Experimental evidence on the impact of DT Maize and index insurance on small-holder maize farmers in Mozambique and Tanzania

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From Field Trials to the "Real World"

Laura Paul's research showed that, on average, DT maize effectively protects yields against midseason drought in farmer field trials in SSA.

We now move to the next link in the "evidence chain".

Do these gains hold up when DT varieties are introduced in real-world context that we most care about?

- Vulnerable, small-holder maize farmers in Mozambique and Tanzania;
- Thin input and output markets.

From Field Trials to the "Real World"

Both farmers in the field trials and "real world" farmers face significant weather-related production risk.

But there are important differences.

Farmers in Fields Trials are not randomly picked off the street!

- Relatively good access to complementary inputs
- Can afford complementary inputs
- The alternative to which DT varieties are compared are commercially available ***improved maize*** varieties

The average "Real-World" small-holder farmer in Tanz & Moz:

- Minimal access to complementary inputs
- Lack liquidity/credit to purchase complementary inputs (if available)
- Low yielding, ***local maize*** varieties are the norm against which we will compare DT varieties.

Primary Research Questions

Among the population of small-holder maize farmers in SSA, what are the impacts of DT seeds by themselves and DT seeds bundled with insurance on *maize yields*?

1. Do DT seeds offer any yield advantage in "normal" years? If so, how much?
2. How well do DT seeds protect against yield loss in seasons characterized by mid-season drought?
3. Do DT seeds and Index Insurance in seasons characterized by severe weather shocks help farmers maintain yields in the ***following season***?

Inter-seasonal impact mechanisms

3. Do DT seeds and Index Insurance in seasons characterized by severe weather shocks help farmers maintain yields in the ***following season***?

- How might DT & Index Insurance strengthen farmers' resilience & ability to recover from shock?
  - Liquidity 1: If DT trait effectively protects yields against drought, farmers may have sufficient liquidity to re-invest in good seeds and fertilizer next season;
  - Liquidity 2: If yields are low because of catastrophic covariate weather shock, insured farmers receive payout that allows them to maintain "seed capital" and re-plant next season.
  - Learning: Having seen benefits of DT varieties & insurance in bad year, farmers may further substitute toward DT/improved varieties and away from low-yielding local varieties next season.

Secondary Research Questions

Can we unpack the impacts of the intervention on yields via their impacts on farmers' seed investment?

- How do severe weather shocks affect farmers' investment in improved seeds in the following season when DT and Insurance are not available (i.e., for control group)?
- Do DT and Index Insurance prevent against decapitalization of seed stock following a weather shock?
- Are seed-use patterns consistent with farmers learning about the benefits of DT and Index Insurance?

Research Design: RCT with 2 Treatment Arms

- Treatment 1 (DT): Marketing of DT seeds
  - Village-level information meetings about DT seeds
  - Make seeds available for purchase in the village

Research Design: RCT with 2 Treatment Arms

- Treatment 2 (DTII): Marketing of DT seeds bundled with index insurance
  - Village-level information meetings about DT seeds & Index Insurance
  - Make insured seeds available for purchase in the village
  - Insured seeds marked up 20% for insurance premium
  - Stand-alone index insurance NOT available

“This seed is insured”

The Index Insurance Contract

- Insurance payout in the form of seed replacement next season
- Two triggers designed to complement biological insurance of DT maize
- Insurance pays out if either:
  - Establishment rainfall (40 days after planting) < 70 mm or;
  - Predicted end-of-season average yield in village $< 65\%$ of historical mean.
    - Prediction based on NDVI and full-season rainfall in the village

Implementation Partners

- Seed Company Partners
  - 2 Local seed companies in Mozambique
    - Phoenix (OPV)
    - Klein Karoo (hybrid)
  - 3 Local seed companies in Tanzania (hybrids only)
    - Iffa
    - Suba
    - Meru
  - All grow CIMMYT-developed DT Maize varieties

- Insurance Company Partners
  - Mozambique: Hollard
  - Tanzania: UAP

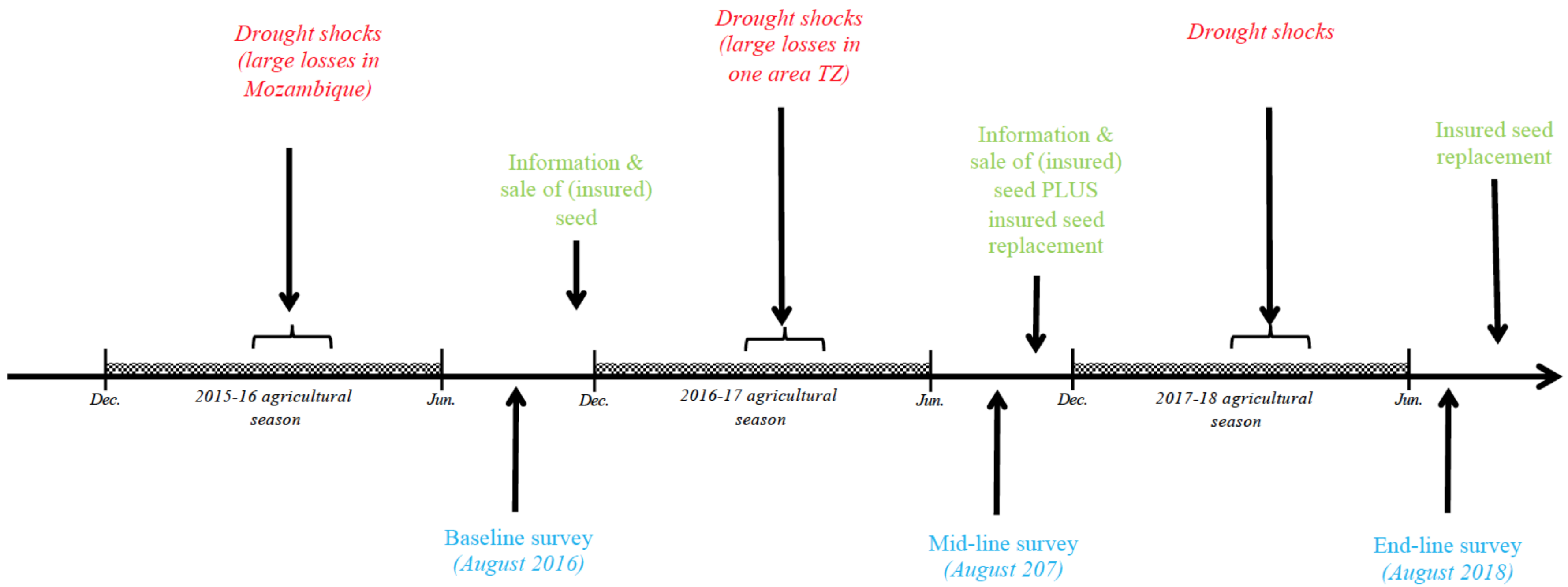
Assignment to Treatments and Sample Selection

- Population of interest: Small scale, rainfed maize producers exposed to moderate to high drought risk in Tanz. and Moz.
- Create strata of 3 agronomically similar communities
- Within each strata:
  - 1 community assigned to Control
  - 1 community assigned to Treatment 1 (DT only)
  - 1 community assigned to Treatment 2 (DT bundled w/insurance)
- Approx. 20 hhlds randomly selected from each community

Country	# Strata	# Communities	# Hhlds
Mozambique	18	64	1,237
Tanzania	30	90	1,767
Total	**48**	**154**	**3,004**

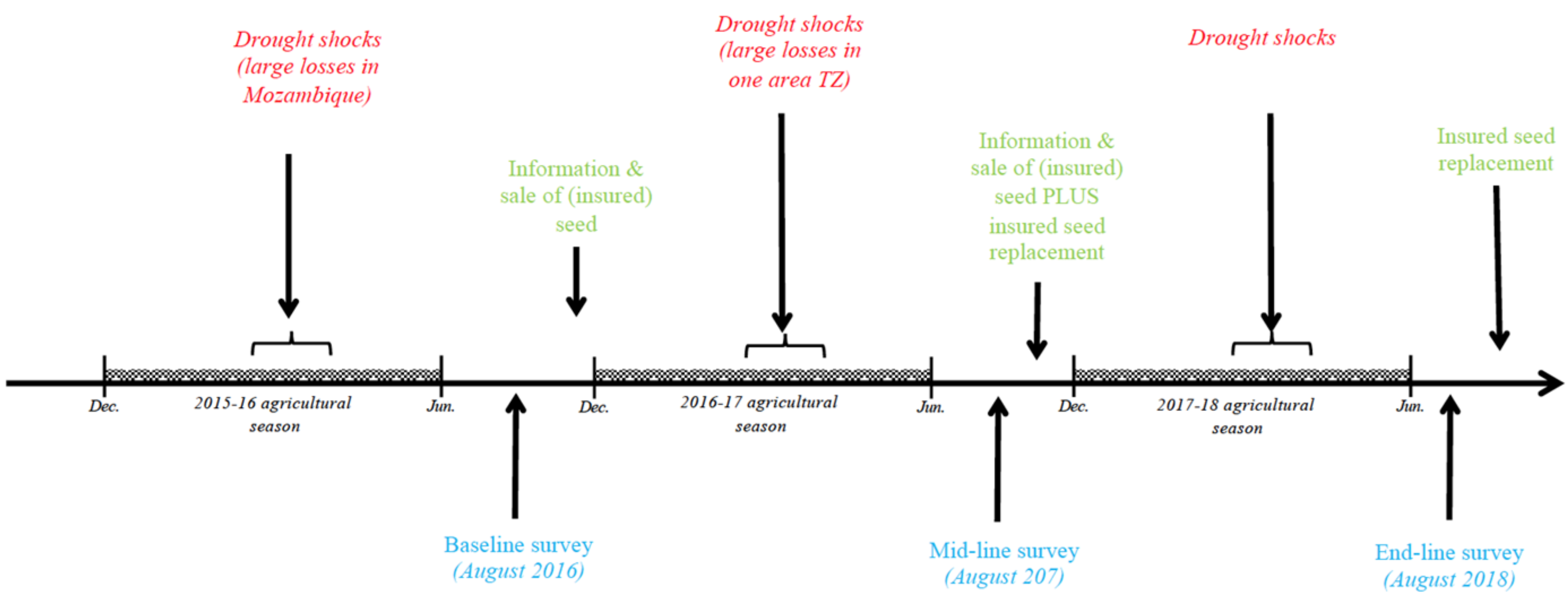
Timing

- Maize season runs from December through June.
- Three survey rounds implemented after harvests of:
  - 2015-16 season (Baseline); 2016-17 season (Midline); 2017-18 season (End-line)
- Marketing interventions occurred in Oct-Nov prior to planting for midline and end-line seasons.



Three year panel allows us to estimate:

- How large are within-season yield losses due to weather shocks using all 3 years?
- How effective are DT seeds at mitigating these losses at midline and end-line?
- How large are yield losses in the year *following* a severe weather shock (shock transmission from baseline to midline and midline to end-line)?;
- How effective are DT seeds and Index Insurance at mitigating these inter-seasonal losses (midline to end-line)?



Definitions of Weather Shocks

- Midseason Drought: Rainfall during the second 40 days after planting (i.e., during pollination period) was less than 200 mm.

- Severe Yield Shock: Average yields in the community were predicted to be less than 65% of historic mean.
  - Predictions based on satellite imagery of vegetative growth (NDVI) and full season rainfall;
  - Result of significant covariate weather shock (typically severe drought);
  - Index Insurance would be triggered

Frequencies of Weather Shocks

- In order to explore how effective DT & Insurance are in mitigating weather shocks, we (unfortunately) need farmers in the sample to face weather shocks!
- Lots of midseason droughts in both countries in all years;
- Some Severe Yield Shocks in both countries
  - Central Mozambique faced extreme drought in baseline (2015-16) season
  - Some areas in Tanzania experienced severe drought in midline (2016-17) season

	Mozambique			Tanzania		
% Hhlds affected by	2016	2017	2018	2016	2017	2018
Midseason Drought	100%	11%	62%	61%	69%	50%
Severe Yield Shock	91%	0%	0%	0%	15%	11%

Descriptive Statistics of Sample: Baseline

	Mozambique		Tanzania	
	Plant only local seed	Plant some improved seed	Plant only local seed	Plant some improved seed
% Farmers	79%	21%	29%	71%
Maize Area (ha)	2.6	3.1	1.7	1.6
Seed Use (kg/ha)				
-Local	13.9	9.7	19.3	14.4
-Improved	0	1.8	0	8.1
-Total	13.9	11.5	19.3	22.5
Use fertilizer	1.0%	4.3%	1.5%	7.2%
Had loan	1.5%	2.2%	3.3%	3.2%

- Minimal credit and fertilizer use in both countries
- Minimal use of improved seed in Mozambique
  - Only 21% planted improved seed & they planted very little (1.8 kg/ha)
- Improved seed use more common in Tanzania
  - 71% planted DT seed & they panted 8.1 kg/ha
  - But local varieties still the vast majority of seed

Take-up Rates by Treatment Group

	Mozambique		Tanzania	
	Midline	Endline	Midline	Endline
Seed Only Treatment				
% purchased DT	44.3%	43.9%	53.4%	46.9%
Amt purchased (kg)	6.6	3.3	12.2	19.5
DT as % of total seed	21.8%	19.1%	66.9%	75.8%
Insured Seed Treatment				
% purchased DT	38.2%	34.2%	48.6%	40.6%
Amt purchased (kg)	2.6	2.9	13.8	15.1
DT as % of total seed	15.2%	19.2%	67.0%	76.7%

- Takeup rates in both countries 6 – 9% pts lower for insured seed (20% higher price)
- Takeup rates in both countries fall from midline to endline by 1 – 8% pts
- Takeup rates consistently higher in Tanzania than Mozambique
  - % purchasing any DT seed 3 – 10% pts higher in Tanz
  - Avg purchase in Tanz = 12 – 20 kg vs 3 – 6 kg in Mozambique

Econometric Approach

- Goal: Estimate the impact of adoption of DT seeds and Index Insurance on yields.

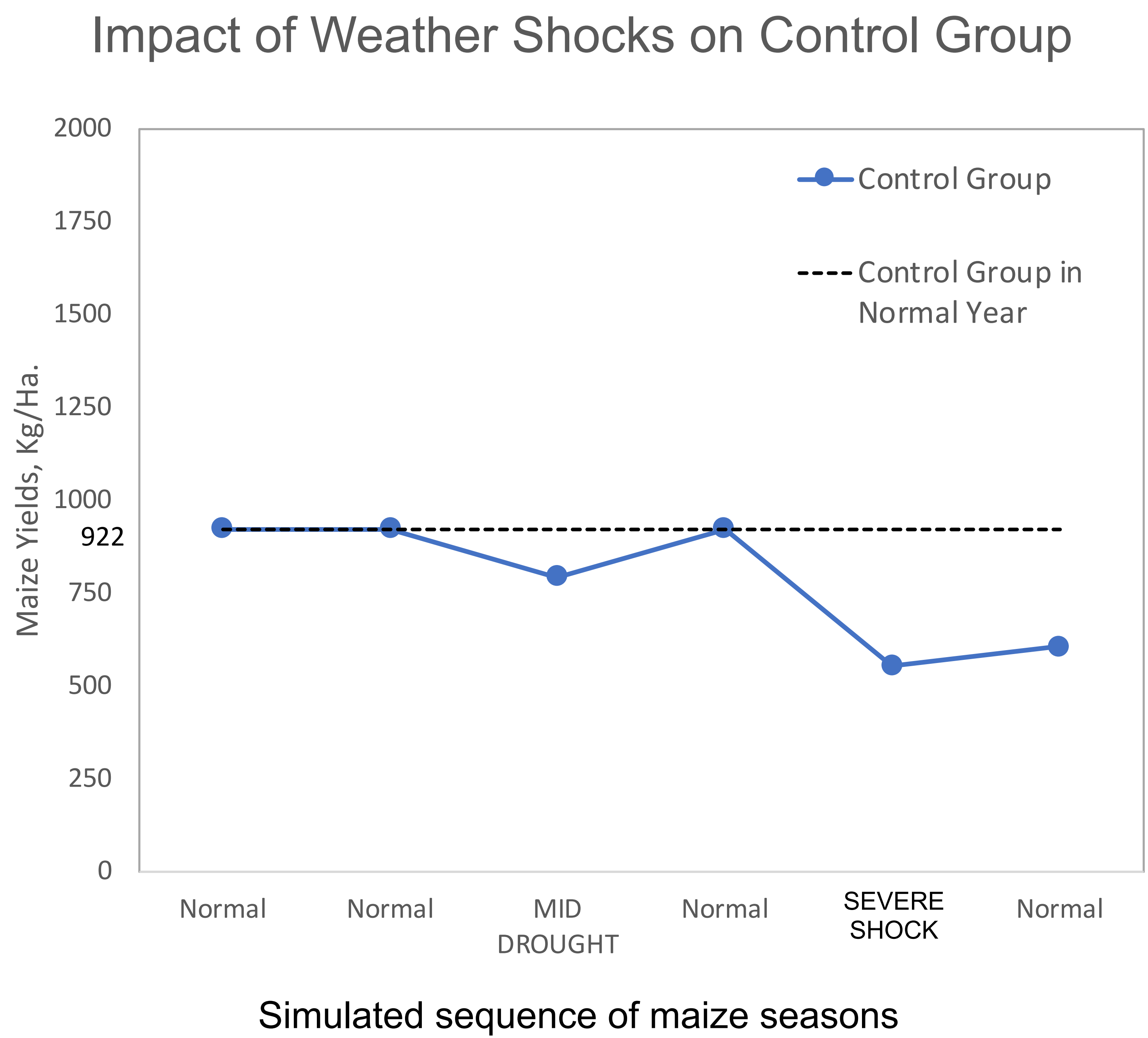
- Method: Regression analysis
  - Dependent variable: Maize yields
  - Independent variables:
    - Current & Lagged weather shocks
    - Adoption of each treatment: 1) Purchased DT seeds, 2) Purchased Insured Seeds
    - Interaction of the adoption of treatment variables with current and lagged weather shocks.

- Technical Details in Appendix slides

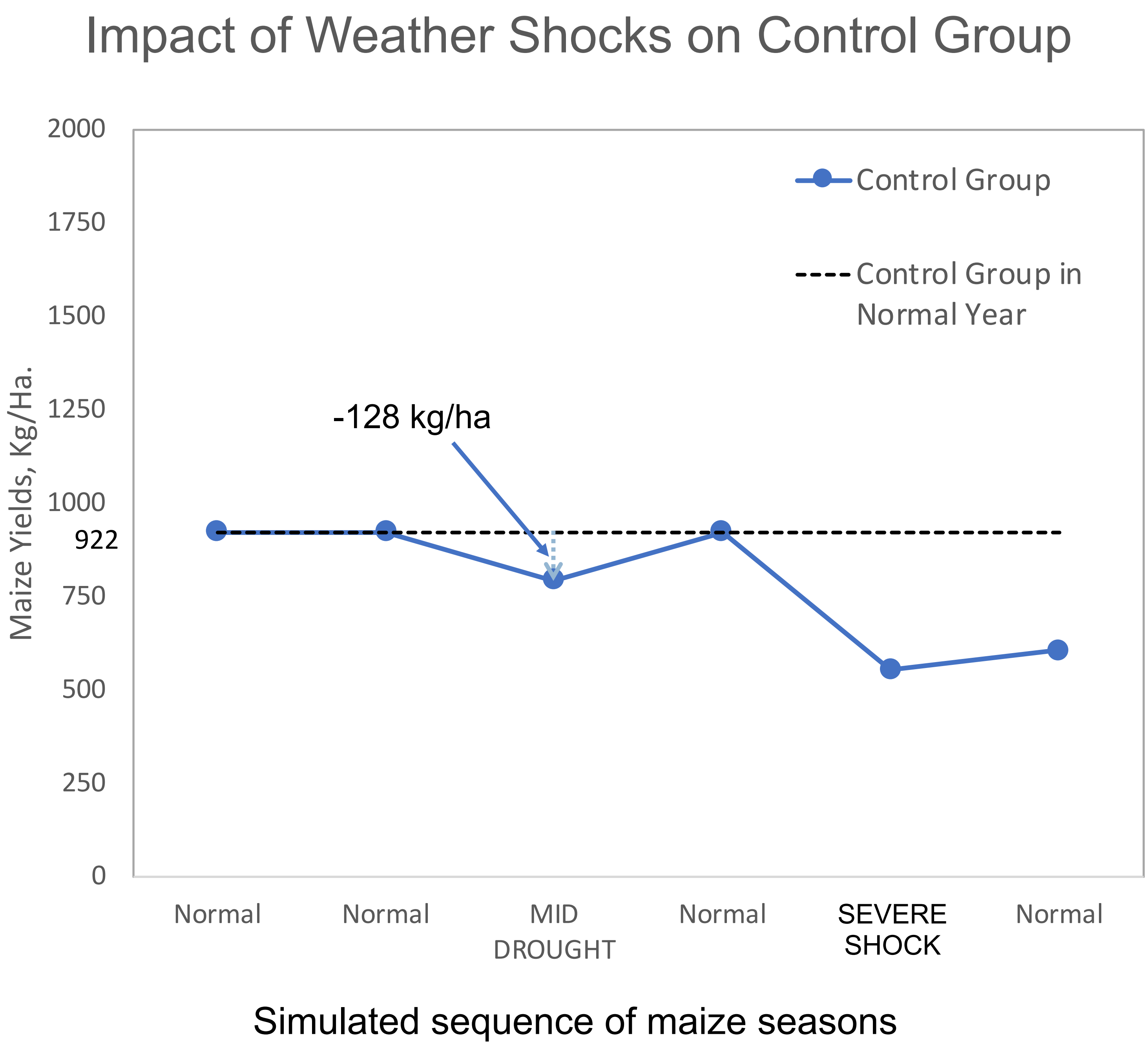
Presentation of Results

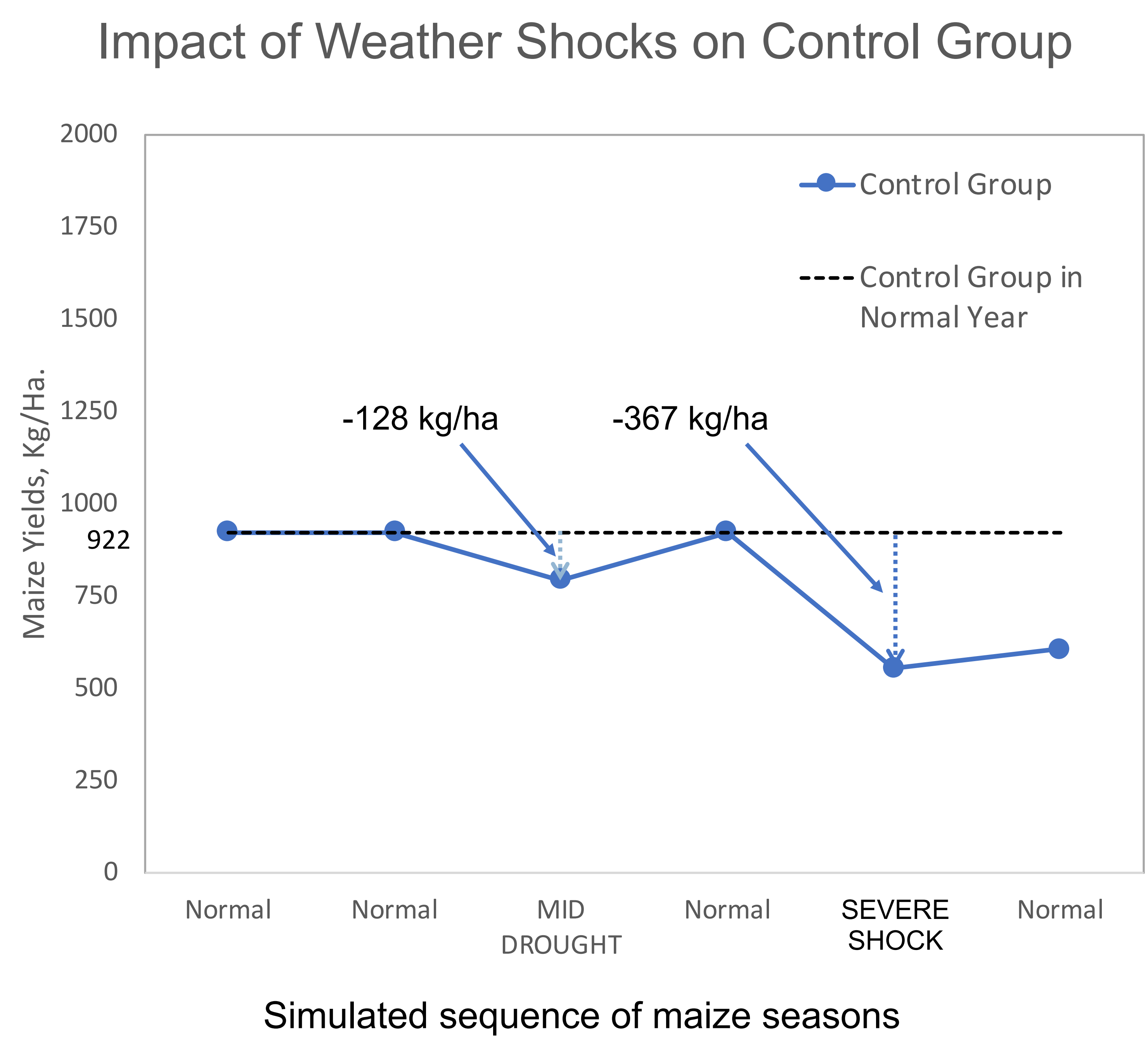
- Use results from regressions to simulate a sequence of 6 years with different weather outcomes: Normal, Normal, Midseason Drought, Normal, Severe Yield Shock, Normal.
  - First show predictions for control group;
  - Then show how adoption of DT seeds impacts yields;
  - Then show how index insurance (in addition to DT seeds) affects yields.

- Keep in mind “path dependence”
  - Yields under “Normal” weather may depend on the weather in the previous year!

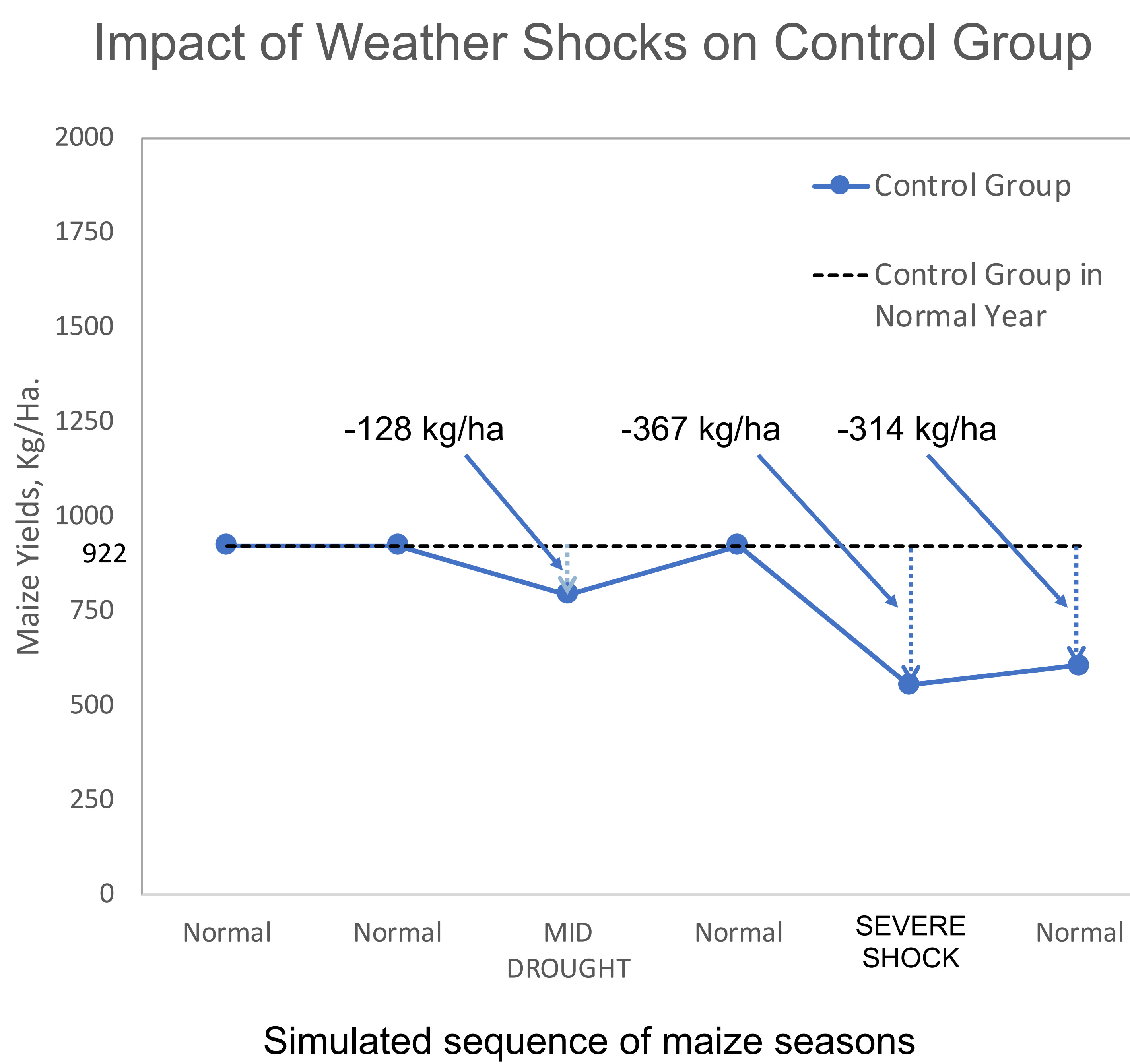


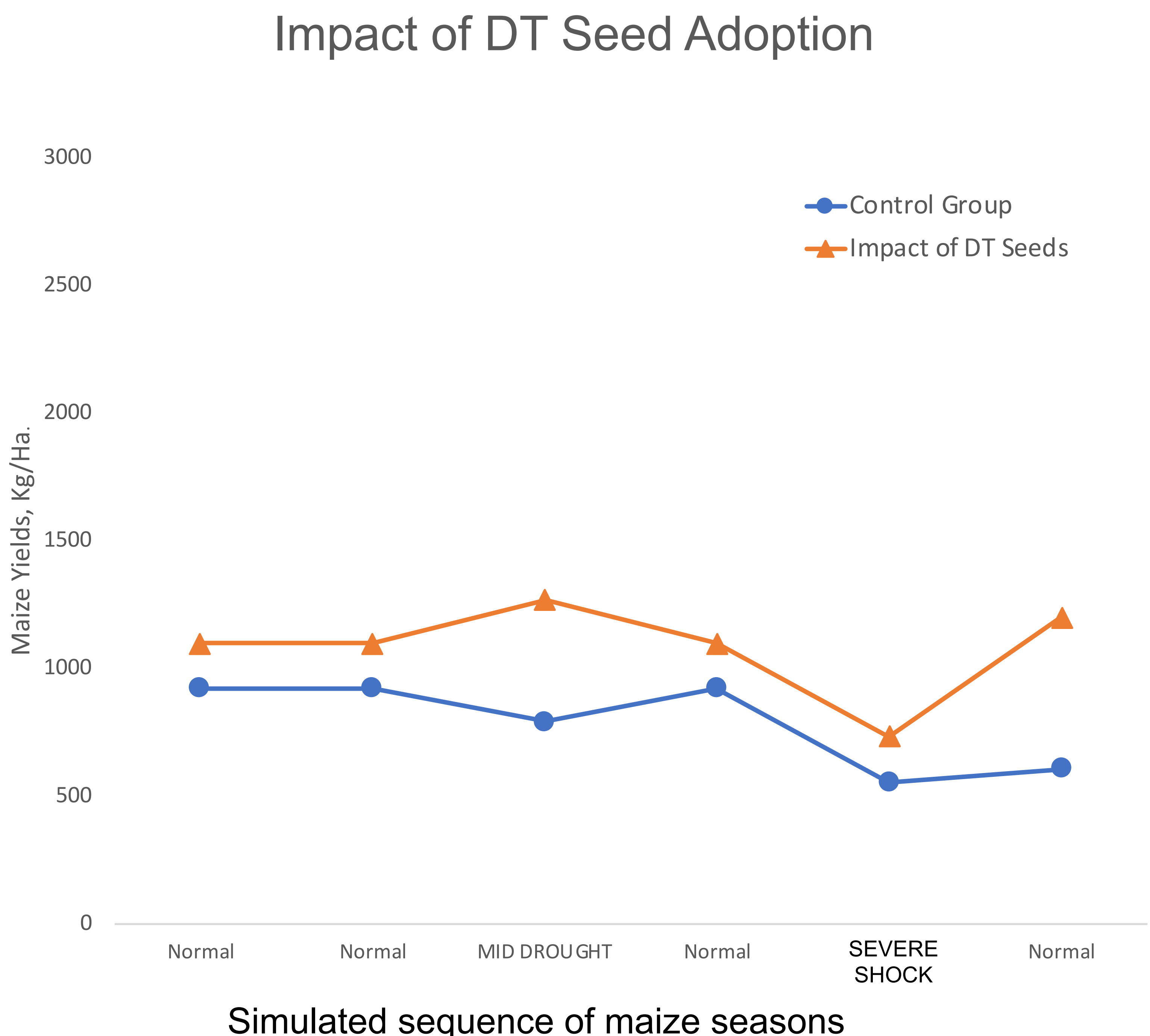
Impact of Weather Shocks on Control Group
2000
1750
1500
1250
1000
922
750
500
250
0
Maize Yields, Kg/Ha.
Control Group
Control Group in Normal Year
Normal
Normal
MID DROUGHT
Normal
SEVERE SHOCK
Normal
Simulated sequence of maize seasons


Impact of Weather Shocks on Control Group
2000
1750
1500
1250
1000
922
750
500
250
0
Maize Yields, Kg/Ha.
Control Group
Control Group in Normal Year
-128 kg/ha
Normal
Normal
MID DROUGHT
Normal
SEVERE SHOCK
Normal
Simulated sequence of maize seasons

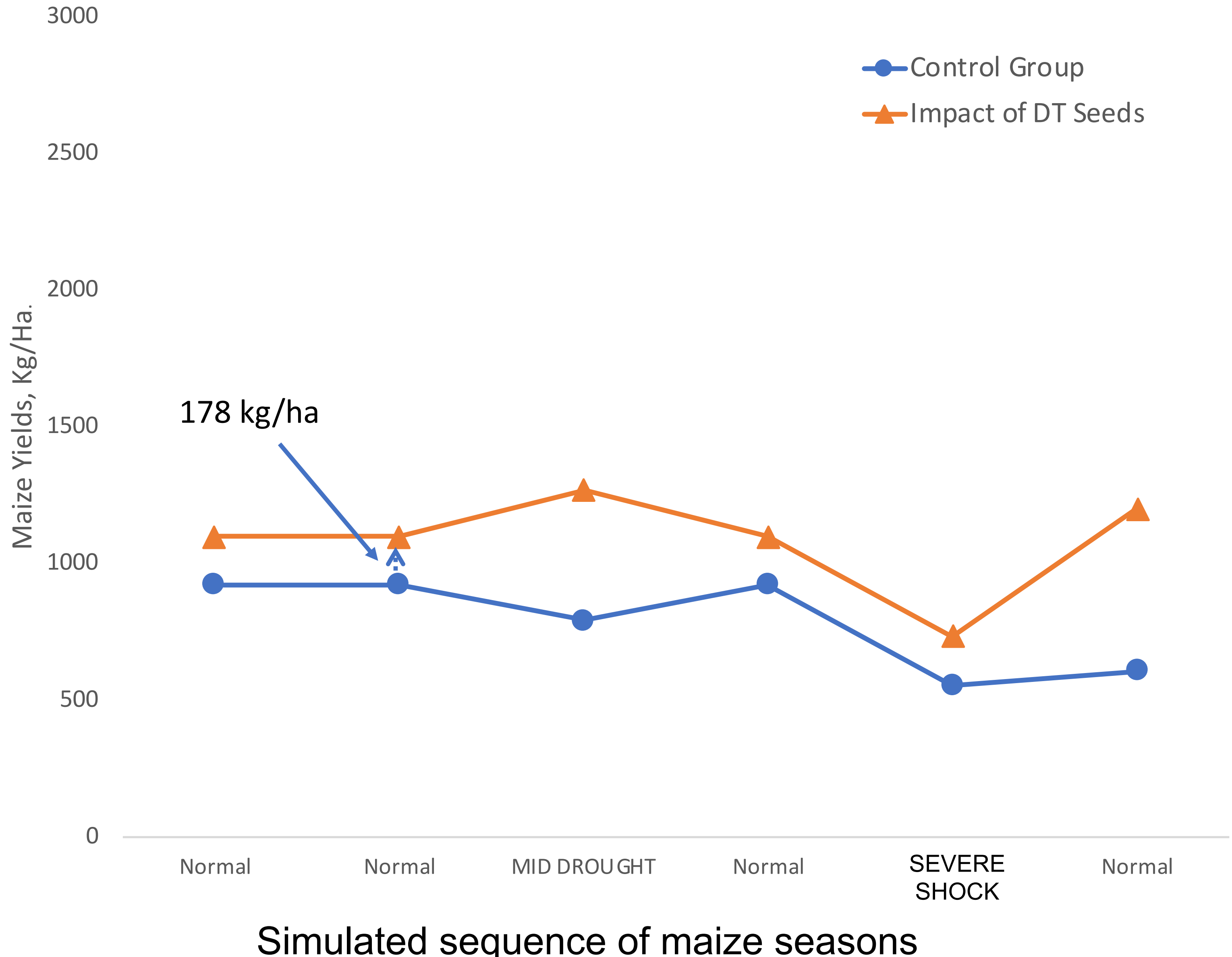


Impact of Weather Shocks on Control Group
Control Group
Control Group in Normal Year
-128 kg/ha
-367 kg/ha
Maize Yields, Kg/Ha.
2000
1750
1500
1250
1000
922
750
500
250
0
Normal
Normal
MID DROUGHT
Normal
SEVERE SHOCK
Normal
Simulated sequence of maize seasons

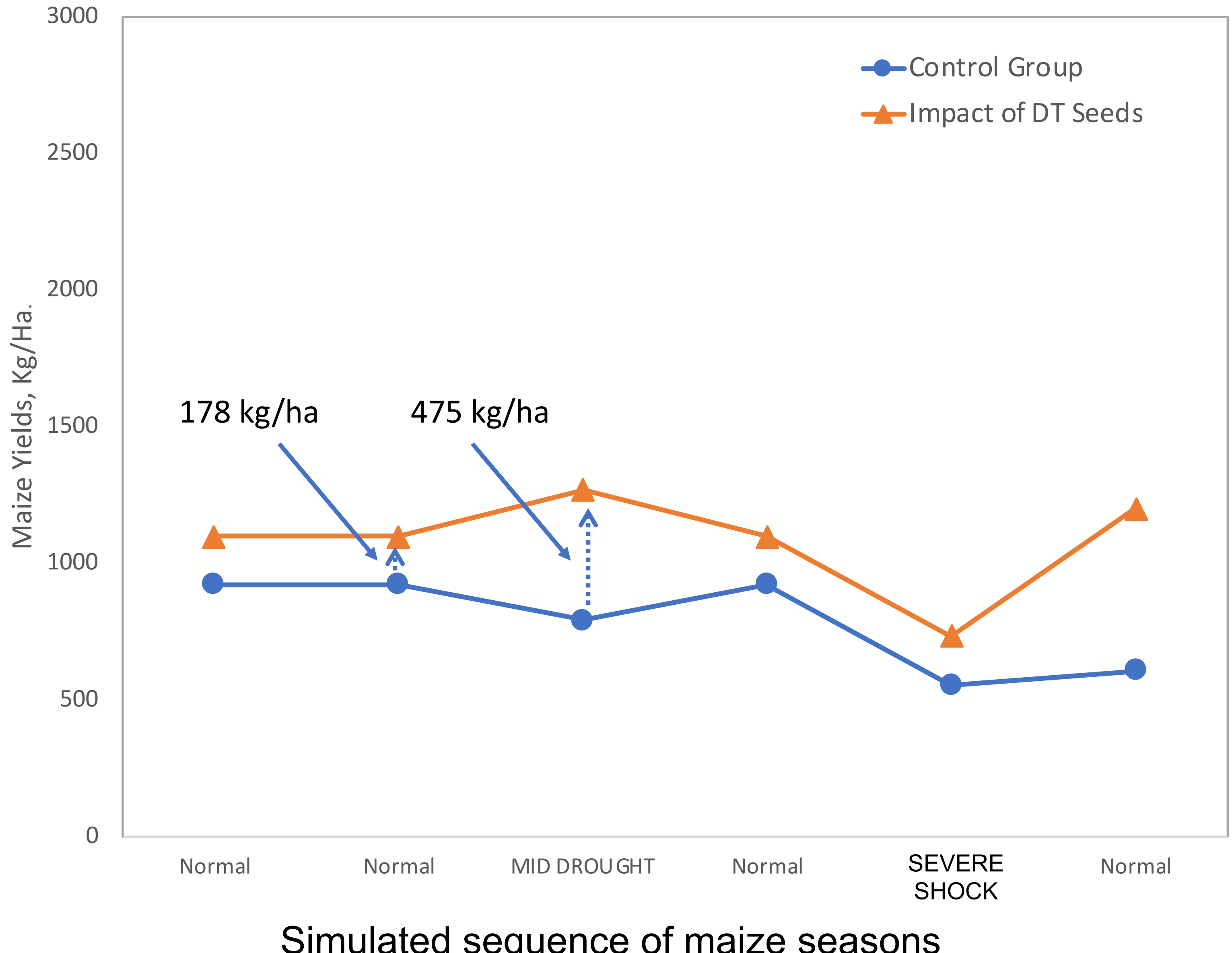

Impact of Weather Shocks on Control Group
Control Group
Control Group in Normal Year
2000
1750
1500
1250
1000
922
750
500
250
0
Maize Yields, Kg/Ha.
-128 kg/ha
-367 kg/ha
-314 kg/ha
Normal
Normal
MID DROUGHT
Normal
SEVERE SHOCK
Normal
Simulated sequence of maize seasons


Impact of DT Seed Adoption
3000
2500
2000
1500
1000
500
0
Maize Yields, Kg/Ha.
Control Group
Impact of DT Seeds
Normal
Normal
MID DROUGHT
Normal
SEVERE SHOCK
Normal
Simulated sequence of maize seasons

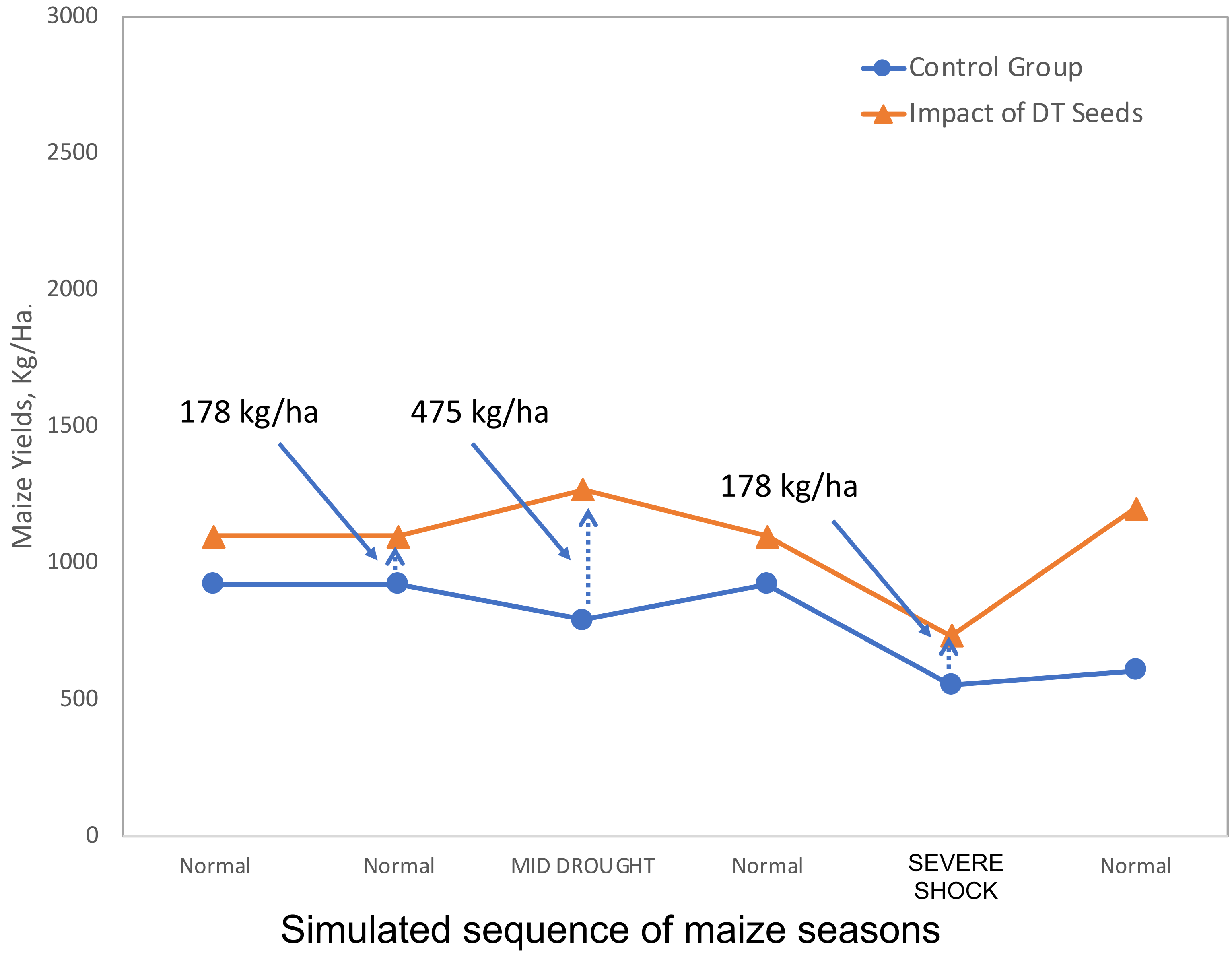
Impact of DT Seed Adoption

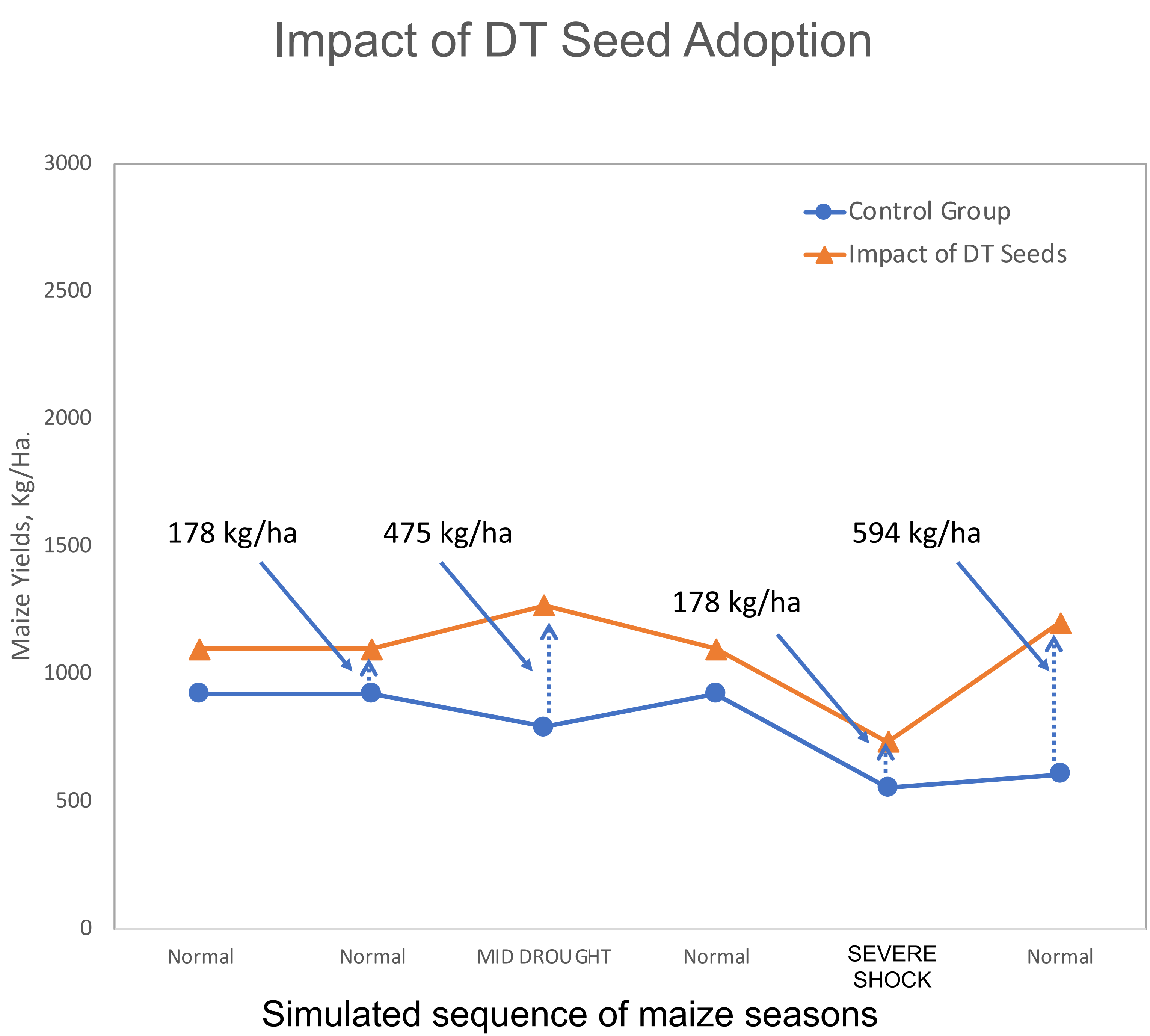


Impact of DT Seed Adoption

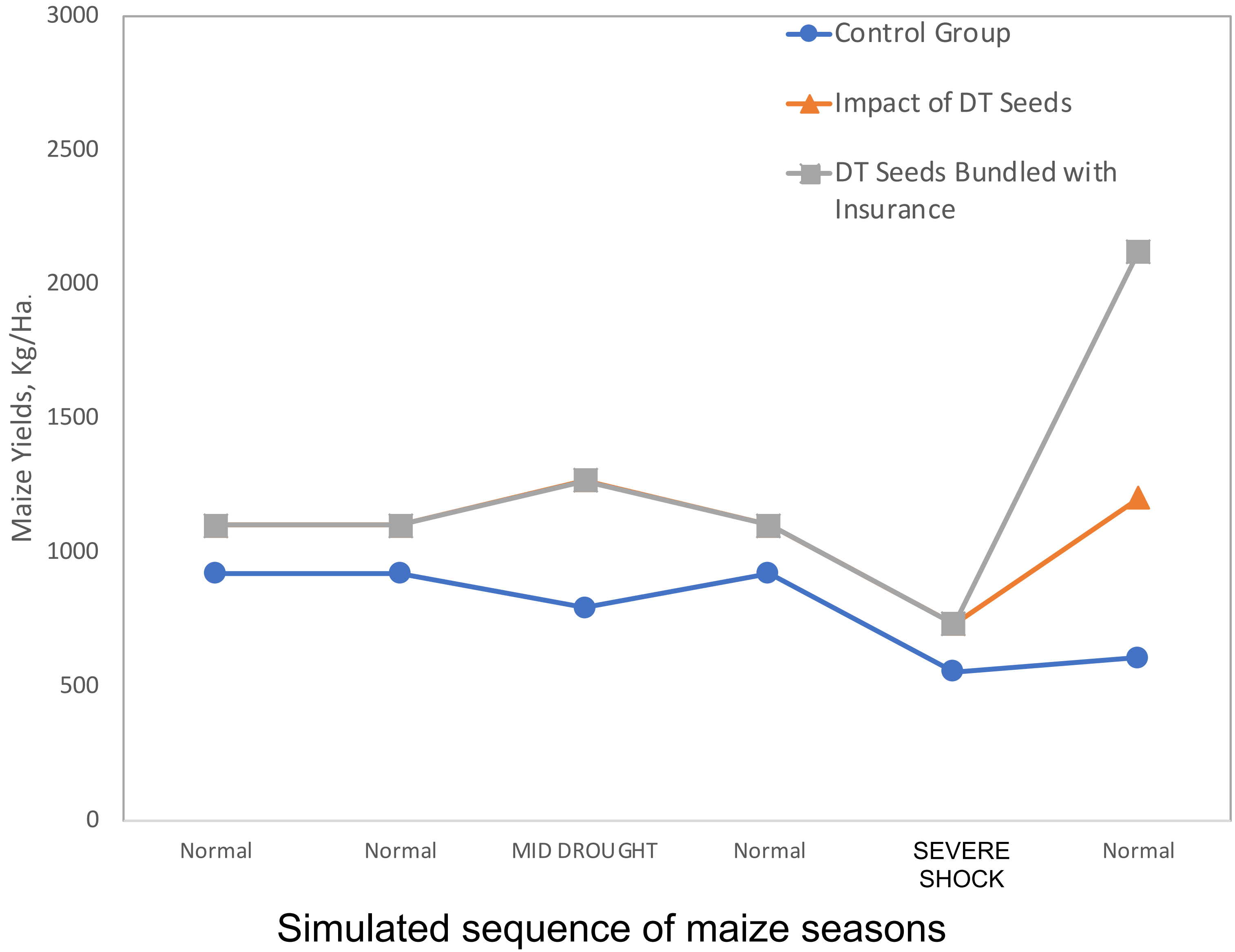


Impact of DT Seed Adoption

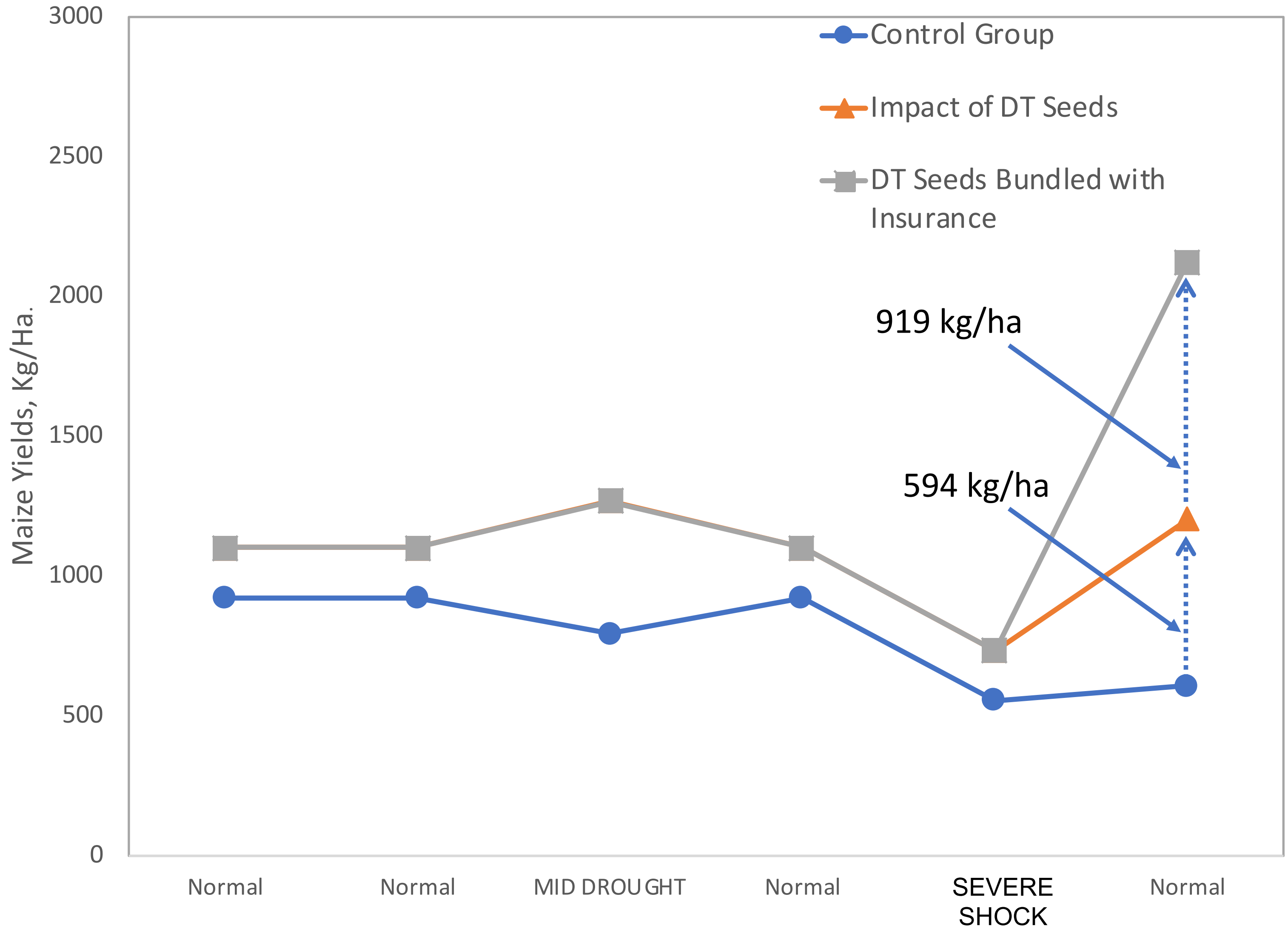



Impact of DT Seed Adoption
3000
2500
2000
1500
1000
500
0
Maize Yields, Kg/Ha.
Control Group
Impact of DT Seeds
178 kg/ha
475 kg/ha
178 kg/ha
594 kg/ha
Normal
Normal
MID DROUGHT
Normal
SEVERE SHOCK
Normal
Simulated sequence of maize seasons

Impact of Insurance



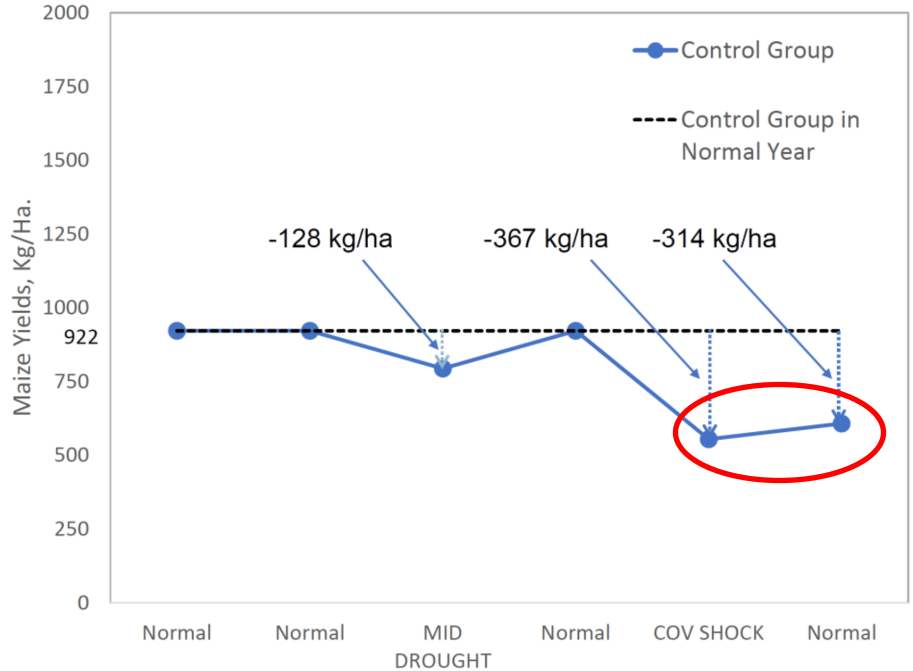
Impact of Insurance



Simulated sequence of maize seasons

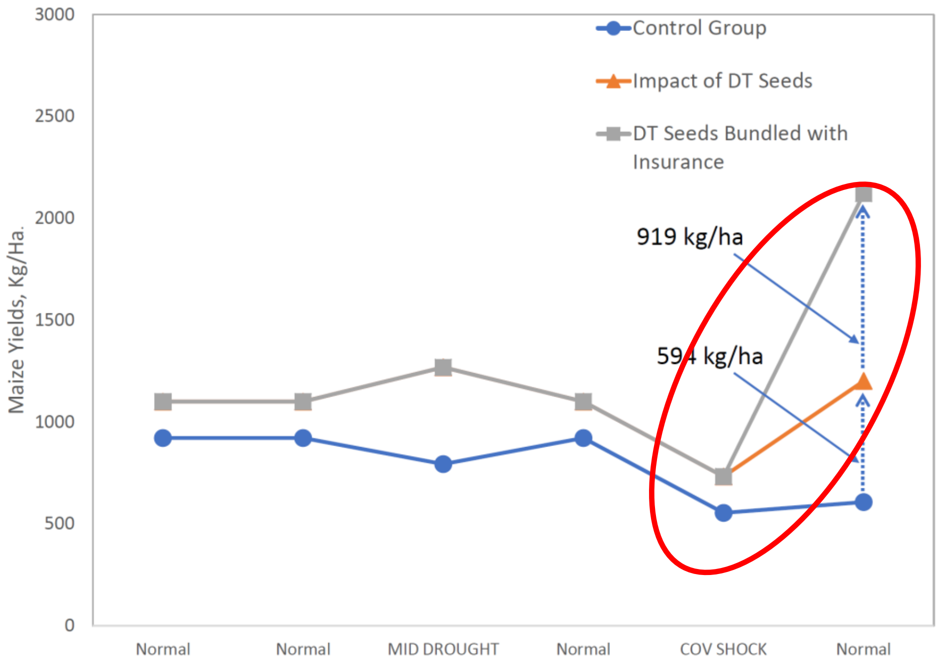
Unpacking Inter-Seasonal Impacts: Protecting Seed Capital?

- We just saw that severe weather shocks have persistent effects on yields:
  - Yields fall within-season
  - Yields do not recover next season
- Can persistence be explained by farmers' seed use?
- In our context, seed is the most important investment.
- If weather shocks cause yields to fall, farmers may not be able to afford as much improved seed next season
  - Seed capital eroded
  - Yields fall
- Do we see Control group's use of improved seeds fall after severe yield shock?



Unpacking Inter-Seasonal Impacts: Protecting Seed Capital?

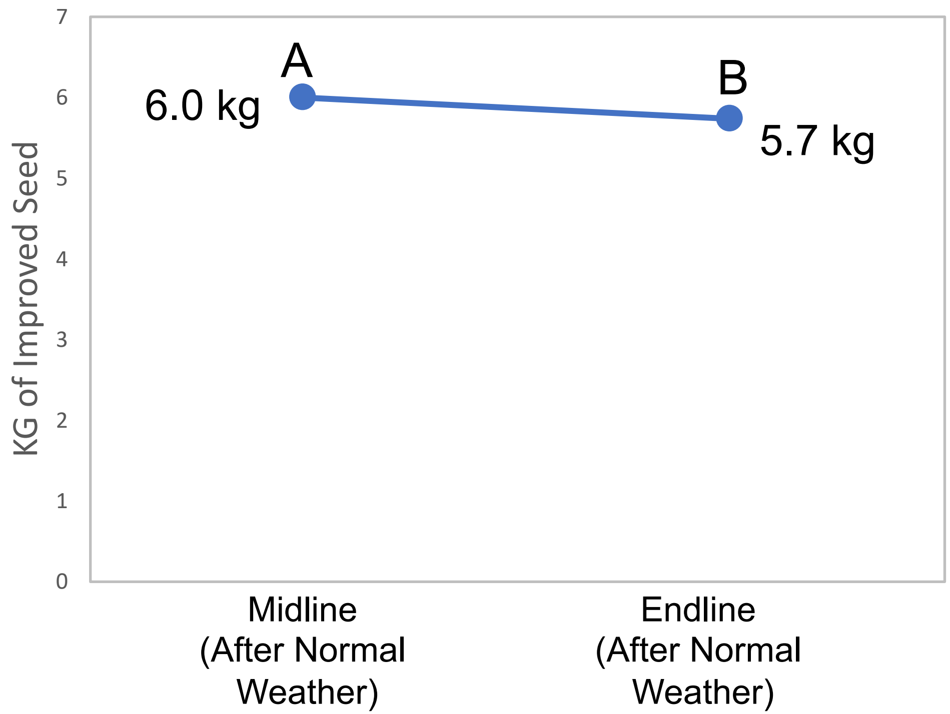
- We also saw that DT -- and especially Insurance -- allow yields to recover following a severe shock.
- Do we see treated farmers maintaining, or even increasing, their seed capital after a major weather shock?
- Multiple potential mechanisms
  - Insurance payout maintained stock of improved seed;
  - Farmers ***learned*** benefit of DT last season (during shock) and intensified seed use next season;
  - Farmers ***learned*** that insurance actually worked and intensified seed use next season
- If learning is key, what happens in years after normal weather (when minimal learning occurs)?



Unpacking Inter-Seasonal Impacts: Protecting Seed Capital?

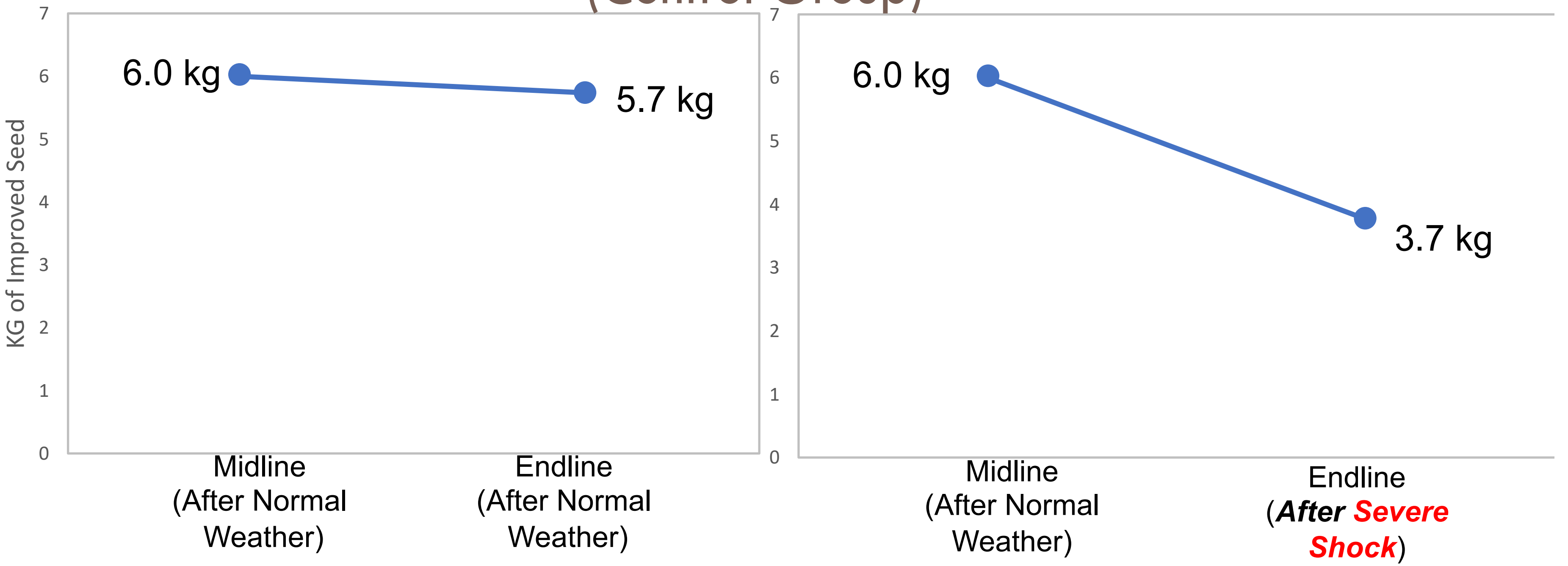
- More regression analysis
- Dependent variable: Quantity of Improved Seed
- Independent variables:
  - Treatment status (control, seed-only group, insured-seed group)
  - Year (midline versus endline)
  - ***Last season's weather*** (normal, mid drought, severe shock)
- Plot predicted seed use
  - At midline following a baseline season with normal weather;
  - At endline following a midline season with:
    - Normal weather
    - Severe Yield Shock

Impact of Endline vs Midline period on Improved Seed Use (Control Group)



- A: Following a baseline season with normal weather, control group farmers planted 6 kg of improved seed during midline.
- B: Following a midline season ALSO with normal weather, control group farmers planted 5.7 kg of improved seed at endline.
- Previous season weather did not change, so change along this segment = impact of other changes (eg., input or output prices) from midline to endline on control group.
- Non-weather features at endline period reduce improved seed use slightly (0.3 kg) compared to midline.

Impact of Severe Shock at Midline on Improved Seed Use (Control Group)



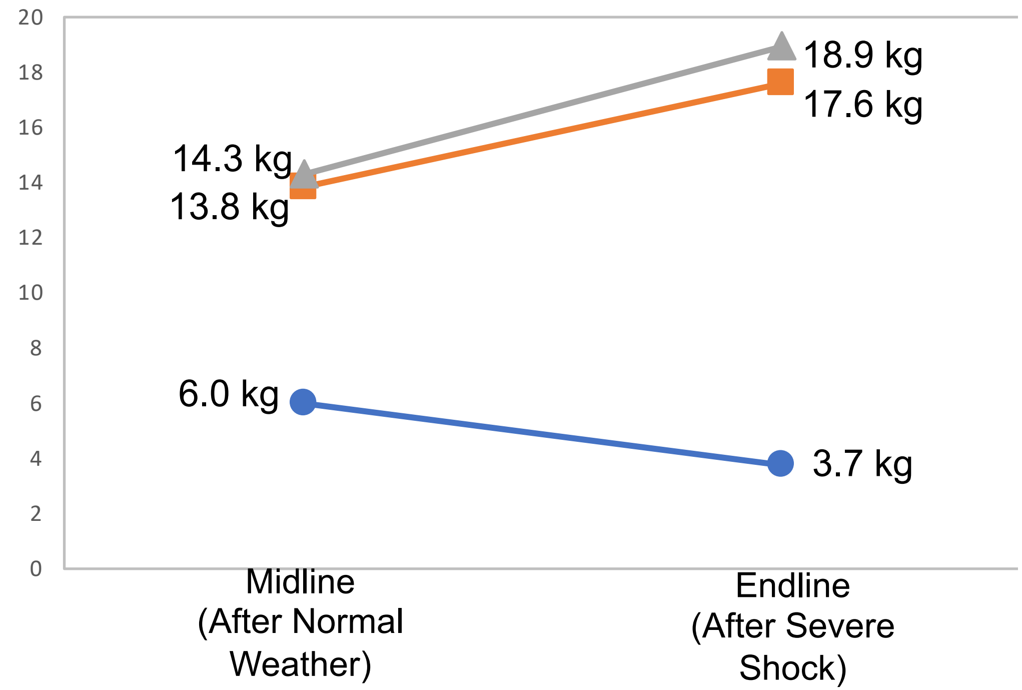
- If instead, endline was preceded by a ***severe yield shock at midline,*** control farmers planted only 3.7 kg at endline.
  - 6 → 5.7 was impact of endline time period;
  - 5.7 → 3.7 = 2 is impact of severe yield shock at midline.
- Severe yield shock at midline reduced use of improved seed at endline by 2 kg (33%).

Pause for Digestion

- For the control group, severe weather shock causes significant decapitalization (33% reduction in improved seed) next period;
- Given relatively high frequencies of severe weather shocks study areas, this is a significant concern (long term persistence of shocks on investment and yields)
- Final step: Do the DT and Insurance treatments prevent this decapitalization?

Impact of Treatments on Seed Use after Severe Yield Shock

(● Control Group; ■ Seed Only Group; ▲ Insured Seed Group)



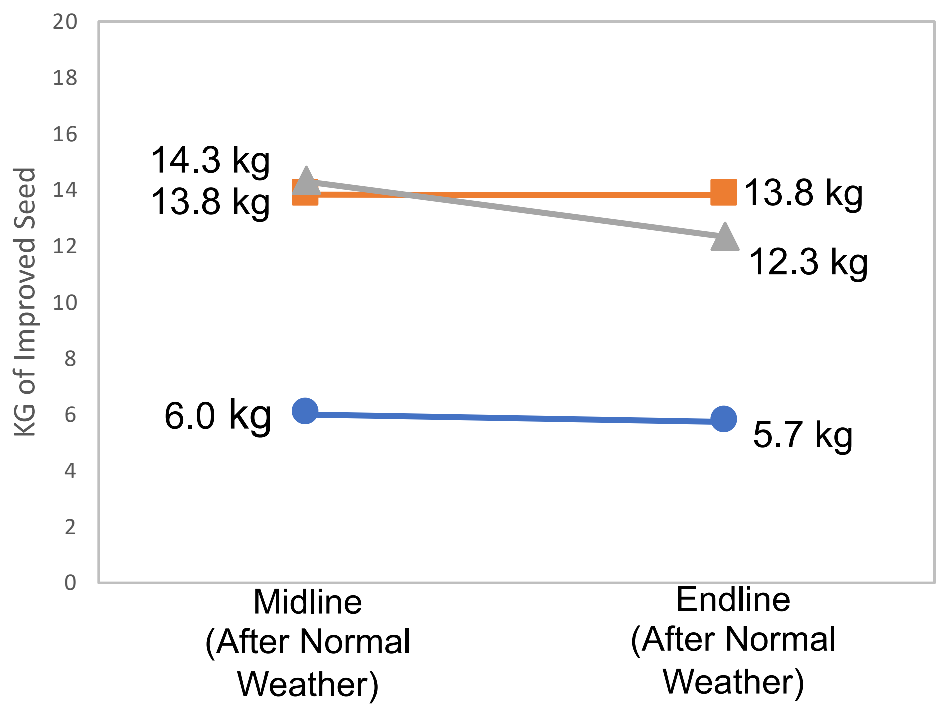
- Vertical distance between control group and treatment groups = impact of treatment at endline, given severe yield shock at midline.
  - Seed-only treatment raises improved seed use by 13.9 kg (= 17.6 – 3.7)
  - Insured-seed treatment raises improved seed use by 15.2 kg (= 18.9 – 3.7)
- Both treatment groups ***increased*** improved seed use after severe shock ("resilience plus")
  - Seed only group increased improved seed by 3.8 kg (= 17.6 – 13.8)
  - Insured seed group increased improved seed by 4.5 kg (= 18.9 – 14.3)

Learning as an Explanation for Resilience Plus?

- Why would investment in improved/DT seed ***increase*** after a severe weather shock?
- When first introduced (at midline), farmers may have tried out DT seed just a little bit.
- Those that had the "fortune" of experiencing a major weather shock may have learned a lot:
  - DT provides biggest benefit precisely when there is a drought.
  - Insurance companies will actually replace the seeds (trust)
- This type of positive learning may have convinced farmers to invest more in DT/improved seeds at endline.
- Under this logic, farmers would not learn much if they adopt DT and experience good weather.

Impacts Dissipate after Normal Weather at Midline

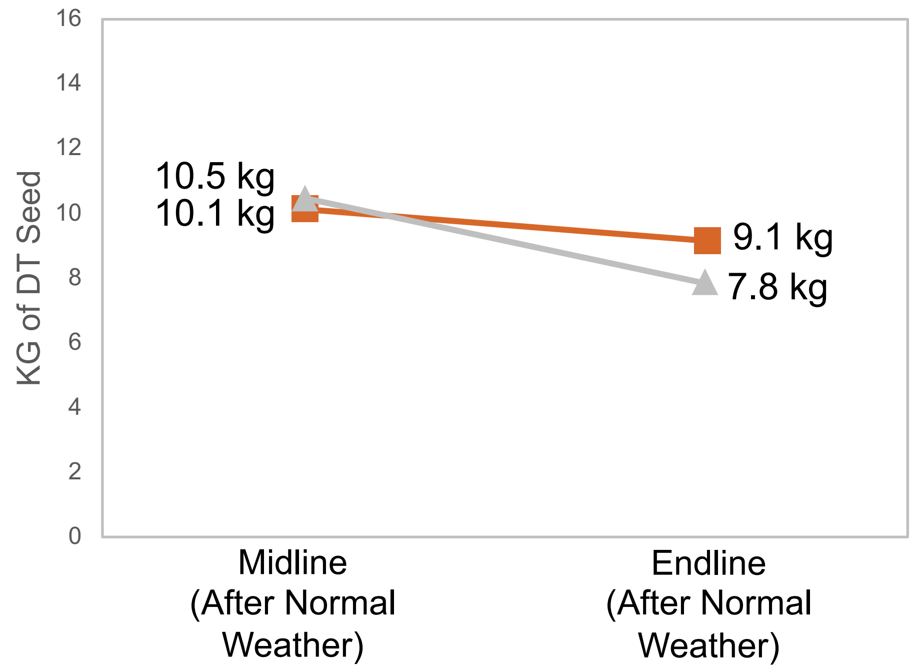
(● Control Group; ■ Seed Only Group; ▲ Insured Seed Group)



- After normal weather at midline:
  - Improved seed use remains constant for seed-only group
  - Decreases (14.3 to 12.3 kg) for insured-seed group
- Suggests that learning was not strong → farmers did not increase DT use and some turned away

DT Use Dissipates after Normal Weather at Midline

(■ Seed Only Group; ▲ Insured Seed Group)



- After normal weather at midline:
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  - Decreases (14.3 to 12.3 kg) for insured-seed group
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Summary

DT Seeds Provide Significant Within-Season Yield Advantage

- DT seeds provide significant protection against midseason drought:
  - During seasons with midseason drought, planting DT seeds raised maize yields by 475 kg (60%) compared to control group.
  - Rough rate of return of 285% assuming:
    - Farmer replaces 10 kg/ha of local seeds with DT seeds;
    - Maize price = USD 0.15/kg
    - DT seed price = USD 2.5/kg

- Without sacrificing yield during normal seasons:
  - During seasons with normal weather, planting DT seeds raised maize yields by 178 kg (18%) compared to control group.
  - Rough rate of return 6%

DT Seeds Enhance Farmer Resilience

- Planting DT seeds during a season with a severe yield shock raises maize yields ***in the following season*** by 595 kg (95%) compared to control group.

- Planting DT allows farmers' yields to fully rebound after severe yield shock.

Index Insurance Provides "Resilience Plus"

- Purchasing insured DT seeds during a season with a severe yield shock raises maize yields ***in the following season*** by 1,500 kg (250%) compared to control group.

- Index Insurance allows farmers to not only rebound to yields typical of a normal year, but surpass those yields.

- Suggests that effective removal of risk allows intensification of investment.

Intensification underlying "Resilience Plus"

- Behavioral response via seed investment helps explain surprising "resilience plus" yield results.
- In the year following a severe weather shock:
  - Control group decapitalized: Investment in improved seed fell by 33%;
  - Treatment groups intensified: Investment in improved seed increased by 30 – 40%.
- Suggests significant learning about the benefits of both DT trait and insurance occurred in these severe shock years.
- Cautionary lessons for scaling up:
  - Primary benefits of DT and especially insurance only occur under major weather shocks.
  - Farmers that initially adopted DT seed but did not experience shock (and thus did not learn) may start switching away from DT and insurance.
  - Additional/persistent education & marketing may be needed in this context

Thank You!

Additional Slides

Treatment on Treated Econometric Specification

$$y_{i,t=(1,2)} = \gamma_1 DROUGHT_{it} + \gamma_2 ZSHOCK_{c,t} + \gamma_3 ZSHOCK_{c,t-1} + \gamma_4 ZSHOCK_{c,t-1} I(t=2)$$
$$+ \beta_1^1 \mathrm{DT}_i + \beta_1^2 \mathrm{II}_i + \beta_2^1 \mathrm{DT}_i \times DROUGHT_{it}$$
$$+ [\beta_3^1 \mathrm{DT}_i \times ZSHOCK_{c,t-1}] I(t=2) + [\beta_3^2 \mathrm{II}_i \times ZSHOCK_{c,t-1}] I(t=2)$$
$$+ \theta y_{i,0} + v_s + e_{it}$$

Where the variables are defined as follows:

- $y_{i,t}$: Maize yield in period t (kg/ha)
- $DROUGHT_{it} = 1$ if mid-season rainfall < 200 mm
- $ZSHOCK_{c,t} = 1$ if predicted avg yield in the community $< 65\%$ of historical mean (insurance triggered);
- $DT_i = 1$ if farmer i planted DT maize
- $II_i = 1$ if farmer i purchased insured seed
- $I(t = 2)$: Indicator for end-line
- $y_{i,0} =$ Yields at baseline
- v_s: Triad fixed effect

Definition of Instrumental Variables

$$
\begin{aligned}
y_{i,t=(1,2)} = {} & \gamma_1 DROUGHT_{it} + \gamma_2 ZSHOCK_{c,t} + \gamma_3 ZSHOCK_{c,t-1} + \gamma_4 ZSHOCK_{c,t-1} I(t=2) \\
& + \beta_1^1 \mathrm{DT}_i + \beta_1^2 \mathrm{II}_i + \beta_2^1 \mathrm{DT}_i \times DROUGHT_{it} \\
& + [\beta_3^1 \mathrm{DT}_i \times ZSHOCK_{c,t-1}] I(t=2) + [\beta_3^2 \mathrm{II}_i \times ZSHOCK_{c,t-1}] I(t=2) \\
& + \theta y_{i,0} + v_s + e_{it}
\end{aligned}
$$

Our TOT specification includes 5 endogenous variables (any term that includes either DT_i or II_i). We use the following instruments in our IV estimation:

- T1: Assignment to seed only treatment
- T2: Assignment to seed-with-insurance treatment
- T1*$\mathrm{DROUGHT}_{it}$
- T2*$\mathrm{DROUGHT}_{it}$
- T1*ZSHOCK_{it-1}
- T2*ZSHOCK_{it-1}

Results: Treatment on Treated

	Coefficient	Std Error	Z value	P > Z
$DROUGHT_t$	-128.1	107.2	117.9	0.096
$ZSHOCK_t$	-367.5	77.0	-4.77	0.000
$ZSHOCK_{t-1}$	-101.5	21.7	-4.67	0.000
$ZSHOCK_{t-1}I(t=2)$	-213.0	97.0	-2.20	0.028
DT	178.6	107.2	1.67	0.096
II	-69.7	75.8	-0.92	0.358
DT x $DROUGHT_t$	296.3	105.5	2.81	0.005
(DT x $ZSHOCK_{t-1}$)$I(t=2)$	416.0	393.1	1.06	0.290
(II x $ZSHOCK_{t-1}$)$I(t=2)$	919.2	336.9	2.73	0.006
y_0	0.16	0.026	6.16	0.000
Control Mean	539			
Observations	5407			