Geomatic Techniques to Support Phytosanitary Products Tests whithin the EPPO Standard Framework

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The Traditional Approach to Agricultural Trials

Block 3	R	C	T
Block 2	T	R	C
Block 1	C	T	R

C Control
T Tested Product
R Reference Product

ANOVA Model:

$$y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$$

Where:

- y_{ij} = response
- μ = overall mean
- α_i = treatment effect
- β_j = block effect
- ε_{ij} = random error

Note:

This is the additive model. Modern approaches may include interaction terms: $\alpha_i \times \beta_j$

Key Assumptions of Traditional ANOVA

Statistical Assumptions:

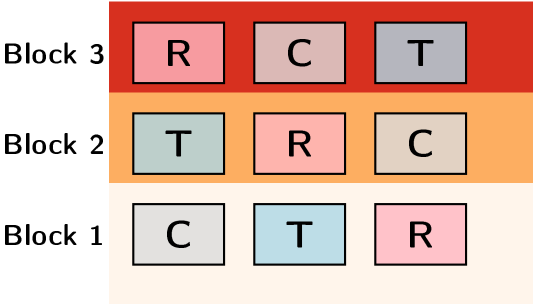
- **Randomization**: Treatments randomly assigned within blocks
- **Replication**: Each treatment appears in each block
- **Independence**: Observations are independent given the design
- **Homoscedasticity** : Equal variances across treatments
- **Normality**: Residuals follow normal distribution

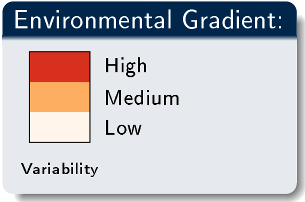
Consequences of Assumption Violations:

- **Invalid conclusions of parametric tests**: Need for non-parametric tests leading to reduced statistical power

Based on R. A. Fisher, Statistical Methods for Research Workers, in S. Kotz & N. L. Johnson (eds.), Breakthroughs in Statistics: Methodology and Distribution, pp. 66–70, Springer, New York, 1992.

The Right Blocking: Capturing Environmental Variability





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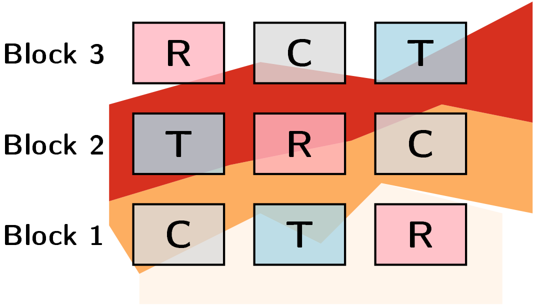
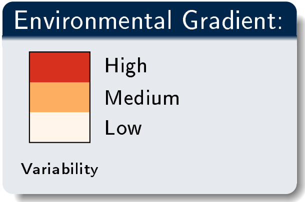
Success of Blocking Strategy:

- **Within-block homogeneity**: Treatments compared under similar conditions
- **Between-block heterogeneity**: Environmental gradient captured by block effects

The Wrong Blocking: Assumption Violation





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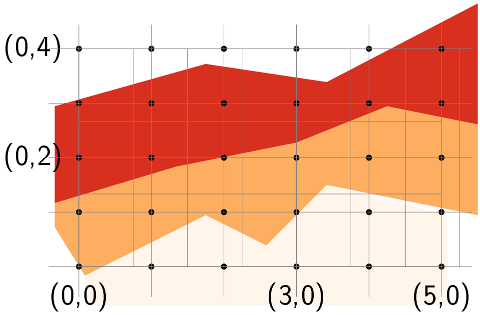
Heteroscedasticity Assumption Violation Problem:

- **Blocks fail to capture environmental variability**: Treatments compared under different conditions
- **Invalid parametric test**: Residual variance differs across treatments

Geostatistical Approach: Spatial Linear Mixed Models



● Georeferenced observations

(x,y) Geographic coordinates

Spatial LMM:

$$y(s_i) = \mu + \alpha_j + f(s_i) + \varepsilon_i$$

Where:

- $y(s_i)$ = response at location s_i
- μ = overall mean
- α_j = treatment effect
- $f(s_i)$ = spatial random field
- ε_i = measurement error
- $s_i = (x_i, y_i)$ = coordinates

Current Limitations in Statistics for Agricultural Trials

Traditional Approach Issues:

- **Human-dependent blocking**: Environmental variability assessment relies on experimenter experience
- **A priori identification**: Must identify variance sources BEFORE data collection

The Challenge:

How can we capture environmental variability mathematically rather than through human judgment?

The Missing Link: Spatial Coordinates

Geostatistical Methods Advantages:

- ✓ **Mathematical modeling** of environmental variability
- ✓ **Post-hoc analysis** - no need for prior knowledge
- ✓ **Superior performance** in handling spatial heterogeneity
- ✓ **EPPO recognized** approach

Current Barrier:

- × **Requires spatially referenced observations**
- × **Traditional manual assessments lack coordinates**
- × **Implementation gap** in practical field trials

Central Research Question

Can geomatics technologies provide spatially referenced observations that enable geostatistical analysis within EPPO-compliant Plant Protection Product trials?

Specific Objectives:

1. Establish minimum dataset requirements for digital data collection
2. Demonstrate feasibility across all EPPO variable types
3. Validate performance against traditional methods
4. Provide practical implementation guidelines

European Plant Protection Organization (EPPO)

Key Standards:

- **PP 1/152(4)**: Design and analysis of efficacy evaluation trials
- **PP 1/333(1)**: Digital technology adoption guidelines

Variable Types in EPPO Assessments:

1. **Continuous/Discrete**: Plant counts, measurements
2. **Ordinal**: Severity scales (0-100%), damage ratings
3. **Binary/Nominal**: Healthy/diseased, disease classification

Benchmark: $R^2 > 0.85$ compared to manual assessment

PPP Development & Regulation

PPP Categories:

- Fungicides
- Insecticides
- Herbicides
- Plant growth regulators
- Acaricides
- Nematicides

Critical Evaluation Needs:

- **Efficacy**: Does it work?
- **Selectivity**: Is it safe for crops?
- **Environmental impact**: Side effects?

Technical Arsenal

Core Technologies:

- **Photogrammetry**: 3D model generation from 2D images
- **Spectral Imaging**: Multi/hyperspectral sensors
- **Machine Learning**: Object detection, classification, regression
- **GNSS/UAV**: Precise spatial positioning

[Technology diagram would go here]

Study 1: Automated Plant Counting

Problem Statement:

Manual plant counting is:

- **Time-consuming**: Hours per plot
- **Subjective**: Inter-observer variability
- **Error-prone**: Missed or double-counted plants
- **Non-spatial**: No coordinate information

Solution Approach:

- UAV photogrammetry
- Deep learning object detection
- Automatic spatial referencing
- $R^2 > 0.85$ validation

[Plant counting example image]

Minimum Dataset Findings

Architecture	Images Needed	R^2
RT-DETR (Transformer-mixed)	60	0.89
YOLOv8 (CNN)	110	0.87
YOLOv5 (CNN)	130	0.86
Few-shot models	N/A	< 0.85
Zero-shot models	N/A	< 0.85

Table: Performance comparison across architectures

Critical Finding:

NO out-of-distribution trained model achieved $R^2 > 0.85$

In-domain training data is essential for agricultural applications

Questions & Discussion

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Key Publications:

1. "On the Minimum Dataset Requirements..." - *Remote Sensing* (2025)
2. "Supporting Screening of New Plant Protection Products..." - *Agronomy* (2024)
3. "Anomaly Detection for Plant Disease Classification" - *In preparation*