Development of novel methods for assessing the impact of plant biologicals on crop productivity, climate, environment, and biodiversity

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Innovation Foundation InnoMission project

Project titel:
Climate and Environmentally Friendly Plant Biologicals – Development of novel methods for assessing the impact of plant biologicals on crop productivity, climate, environment, and biodiversity.

Duration: 2022-2025

Partners:
Danish Technological University (project leader)
University of Copenhagen
Aarhus University
Chr. Hansen
FMC
Novozymes
SEGES Innovation

Overall purpose of the project

- Experimental designs and protocols will be developed for using plant biologicals to meet a range of needs and challenges. Procedures will also be established for calculating the impact of plant biologicals on climate, biodiversity and the environment.
- Using these designs and protocols, field trials will be conducted over three years to test the impact of plant biologicals on specific pests or their effect as biostimulants.
- In addition, the project will develop data models for analyzing the effects of treatment under varying environmental conditions.

Work packages

1) Development of experimental design and protocols.

2) Development of climate, biodiversity, and environmental impact calculator.

3) Decentralized field trial testing for 3 successive years with the companies.

4) Data management, modelling and data analysis.

5) Project Management & dissemination.

Project timeline

2023

- Design protocols
- Define crop production baselines
- Develop climate impact calculator
- Define risk assessment protocols
- Estimate CO2 emissions
- Build machine learning model
- Field trials

2024

- Design protocols
- Define crop production baselines
- Data analysis
- Implementation and validation of models
- Develop statistical procedures
- Estimate CO2 emissions
- Field trials

2025

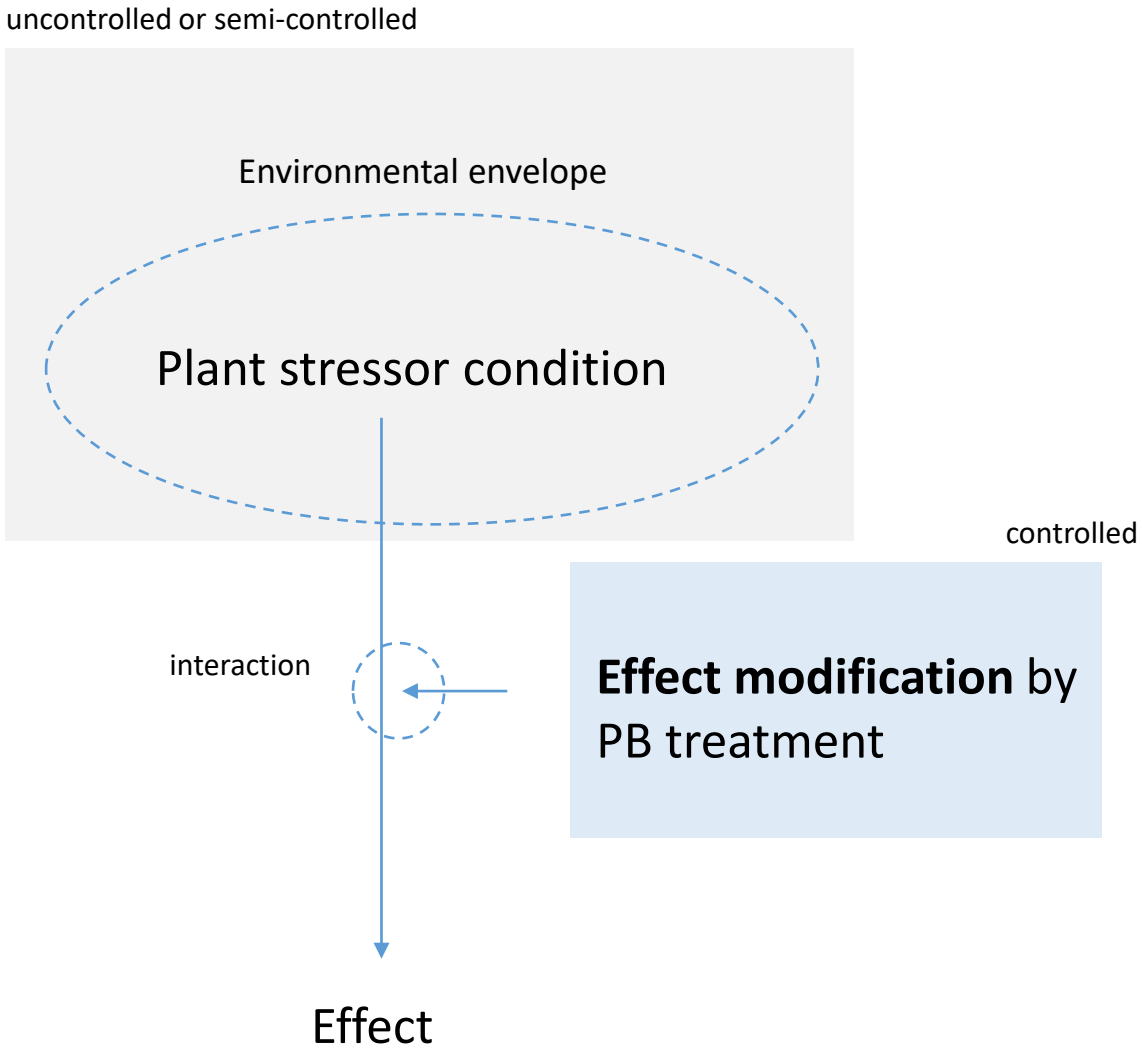
- Data analysis
- Estimate CO2 emissions
- Test and validation of models
- Define best practice for field protocols
- Field trials

The project is open for additional partners if they have concrete ideas for joining the partnership e.g. have products they want to test in field trials. New partners must contribute to co-fund the project and they must be/sign up to be members in the Plant Biologicals Network. Contact Lene Rasmussen lras@plen.ku.dk

Some initial thoughts

on how to investigate the treatment effects of plant biologicals (PB)

PB trials = clinical trials



Challanges

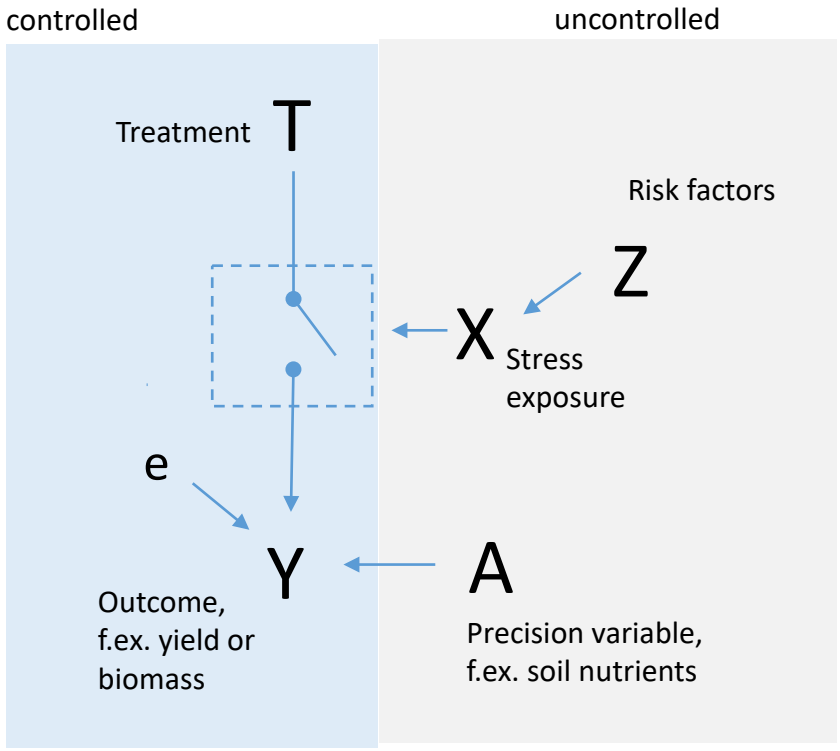
- Mixture of **exploratory** (environ. envelope) and **confirmatory** (treatment effects) research goals

- Mixture of design-based and observational data: **controlled** (treatment, plant variety), **un-controlled** (climate conditions) and **semi-controlled** (soil conditions) variables.

- Observational data of strongly **correlated, inter-dependent** environmental variables defining the stressor condition

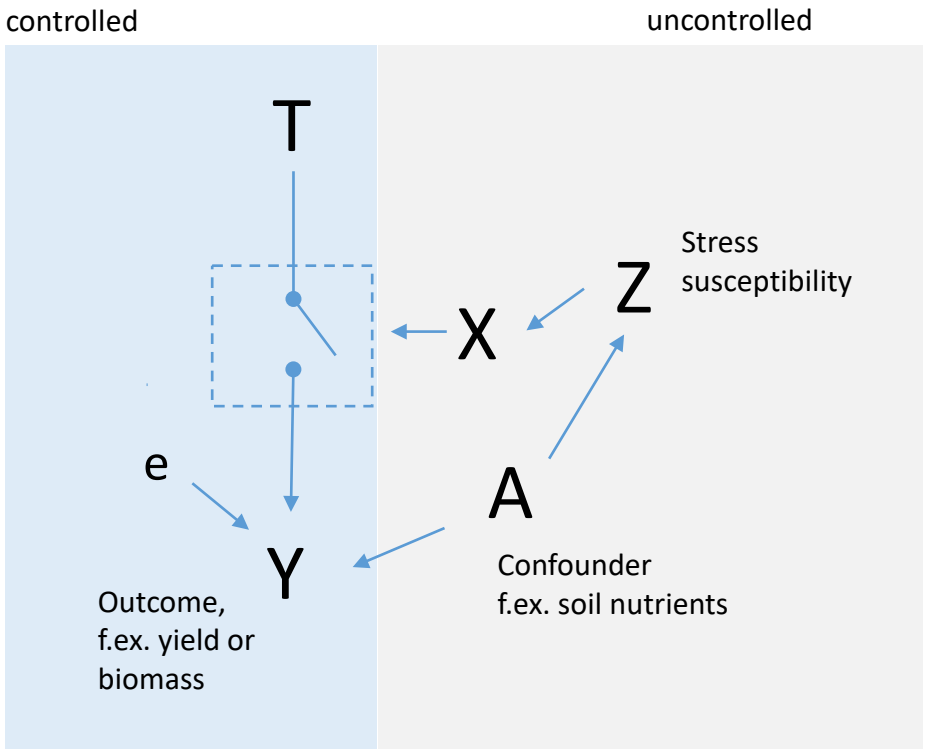
- Effect sizes for PB are expected to be smaller than conventional alternatives giving rise to **statistical power issues**

Effect modification



$$Y = \beta_0 + \beta_1 A + \beta_2 T + \beta_3 X + \beta_4 XT + e$$

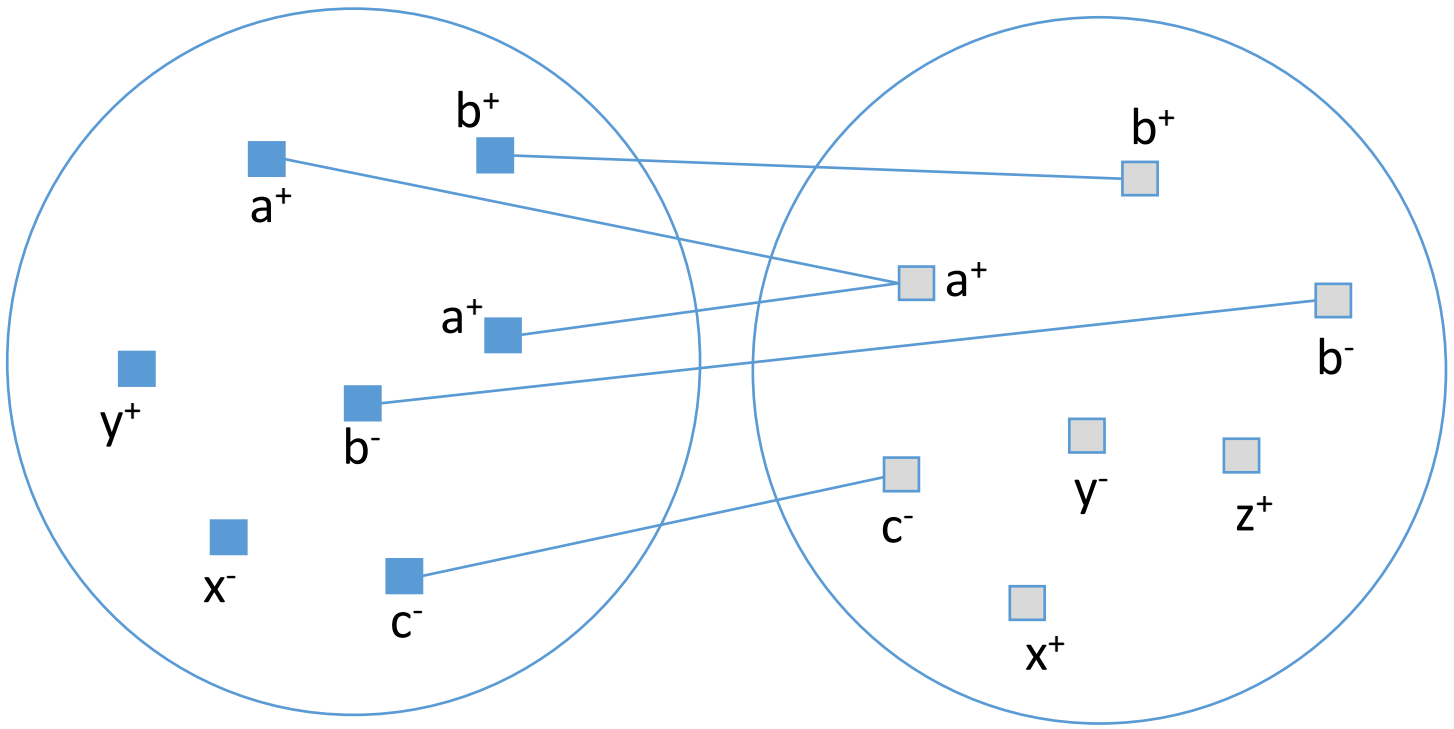
Effect modification under confounding



$$Y = \beta_0 + \beta_1 A + \beta_2 T + \beta_3 AT + e$$
$$Pr(X) = f(A)$$

How observational data are dealt with in the social and ecological sciences

Matching



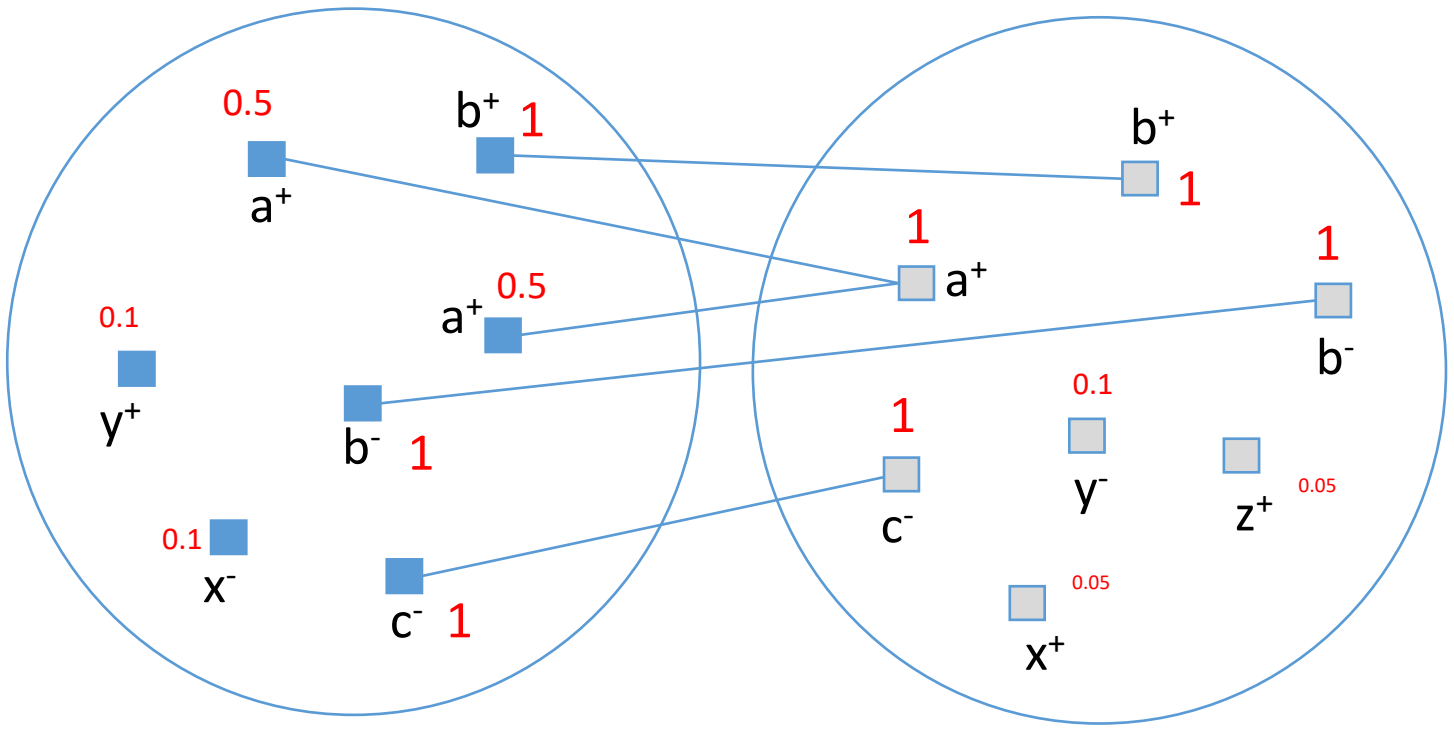
Treatment T: treatment control

Stress exposure: +/-

Risk factors, background variables: a, b, c, x, y, z

- Matching seeks to **balance** treatment comparison groups wrt. *observed* important background or conditioning variables
- Some observations may remain unmatched
- One-to-one and one-to-many matching is possible
- *Unobserved confounders* can only be dealt with by means of randomization

Weighting



Treatment T: treatment control

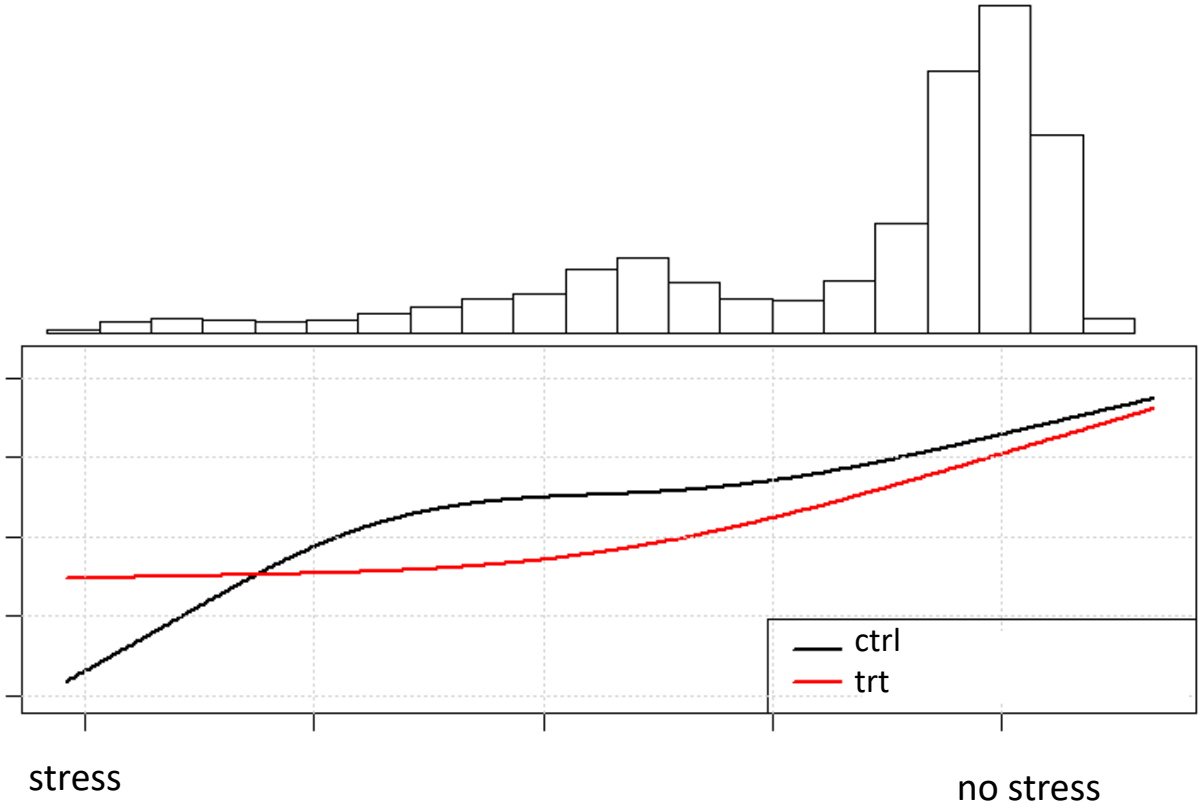
Stress exposure: +/-

Risk factors, background variables: a, b, c, x, y, z

- Inverse probability weighting (IPW) achieves **balance** in treatment comparison groups by means of weighting
- All observations are included, but weighted differently
- *Unobserved confounders* are still only controlled by means of randomization

Why is **balance** important?

Outcome
f.ex. yield

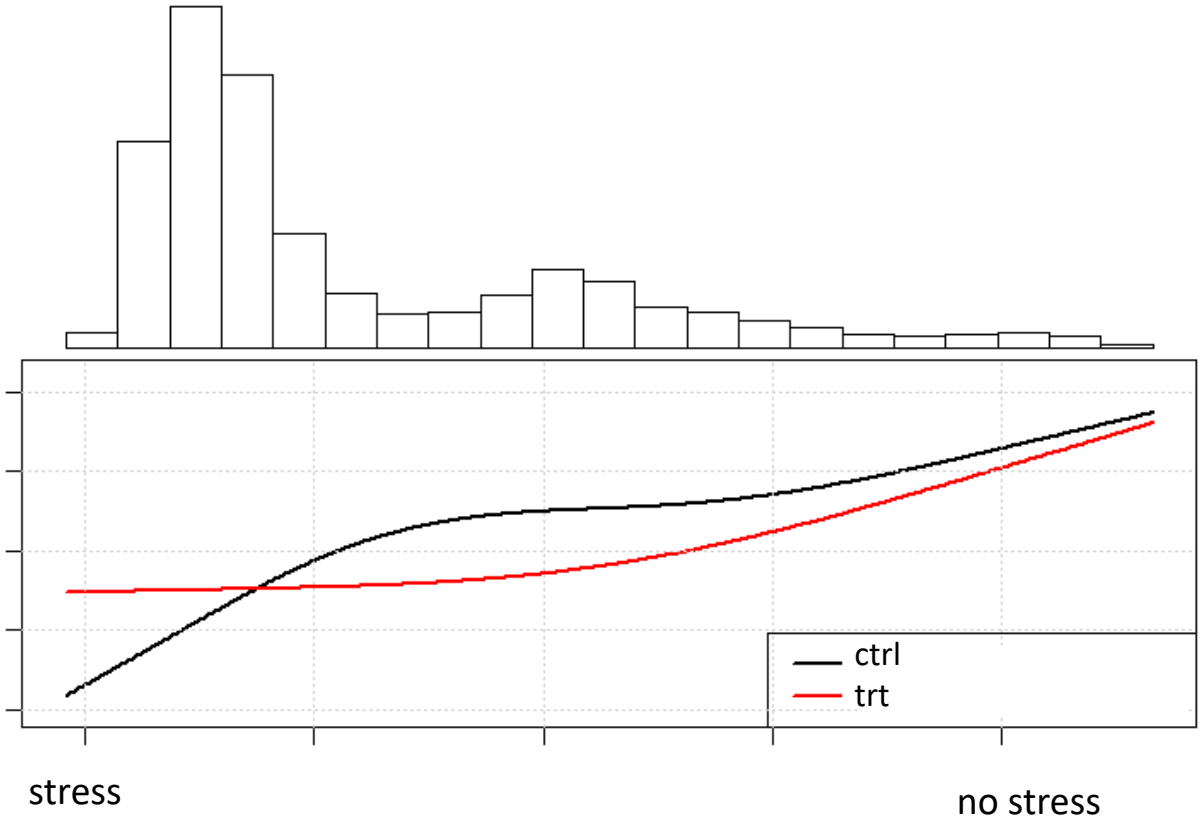


Environmental condition

- When ignoring the environmental condition, we would conclude there is **no overall treatment effect**!
- Taking the environmental condition into account, we still have **low statistical power for detecting a differential treatment effect** where the treatment matters!

Why is **balance** important?

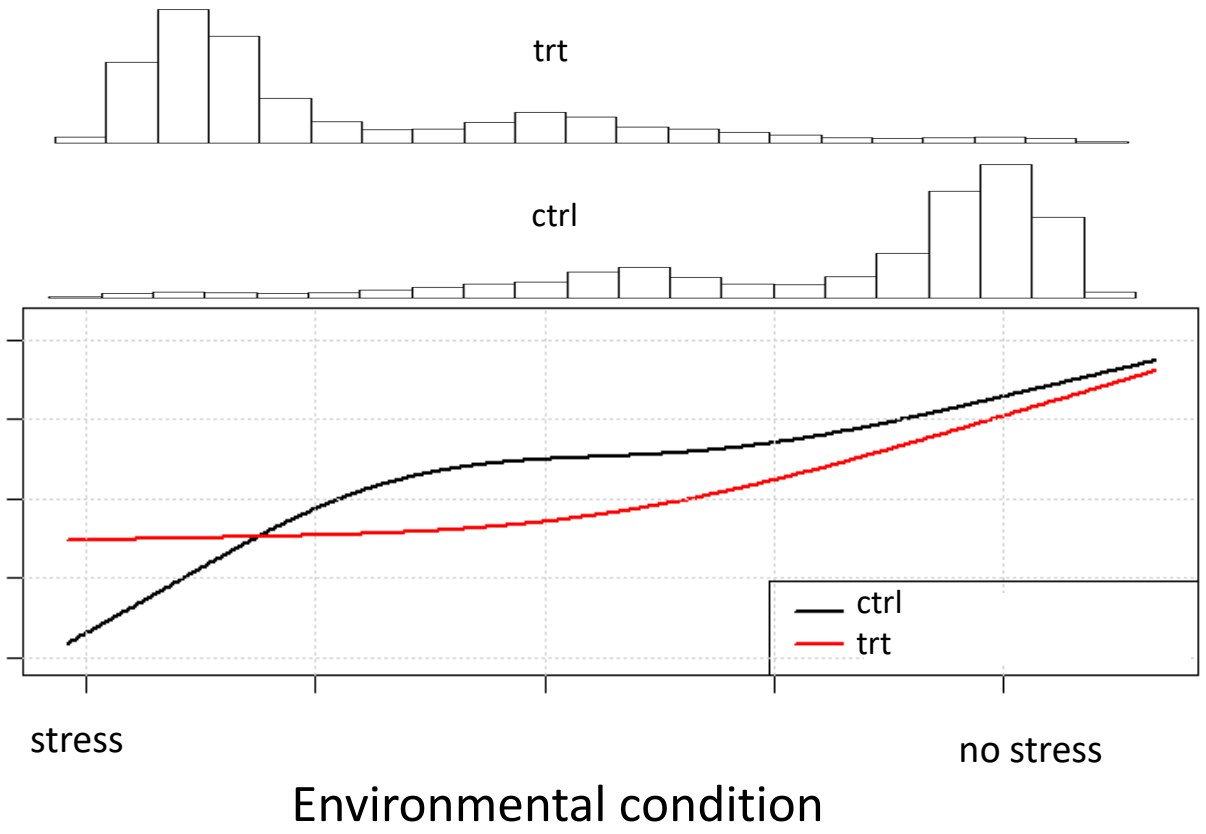
Outcome
f.ex. yield



Environmental condition

- When ignoring the environmental condition, we would conclude **there *is* an overall treatment effect**!
- Taking the environmental condition into account, we have **good statistical power for detecting a differential treatment effect**!, but low power in the rest of the input space.

Why is **balance** important?



Outcome
f.ex. yield

- When ignoring the environmental condition, we would falsely conclude that control has higher yields than treatment! This is **Simpson's paradox**!

- Taking the environmental condition into account, we have low **statistical power for detecting a differential treatment effect**.

Possible solutions, we might explore

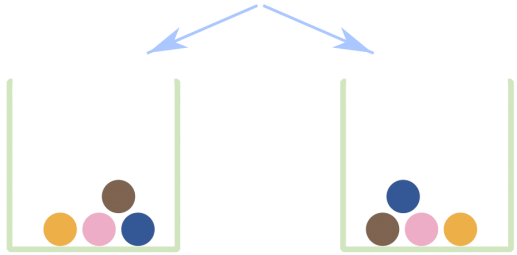
	Pre-trial data-based	**Trial design based**	**Post-hoc analyses based**
Solution	- Data-based trial locality selection - Sensor-based mapping of spatial within-field heterogeneity at trial locality - **Matched Pairs design**	- Generalized Randomized Block Designs (**GRBD**)	- Matching - IPW weighting - Model-based adjustments - Structural Equation Models (SEM)
Pros	- Ensures sufficiently large and balanced sample across whole stressor range - Hypothesis of environmental envelope of stressor condition is utilized for targeted sampling -> reduced sampling burden	- No pre-trial sampling required - Robustness assessment possible	- No sampling burden
Cons	- Pre-trial sampling burden - Pre-trial conditions ≠ trial conditions	- No guarantee to achieve sufficiently large and balanced sample across whole stressor range	- No guarantee to achieve balance and un-biased estimates of effect modification

Sample points
with environmental
characteristics

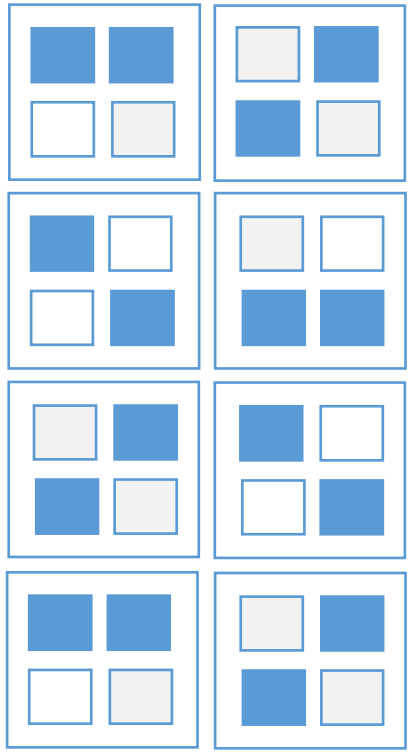
Matched Pairs Design:

First Step:
Match each sample pt. with its closest partner

Second Step:
1 sample pt. from each pair gets randomly assigned,
and the other is automatically assigned to the other group



GRBD



- Each block with multiple treatment replicates
- Each block's environmental characteristics are measured and assumed to be homogeneous within a block
- Within-block variances are utilized to estimate treatment robustness across environmental conditions

Thank you!

DANISH
TECHNOLOGICAL
INSTITUTE