem to have significantly shorter or longer ASI periods than others:
    - DH 04, SC 403 and SC 513 have significantly longer ASI windows than ZM 607
    - DK 777, SC 608, H 520 and to some extent PAN 4M21 have shorter ASI windows than ZM 607
    - The shorter ASI windows could be a major beneficial characteristic of these varieties in some regions and circumstances, so we should consider it in our decisions to push for varietal release

Regression on ASI period		
Factor variable	**Coefficient**	**p-value**
Varieties vs. ZM 607 baseline (only significant results shown)		
DH 04	1.67	0.106*
DK 777	-1.83	0.022**
H 520	-1.55	0.022**
PAN 4M21	-0.68	0.158 (borderline signif)
SC 403	2.78	0.007***
SC 513	1.1	0.18 (borderline signif)
SC 608	-3.5	0.001***
A season (vs. B)	-0.63	0.071*
Days planted after Sept 15 or Feb 15	0.02	0.069*
Soil fertility	0.91	0.001***
Slope of field	-0.01	0.531 NS
Compost	-0.01	0.006***
Germination rate	0.01	0.327 NS
Drought at planting	1.94	0.001***
Drought at flowering	1.28	0.001***
AEZ vs. Lake Kivu baseline (only significant results shown)		
Bugarama	-5.13	0.001***
Congo Nile	1.61	0.001***
Cyangugu	3.96	0.001***
Eastern Ridges	-5.46	0.001***
Eastern Savannah	-4.92	0.001***
Volcanic Cones	-2.11	0.005***

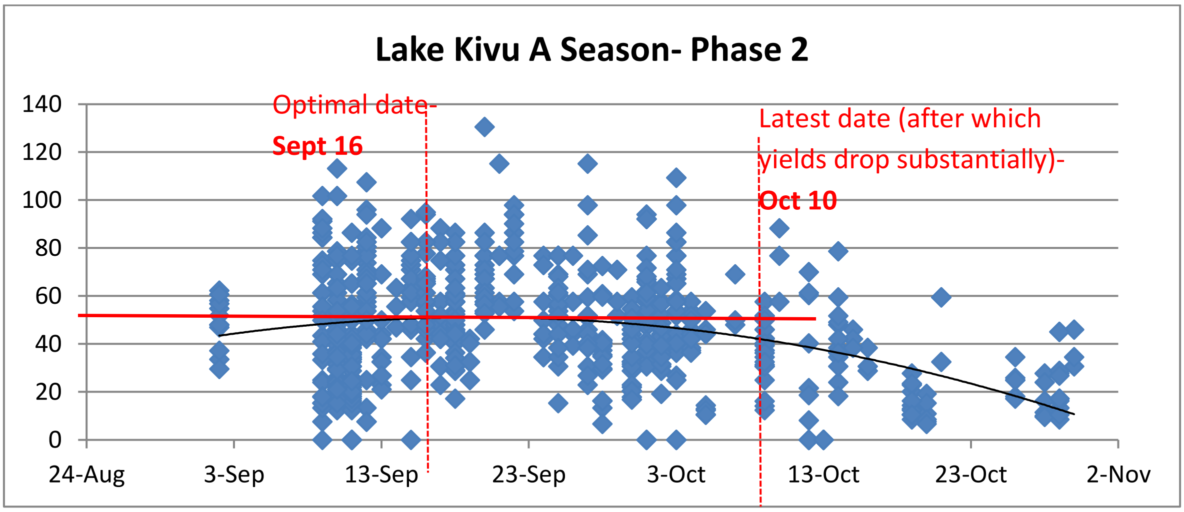
Sample size: 2,367
R-squared: 0.281

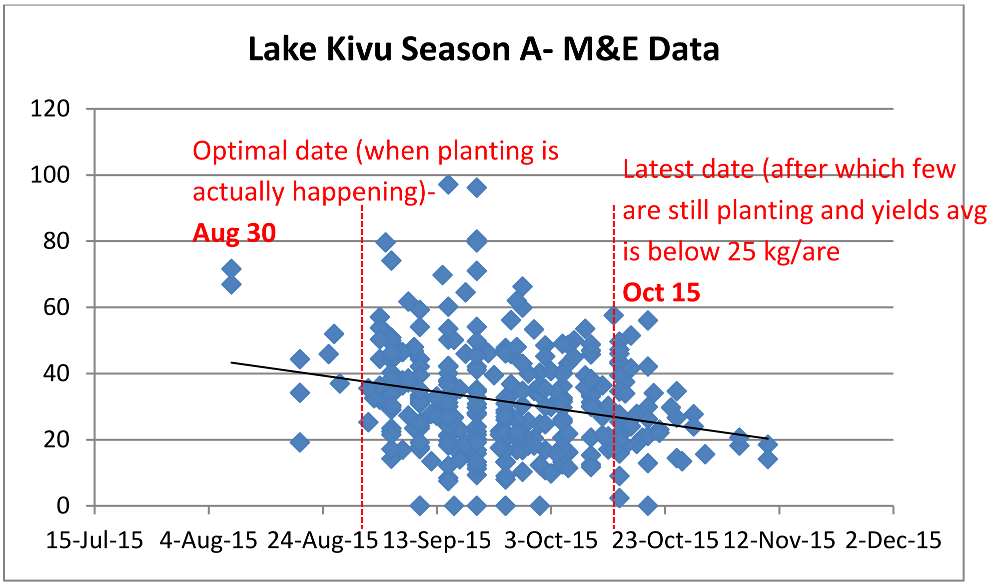
- **Detailed Investigation:** Optimal Planting date
  - Both the M&E and the Phase 2 regressions make it clear that planting earlier in the season correlates with higher yields. There are a number of strong theoretical reasons why this should be:
    - Planting early increases the chance of the plants being hearty and more resistant to the stresses that generally manifest themselves later in the season, like pest attacks, disease pressure or low rainfall
    - The rains often stop in December-January for A season and May for B season, so planting early is important for assuring that the crops have reached maturity before this happens
  - In TUBURA's work distributing maize seed and other products we generally do try to distribute maize seed as early as possible in the season, before the seasonal rains begin or very shortly thereafter, to give farmers the best chance
    - Generally this falls from Aug 15-Sept 15 for A season and Jan 20-Feb 20 for B season
    - The different cells have distribution dates scattered throughout that window of time, and Field Officers with cells that need to plant earlier can request an earlier distribution date in the schedule
  - Unfortunately, in 2017A the imported hybrid maize seed which TUBURA planned to distribute did not arrive in Rwanda until the middle and in some cases the end of the normal distribution window. We made the decision to organize separate distribution dates for the maize seed as it arrived and was available for dissemination.
    - In many parts of the West (Congo Nile, Cyangugu, Lake Kivu) the seed was distributed from late September through early October
    - In the Central Plateau areas, for which we waited for PAN 53, the last variety to arrive, distributions did not happen until late October.
    - Though the analysis is still underway by the M&E team, it appears that in 2017A in particular maize yields suffered significantly because of this late planting. Reports from the field the season suggested big losses on H 629 in the West and on PAN 53 in the Central Plateau because of climate issues exacerbated by late planting times.
    - In the Central Plateau this was further underlined by observations of PAN 53 in Ihuriro parcels planted on-time in September (because we used old seed in stock for those parcels) which had good harvests standing nearby PAN 53 in a normal client field who planted 1 month later and had terrible production.
  - Here we have tried to analyze the Phase 2 and M&E harvest date to estimate the optimal planting date per AEZ in each season as well as the cut-off date beyond which maize yields are expected to be very low.
    - In the future, if maize seed supplies arrive after that cut-off date then we can consider making the decision not to distribute the maize at all and to encourage farmers to plant another crop (with shorter maturity time or drought tolerance) on the land instead
    - The methodology that we followed was to chart maize harvests on the Y-axis and planting date on the X-axis to observe the distribution of planting times and its relation to yields
    - We attempted to generate lines of best fit to describe these scatter plots, and to observe the optimal point on the line which seemed generally to maximize yields
    - We did this separately for the M&E and the Phase 2 data and then took a general average of the two results to generate the final dates for the table below
    - Examples of the scatter plots used for this analysis are shown below, but the full set can be found in the Phase 2 combined dataset and M&E combined dataset in the tabs labeled "Optimal Planting graphs"
    - In addition to the graphical, mathematical solution, our final decision about the optimal date also took into account the numbers of people planting at a given time; where the line of fit was linear, for example, it might suggest a planting date far earlier than the beginning of the

rains, so we adjusted the optimal date to be the earliest point at which a substantial number of plantings had been done

- After using the graphs to estimate optimal planting dates per AEZ, we also estimated a "cut-off date" beyond which it looked like yields dropped off significantly and/or the majority of farmers were no longer planting
- A more sophisticated mathematical solution to this question is possible, but this is our solution for now given a lack of time

- Example for Lake Kivu AEZ in A Season:
  - The Phase 2 data has a parabolic line of best fit, so the optimum point is at the top of the parabola, which is around Sept 16.
  - The latest recommended date is trickier to observe, but we generally looked for the point where the line of best fit begins to become more steeply negative and where there are more points under that above the yield line for the optimal planting date. This happens at around Oct 10
  - For the M&E data this line of best fit is linear, meaning the mathematical optimum would fall outside of the frame of this graph, earlier in the year. However, we generate a cut-off point assuming that the earliest farmers are planting as early as possible based on rain. When we look at the earliest planting date when a sizeable number have started planting this is Aug 30.
  - Estimating the latest recommended planting date is much less straight forward. We decided to put the date at where the line of best fit has an average of 25 kg/are, which is 10 kg/are lower than the current national average maize yields. After this date the numbers of farmers planting is also much lower. This is Oct 15.
  - To generate our final numbers we take an average of the M&E and Phase 2 to estimates to get an optimal planting date of Sept 7 and a cut-off date of Oct 12.





AEZ	A Season		B Season	
	Optimal planting date	Latest advisable planting date	Optimal planting date	Latest advisable planting date
Bugarama	Oct 5	Oct 30	Feb 22	March 17
Eastern Ridges	Sept 5	Oct 18	Feb 15	March 15
Eastern Savannah	Sept 1	Oct 4	Feb 11	March 5
Central Plateau	Sept 1	Oct 25	Jan 30	March 3
Mayaga-Bugesera	Sept 10	Oct 9	Jan 25	March 1
Congo Nile	Aug 30	Oct 10	Jan 20	Feb 27
Lake Kivu	Sept 7	Oct 12	Jan 25	Feb 22
Cyangugu	Sept 6	Oct 25	Feb 9	March 25

- **Detailed Investigation:** MLND
  - We will not go into much detail in this report, but wanted to share the fact that TUBURA is engaged in a separate project to investigate the prevalence and effects of MLND
  - In 2014B when there was a very severe outbreak of MLND in Rwanda TUBURA helped to set up the "MLND Task Force" together with RAB to investigate and address the problem.
    - We have helped to organize and fund efforts to test maize for MLND to check both the prevalence of the disease and its effect on yields
    - Solutions we have implemented to deal with the disease have included trainings for Field Officers and farmers on how to identify the disease, the procedure or uprooting and destroying diseased plants, and prevention measures like destroying infected residues and controlling pests
  - A summary of our past work from 2014B to the present and results can be found here.
    - Generally we found that MLND prevalence is much lower in A season than in B season, probably because of the short turn-around time between the two seasons which increases all pest and disease pressures in the B season.
    - Going into the 2015B season we actually discussed and investigated the possibility of offering no maize at all and working with the Government to discourage its production, but in the end we decided not to.
      - Details can be found in the 15B folder in the link above.
      - We may want to revisit this idea again in the future, particularly given the relative impact of disease problems versus other factors found in our regression analysis.
    - The most rigorous investigation is still the process at the moment, via a very comprehensive MLND prevalence study from 2017A-B.

- The report of that study as of the end of 2017A can be found here.
- We again found very little MLND in A season, but we will check the same cells in B season to see whether and by how much the disease increases.

Recommended Next Steps

- For maize at scale:
  - Systems should use the variety ranking list and AEZ priority list attached to this report to allocate varieties in the cases of limited supply
    - Make sure to allocate varieties by AEZ, which is already noted in the Roster
    - In the Central Plateau AEZ, split the sites into 2 sections for variety allocation:
      - Central Plateau High: average altitude 1800 m and higher, from ArcGIS data
      - Central Plateau Mid: average altitude below 1800 m, from ArcGIS data
    - Where a given cell has two AEZs, look at the list of varietal rankings for each and try to pick a good "compromise" variety to offer; make certain to avoid any of the "unacceptable" varieties on the list for either AEZ in the cell
  - If supply becomes more reliable in the future then we should return to offering catalogs of multiple suitable varieties by AEZ and training farmers about the differences
    - If this happens then we should put 4 different maize varieties into the Ihuriro demonstration parcels again, but until then we should avoid this, because showing farmers the best variety but then not offering it for sale can cause anger and reduce adoption of the sub-optimal variety
  - Work with the government to push for release of the following varieties, in order of priority:
    - DK 777
    - SC 608
    - WE 1101
    - H 520
  - Work with the government and seed suppliers to push especially hard for adequate supplies each season of the following varieties, in order of priority:
    - SC 637
    - PAN 4M21
    - PAN 53
    - SC 403
    - All other acceptable varieties
  - Share our full maize data will the government and have high-level discussions about which varieties are suitable and which are the top priorities by AEZ, to try to get on the same page and make for smoother seed ordering and allocation later
  - Revisit and refine impact estimates for B season maize, checking again whether we should consider a "no maize B season", using various sources:
    - 17B Phase 1 and 2 maize trial results
    - M&E 17B maize harvest survey results
    - 17B MLND sampling results and comparison between A & B season prevalence
    - 17B armyworm follow-up surveys
    - Updated regressions on yield drivers using all these sources of data
  - In maize marketing and planting trainings emphasize:
    - The importance of planting early even if rain is unreliable and you need to do gap filling, given our findings that later planting consistently lowers yields
    - The importance of water at pollination time and how to ensure it (considering irrigation just for a few days at flowering, using mulch until flowering, trying certain maize varieties with shorter Anthesis to Silking intervals)
    - The difference between Hybrid vs. OPV, because many farmers are still confused based on our training retention survey
  - In M&E harvest surveys in the future:

- Consider making maize variety type, or at least hybrid vs. OPV, a more central part of the survey and actually stratifying the sample to include balanced representation of variety
- Continue to collect data on other factors which might affect yields and then running multiple regression to compare fertilizer, program, variety and these different factors. This should include, in order of priority:
  - Planting date
  - Farmer's rating of field's soil fertility
  - Compost quantity and quality
  - Slope of field
  - Existence and severity of drought problem during the season
    - Ideally split into "at planting" and "at flowering"
  - Existence and severity of disease problem during the season
  - Existence and severity of pest problem during the season

- For maize variety trials:
  - Refer to the attached maize variety choice list to see which specific varieties we recommend trialing further or for the first time in a given AEZ. General rules of thumb include:
    - Test all released varieties that might possibly succeed in a given AEZ in 1-2 A seasons and 1-2 B seasons if they have not previously been tested
      - This should include SC 637 everywhere; we previously did not think it could work in the drier areas, but in 15A it had very good yields in a Mayaga-Bugesera cell at 1500 m, so we need to try it in more locations
    - Check for all varieties which have only been tested in either A season or B season but not the other, and make certain to also test in the missing season
    - Do a new rounds of 1-2 A season and ideally 1-2 B season trials for varieties which were previously only tested 1-2 times in a given AEZ and for which our current data confidence is low
      - We particularly need to do more trials of H 629, SC 719 and PAN 691 in the Cyangugu and Lake Kivu zones
      - We also need to test SC 513, SC 403 PAN 53 more extensively and comprehensively in Bugarama, the East and Central Plateau
      - We should speak to Pannar, SeedCo and Kenya Seed about the state of their current pipelines to see if any of the new varieties we trialed before and had promising by sparse results on (PAN 7M89, H 520, etc.) are worth pursuing and trialing more, or not
  - Continue to do individual field-level conversion in maize trials each season
    - Analyze the averages by AEZ, variety, etc. to see where the significant differences can be observed
    - Depending on what you see, give advice to M&E on how they should do conversions for their harvest survey
    - Depending on what you see, consider re-doing some of the analysis in this report and retroactively applying revised conversion factors
    - Decide whether you need to continue this indefinitely or whether after 2-3 seasons if you see little between-season variation you can create a list of conversion ratios to use every season
  - Consider reducing the size of the field planted to each variety, maybe to 25 m^2 from the beginning (and harvest box can be even smaller) so that you are able to find more acceptable fields and include more poor-quality fields.
  - During the analysis and report writing period at the end of each season, include a multiple regression analysis on not only variety but also a number of other factors like in this report; compare the results found to what was seen in this report

    - Use this to work with Phase 0 and 1 teams to keep an updated list of relative yield drivers on maize and to prioritize different types of maize trials in the future
    - Particularly focus on trying to refine and improve the analysis of optimal planting date; depending on what you find give advice to Systems and Field Ops
  - When 2017A-B rainfall and soil data are available, add those variables into the database and include them in a revised multiple regression analysis
  - Try to collect data for the first time, or improve/emphasize collection of the following:
    - Rainfall level during 1 week before and 1 week after flowering- have Innovation Officers make certain to collect and clearly note rainfall data in cm during this time
    - Anthesis-silking interval: study more about how to measure this in the field, do more training with the team (how to identify beginning of anthesis, how to identify beginning of silking, how to measure the period of overlap when pollination could be happening)
    - Altitude: Use table GPS to get an altitude measure for every individual field and add to the dataset
    - Disease: revisit how we currently collect disease information and either revisit or at least find an accurate way to combine the data to create the best summary variables to include in regressions (dummy for any severe disease, like done in this report? Dummy for severe disease of any time specifically before flowering? Variable for severity level of each disease of interest?)
  - Try to do more to stratify the sample and get balance within the sample across some of the variables which affect yields across cells and fields:
    - Altitude: If you collect GPS data during field selection, consider stratifying the sample to get a range of altitudes within each cell
    - Soil type, pH and level of fertility: Measure this 40+ possible fields in each cell and select fields which ensure the highest level of variability (try to get 1/3 each of poor fertility, medium and low fertility fields per cell?)
    - Compost amount: Consider randomly assigning the quantity that you want each farmer to use rather than allowing them to choose, and trying to get a range of values that includes some 0s
    - Planting date: Consider also randomly assigning planting date rather than letting farmers choose, and/or making certain that a few fields in each cell are planted 1-2 weeks earlier than other and a few fields are planted 1-2 weeks later to get more variation in this factor
    - If farmers object to any of these randomly-imposed additional rules, consider offering compensation to those with unfavorable "treatments"

---

[i] TUBURA Rwanda Monitoring & Evaluation (M&E) Crop Mix Survey 2016A. Link.

[ii] Crop Yield Gaps and Fertilizer Application. One Acre Fund Internal Consulting Team Memo. May 2014.