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A Three-Level Factorial Approach to Evaluating Pea Production Practices

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Three-level full factorial designs provide a systematic approach for studying several agricultural management factors simultaneously and assessing both their individual and interactive effects. This article illustrates the application of a five-factor, three-level factorial design for evaluating pea-production practices involving variety, sowing date, sowing density, fertilizer dose, and plant-protection strategy. The complete design consists of 3^5 = 243 treatment combinations, providing comprehensive information on treatment responses and possible nonlinear trends. The article also demonstrates the use of the lfebd3 R package for generating, checking, and analyzing the experimental design. Although full factorial designs require considerable land, labour, time, and financial resources, they are valuable when complete treatment coverage and detailed interaction information are required for agricultural decision-making.

Keywords: Three-level factorial design; full factorial experiment; pea production; R package.

Introduction

Agricultural production is influenced by several management factors at the same time. Crop yield may depend on variety, sowing date, fertilizer dose, irrigation schedule, plant density, and crop-protection practice. The influence of one factor can also change according to the level of another factor. For example, a high fertilizer dose may be beneficial under adequate irrigation but less effective when water is limited. A three-level factorial experiment studies each selected factor at three settings, commonly described as low, medium, and high. The middle level is especially valuable because it can reveal whether the response follows a straight trend or bends toward an optimum. A full factorial design includes every possible combination of these levels. It therefore gives a complete picture of how the factors act individually and jointly. The cost of this completeness is experimenting size. With five factors at three levels, the number of treatments is 3^5 = 243. Each treatment must be prepared, randomized, managed, observed, and analysed. Careful planning and computer-based generation are therefore important before the experiment is started. Yadav et al. (2026) proposed methods for constructing efficient row–column designs for three-level factorial experiments arranged in three rows, enabling improved control of variation in two directions.

Role of R Packages

The functions below were checked against the current lfebd3 (Kumar et al., 2026) package documentation. For a complete three-level factorial experiment, the correct generator is lfebd3(n), where n is the number of factors. Dash et al. (2025) developed FactChar, a computational tool for characterizing factorial block designs and assessing their important structural and diagnostic properties. The function returns a data frame containing a Run column and a Treatment column. Treatment labels are formed from factor levels coded as 0, 1, and 2. Thus, lfebd3(5) generates all $3^5 = 243$ treatment combinations for five factors.

```
library(lfebd3)
design <- lfebd3(n = 5)
design
```

The package also provides lfebd3_analyze(), which combines generation and analysis in one call. For a complete five-factor design treated as a single block, block_size is set equal to 243. Using fast = TRUE is practical for screening a design of this size.

```
analysis <- lfebd3_analyze(
  type = "lfebd3",
  n = 5,
  block_size = 243,
  show_design = FALSE,
  run_analysis = TRUE,
  fast = TRUE)
print(analysis)
```

These functions reduce manual enumeration, help confirm the number and coding of treatments, and provide a reproducible record of the design used in the study.

Illustration: Full Factorial Pea-Production Experiment

Suppose a researcher wants to identify a suitable combination of practices for pea production. Five factors are selected, and each factor is studied at three levels. The complete experiment contains $3^5 = 243$ unique treatments. One treatment may combine variety V_1, early sowing, low density, the recommended fertilizer dose, and moderate plant protection. Another treatment may combine variety V_3, late sowing, high density, a high fertilizer dose, and intensive plant protection. The design includes every such combination exactly once before replication. Observations may include plant establishment, flowering time, plant height, pod number, seed yield, disease incidence, and economic return. The complete arrangement allows the researcher to compare each management factor and examine whether its performance changes across the levels of other factors.

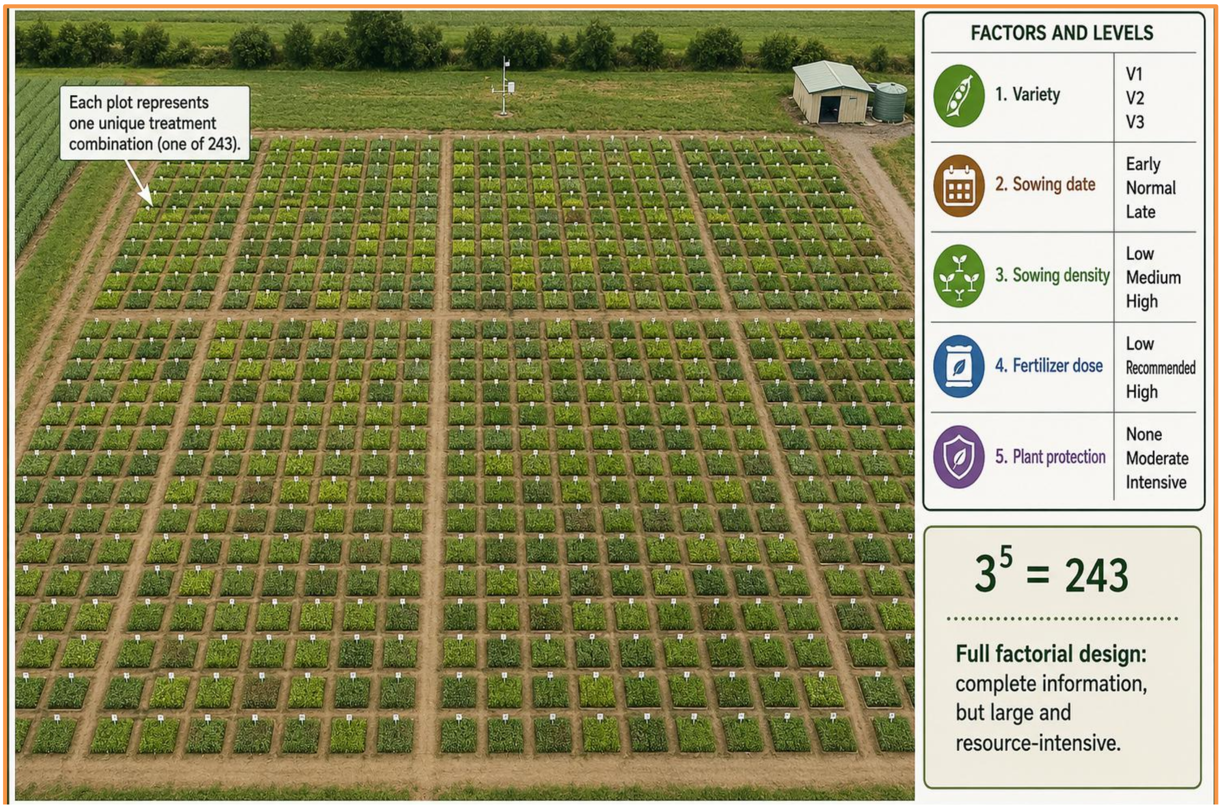

Fig1.Each plot represents one unique combination of five factors at three levels.

Practical Planning Considerations

Before selecting a full factorial design, the researcher should confirm that the available land, labour, seed, fertilizer, irrigation capacity, and observation time are adequate. The factor levels should be scientifically meaningful and sufficiently separated to produce interpretable responses. A randomization plan and data-recording format should be prepared in advance, and replication should be chosen according to the required precision and available resources.

For five factors, one replication requires 243 experimental units; two replications require 486 units. The advantage is that the experiment provides complete treatment coverage. The disadvantage is the high demand on resources. The design should therefore be used when the expected value of complete interaction information justifies the experimental size.

Conclusion

Three-level full factorial designs are useful for evaluating several agricultural management factors simultaneously and for understanding both their individual and combined effects. In the pea-production example, five factors at three levels produce 243 treatment combinations, allowing comprehensive assessment of variety, sowing date, sowing density, fertilizer dose, and plant-protection practices. The inclusion of a middle level also helps identify nonlinear responses and possible optimum conditions. Although such experiments require substantial land, labour, time, and financial resources, they provide complete treatment coverage and detailed information for selecting suitable production practices. The lfebd3 R package further supports accurate generation, verification, and analysis of these designs, making experimental planning more reliable and reproducible.

References

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