Drought-tolerant Technology: A Mixed Blessing

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Introduction

❖ **Motivation**

Climate change is projected to increase environmental stress on major crops in the U.S., corn in particular. One potentially promising technology to enhance corn tolerance to heat and water stress is the Drought-tolerant (DT) corn varieties that became broadly available in 2013 (Tollefson 2011).

However, numerous laboratory and empirical studies have suggested penalties associated with higher drought tolerance in various forms (Zhao et al. 2015; Miao et al. 2021). In addition, in actual corn production the DT varieties may perform differently than in the laboratory due to behavioral differences associated with the decision to plant DT corn, such as planting rate (Lobell et al. 2014).

❖ **Objective**

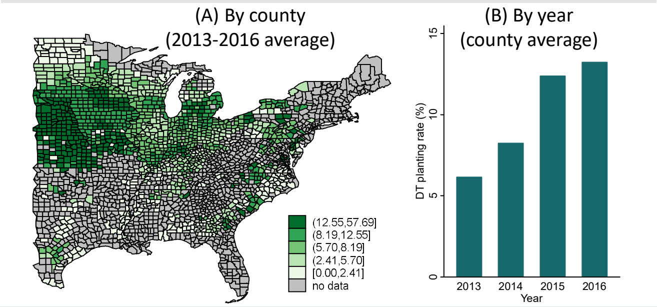
Systematically evaluate the impacts of Drought-tolerant (DT) technology on yield and yield risk in the U.S. corn production context.

Method and Data

DT technology potentially works through two channels: (1) raise the **stress tolerance threshold** beyond which the stress becomes too extreme to tolerate, and (2) mitigate the **extent of damages** associated with extreme stress. To identify the effects through the two channels separately, we estimate the piecewise linear function for both heat and water stress using DT-planting and non-DT subsample, respectively, to estimate the **thresholds** and **piecewise slopes**. Subsequently, the thresholds and effects are compared across the two DT groups to reveal DT effects. An observation is assigned to DT=1 subsample if the DT planting rate is greater than zero, and to DT=0 otherwise.

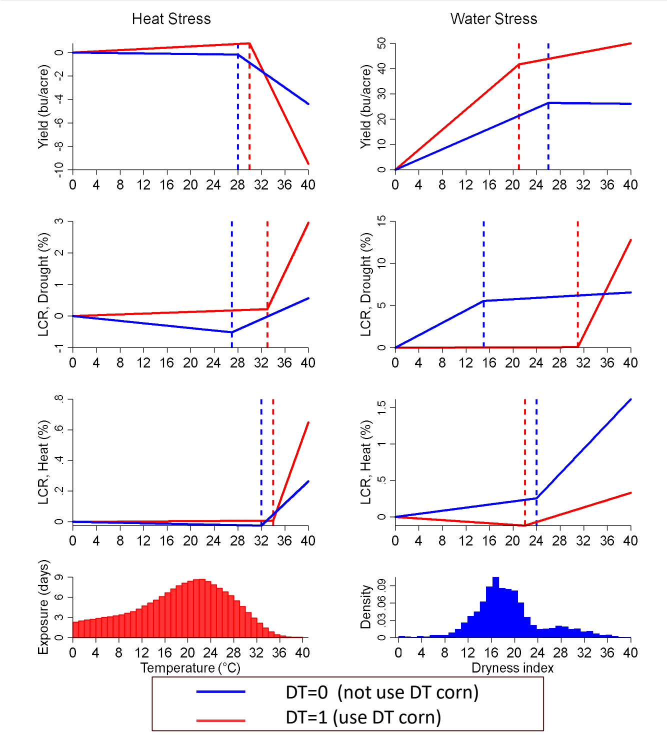
Yield is measured by bushels per harvested acre. Heat- and drought-associated yield risks are operationalized using cause-specific loss-cost ratio (realized indemnity payments associated with the specific cause divided by the maximum indemnity payments recorded in the crop insurance database). The Dryness index is a linear transformation of Palmer Drought Severity Index such that it ranges from 0 to 40 and higher values indicating drier conditions. Our analysis relies on a panel dataset at county level, spanning 2013-2016.

DT planting rate (%)



Results

Piecewise effects of heat and water stress, by DT group.



Test statistics (p-value) for piecewise slopes

Null Hypothesis	Heat Stress: Yield	Heat Stress: LCR, Drought	Heat Stress: LCR, Heat	Water Stress: Yield	Water Stress: LCR, Drought	Water Stress: LCR, Heat
[DT=0: k1] = 0	0.77	0.00	0.73	0.00	0.01	0.35
[DT=1: k1] = 0	0.22	0.13	0.51	0.00	0.94	0.28
[DT=0: k2] = 0	0.00	0.00	0.01	0.97	0.59	0.05
[DT=1: k2] = 0	0.00	0.00	0.02	0.12	0.01	0.04
[DT=0: k1] = [DT=1: k1]	0.25	0.00	0.65	0.00	0.01	0.19
[DT=0: k2] = [DT=1: k2]	0.00	0.03	0.13	0.51	0.01	0.17

Notes: DT=0 (1) denotes the non-DT (DT) subsample, k1 (k2) denotes the slope for the below (above)-threshold piece. For example, the last row tests whether the above-threshold slopes are statistically equal across the two DT groups.

Conclusions

The results suggest that the DT technology is a mixed blessing. On the one hand, the DT corn generally endures higher levels of stress than does its non-DT counterpart, and this is especially the case for drought-related yield risk: the tolerance thresholds of DT corn are much greater than non-DT for both heat and water stress.

However, on the other hand, yield decreases and yield risks increase at a greater rate beyond the threshold for DT group. That is, the yield and yield risk outcomes are more severely compromised under extreme stress for DT varieties.

Taken together, our data tentatively suggest that while DT corn is less likely to be struck by environmental stress, it suffers greater marginal damage when the stress becomes intolerable. Hence the “mixed blessing”.

Discussions

Cautions should be taken in interpreting our results. First, this study does not characterize a pure technical relationship in the way that field and laboratory studies usually do. Rather, we attempt to capture the behavioral factors associated with DT planting, whether they induce DT planting or are in response to it. Hence, the results reflect the aggregate outcome that is possibly mediated by behavioral factors, including but not limited to planting rate (Lobell et al. 2014), co-adoption of other existing traits and tillage.

Second, the average DT planting rate in the DT subsample is 16.8%. Therefore, more precisely the differences between DT and non-DT groups pertain to a relatively low level of DT planting, compared to the traits with long history, such as Bt. However, a higher DT planting rate in the near future is reasonably expected.

References

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