A
Project Report on

Investigating the Effectiveness of Lure Types and Trap Locations in Attracting Spruce Moths using, Factorial Experiment

SUBMITTED
By

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1. Abstract

The Spruce Moth poses a significant threat to spruce forests, causing damage to foliage and potentially impacting ecosystem health. Effective monitoring and management strategies are crucial for mitigating the impact of Spruce Moth infestations. This study aims to assess the influence of lure types and trap locations on the attraction of Spruce Moths through a factorial experiment.

The primary objectives of this research are to
(1) determine the most effective lure type in attracting Spruce Moths,
(2) assess the impact of trap location on moth attraction rates, and
(3) explore potential interactions between lure types and trap locations.

2. Introduction

The Eastern Spruce Budworm, a significant native moth species in North America, particularly targets balsam fir and white spruce while also showing a preference for red and black spruce. Their feeding behavior, focused on consuming needles from the uppermost branches, severely impacts tree health. Continuous defoliation over consecutive years stresses the trees, often leading to their demise within a short span. This cumulative impact compromises the structural integrity and overall health of these crucial ecosystems. To counter this, investigating lure types and trap locations to manage the Spruce Moth population becomes crucial.

Understanding the Spruce Moth's behavior highlights the necessity of targeting specific areas, such as the upper branches of spruce trees, for monitoring and control. Conducting factorial experiments with various lure types and trap placements can offer valuable insights into attracting these moths. Strategically placing traps in different forest locations while using diverse lure types enables researchers to gauge which combinations attract the highest number of Spruce Moths, aiding in targeted interventions.

Efficient management strategies are essential to protect these ecosystems. Identifying effective lure types and trap placements facilitates early detection and monitoring of Spruce Moth populations, enabling timely interventions. Moreover, this understanding allows for the development of more targeted and efficient control measures, potentially lessening the impact of these insects on the vitality and longevity of North American spruce and fir forests.

3. About Dataset

The Spruce Moth dataset encompasses measurements related to the presence of different lure types, including scent, sugar content, and chemical, in various locations of a tree. The dataset is organized based on four specific locations: Top, Middle, Lower, and Ground. For each location, multiple instances of recorded lure types are documented. The primary focus of this dataset is to assess the effectiveness of these various lure types in attracting Spruce moths to a trap positioned within a tree. Table 3.1 illustrates the data of the dataset providing information on the number of moths captured, serving as a quantitative measure of the lure's effectiveness. Each condition or combination of lure type and location is replicated five times, resulting in five observations for each specific condition. This repetition enhances the robustness and reliability of the findings by capturing variability across multiple instances.

In summary, this dataset is designed to analyze and compare the efficacy of different lure types in attracting Spruce moths across various locations within a tree. The number of moths caught serves as a key metric to evaluate the relative success of each lure type in different tree sections, offering valuable insights into the optimization of trapping strategies for managing Spruce moth populations.

Location	Scent	Sugar	Chemical
Top	28	35	32
Top	19	22	29
Top	32	33	16
Top	15	21	18
Top	13	17	20
Middle	39	36	37
Middle	12	38	40
Middle	42	44	18
Middle	25	27	28
Middle	21	22	36
Lower	44	42	35
Lower	21	17	39
Lower	38	31	41
Lower	32	29	31
Lower	29	37	34
Ground	17	18	22
Ground	12	27	25
Ground	23	15	14
Ground	19	29	16
Ground	14	16	19

Table 3.1: Spruce Moth Data

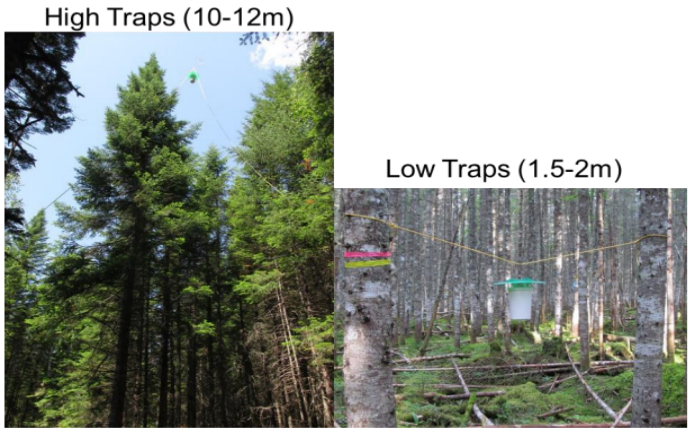

Fig 3.1: Trap Location

4. Identifying the Factors and Treatments

Factor 1 - Lure Type (3 Levels)	Factor 2 - Location (4 levels)
1. Scent 2. Sugar 3. Chemical	1. Top 2. Middle 3. Lower 4. Ground

Table 4.1: Identifying the Factors

The total number of treatments is the product of the levels of these two factors.

In this scenario:

Total Treatments=3×4=12

Each treatment represents a unique combination of factor levels. Let's break down the first few treatments as examples:

Treatment 1: Top & Scent
Treatment 2: Top & Sugar
Treatment 3: Top & Chemical
Treatment 4: Middle & Scent
Treatment 5: Middle & Sugar
Treatment 6: Middle & Chemical and so on.

Each treatment represents a specific condition in the experiment, where the lure type (Scent, Sugar, and Chemical) is applied in different locations of the tree (Top, Middle, Lower, and Ground).

For analysis the data the "Moths" (number of moths found) is considered as "Response Variable", and "Lure and Location" are considered as Explanatory Variable

5. Hypothesis Statement

1) $H_{01}: \mu_{Top} = \mu_{Middle} = \mu_{Lower} = \mu_{Ground}$
   $H_{a1}: Atleast\ one\ of\ the\ \mu\ differes\ from\ others$

2) $H_{02}: \mu_{Scent} = \mu_{Sugar} = \mu_{Chemical}$
   $H_{a2}: Atleast\ one\ of\ the\ \mu\ differes\ from\ others$

3) $H_{03}: There\ is\ no\ interaction\ between\ Location\ and\ Lure$
   $H_{a3}: There\ is\ interaction\ between\ Location\ and\ Lure$

6. Mean of Moth Capture Across Treatments

The mean effect measures the impact of changing the levels of each factor in the model. The graph that plots the average response for each level of the factor is called the "Mean effect plot".

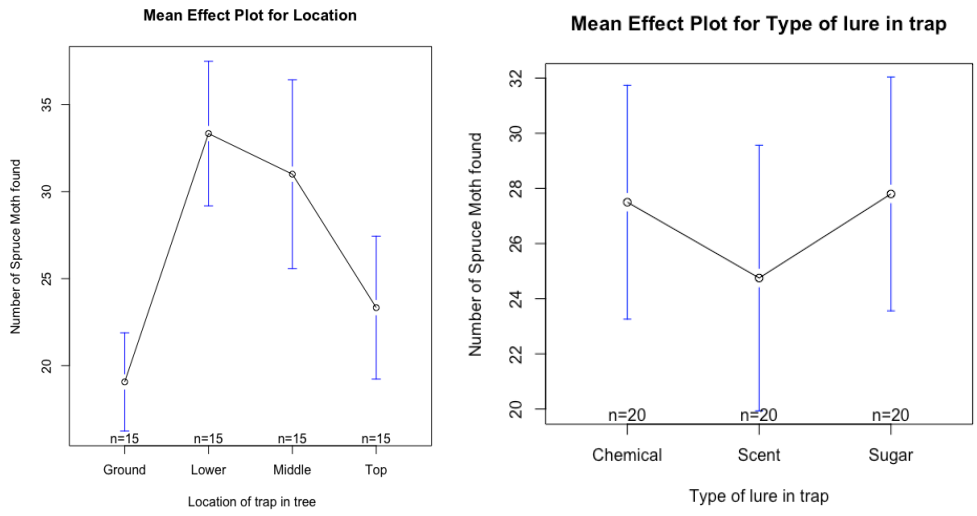

Fig 6.1: Mean Effect Plot

	Type of Lure α_i			
Location β_j	Scent	Sugar	Chemical	Location Mean
Top	$\bar{y}_{11.} = 21.4$	$\bar{y}_{12.} = 25.6$	$\bar{y}_{13.} = 23$	$\bar{y}_{1..} = 23.33$
Middle	$\bar{y}_{21.} = 27.8$	$\bar{y}_{22.} = 33.4$	$\bar{y}_{23.} = 31.8$	$\bar{y}_{2..} = 31$
Lower	$\bar{y}_{31.} = 32.8$	$\bar{y}_{32.} = 31.2$	$\bar{y}_{33.} = 36$	$\bar{y}_{3..} = 33.33$
Ground	$\bar{y}_{41.} = 17$	$\bar{y}_{42.} = 21$	$\bar{y}_{43.} = 19.2$	$\bar{y}_{4..} = 19.067$
Lure Mean	$\bar{y}_{.1.} = 24.75$	$\bar{y}_{.2.} = 27.8$	$\bar{y}_{.3.} = 27.5$	$\bar{y}_{...} = 26.68$

Table 6.1: Factor-Level Group Mean

From the "Mean effect for Location" plot and "Factor-Level Group Mean" table, we can observe that the average count of moth captures is high at the Lower part of the tree (mean count= 33.33) followed by Middle (mean count = 31) and Top (mean count = 23.33) and Ground part of the tree has the least mean count of moth captures (mean count = 19.067).
From this plot, we can assume there may be a significant difference between Ground and Lower Locations which shows much difference in slope whereas middle and Top Location shows an insignificant difference where there is not much difference in slope between them.

From the "Mean effect for Lure Type" plot and "Factor-Level Group Mean" table, we can observe that the average count of moth captures is high at Sugar (mean count= 27.5) followed by Chemical (mean count = 27.5) and Scent has the least mean count of moth captures (mean count = 24.75).
From this plot, we can assume there may be insignificant differences between types of lures as there is not much difference in slope between them.

7. TWO-WAY ANOVA MODEL

$$y_{ikj} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

- Since there are three levels of factor Lure type, i=1, 2,3; and 4 levels of factor Location, j=1, 2, 3,4
- where μ is the overall mean response,
- α_i is the effect due to the i-level of factor Lure Type,
- β_j is the effect due to the j-level of factor Location,
- $(\alpha\beta)_{ij}$ is the effect due to any interaction between the i-level of factor Lure type and the j-level of factor Location, and
- ε_{ijk} is the random error term.
-

A two-way analysis of variance (ANOVA) was conducted to examine the mean effect of Location and Lure Type, as well as their interaction effect on the Number of Moths captured.

	Df	Sum Sq	Mean Sq	F value	p-value
Location	3	1981	660.5	10.45	2.09×10^{-5}
Lure	2	113	56.5	0.894	0.416
Location: Lure	6	115	19.2	0.303	0.932

Table 7.1: Two-way ANOVA statistics

i. Location:

Decision: p-value = $2.09 \times 10^{-5} < 0.05$, we reject H_0

conclusion: there is significant evidence to conclude that at least one of μ_{Top}, μ_{Middle}, μ_{Lower}, μ_{Ground} differs from the others at 5% significance level.

ii. Lure:

Decision: p-value = 0.416 > 0.05, we fail to reject H_0

conclusion: there is insignificant evidence to conclude that μ_{Scent}, μ_{Sugar}, $\mu_{Chemical}$ differ from others at a 5% significance level.

iii. Location: Lure interaction:

Decision: p-value = 0.932 > 0.05, we fail to reject H_0

conclusion: There is no interaction effect between the Location and Lure Type on the number of moths captured at the 5% significance level.

8. Model Assumptions

i. Histogram

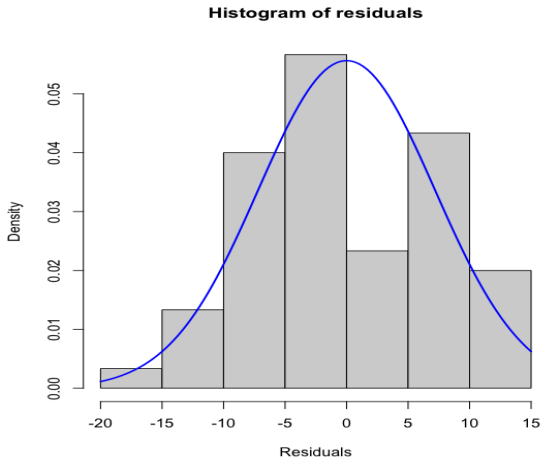

Fig 8.1: Histogram

The histogram of residuals appears to be symmetric and mound-shaped, suggesting that the normal population assumption for the random error terms is reasonable.

ii. Q-Q plot

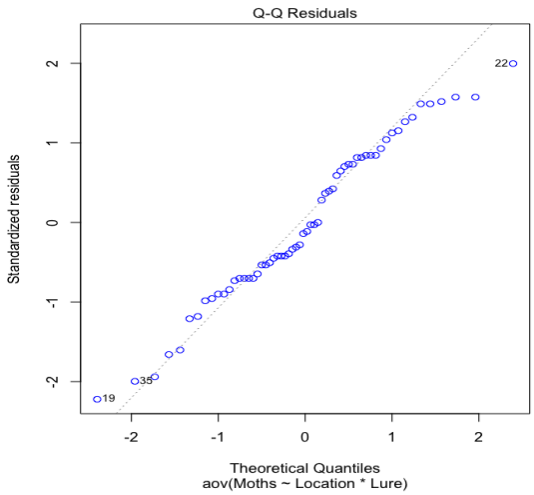

Fig 8.2: Q-Q plot

Most of the data points follow a straight line in the normal probability plot, indicating that the normality assumption for the random error terms is reasonable, but there are some deviations, in the lower tail and upper tail of the data distribution.

iii. Informal Test:

The result showed that the maximum standard deviation divided by the minimum standard deviation was approximately 3.139467 which is greater than 2.

iv. Levene's Test:

The result showed a p-value of 0.7875 which is greater than 0.05 at a 5% significance. Based on this, we consider that there is an equal variance across the different groups.

9. Interaction Effect

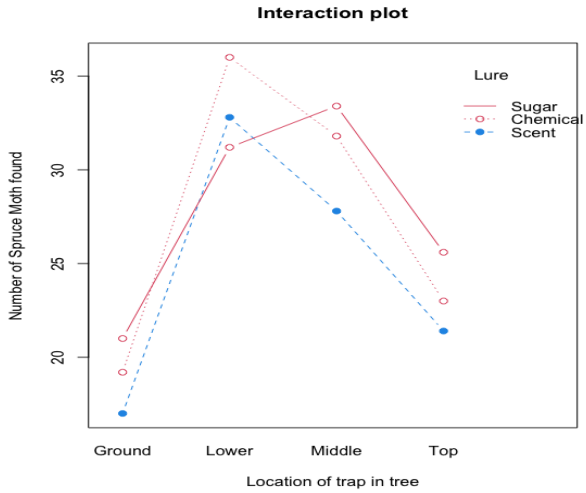

Fig9.1: Interaction Effect

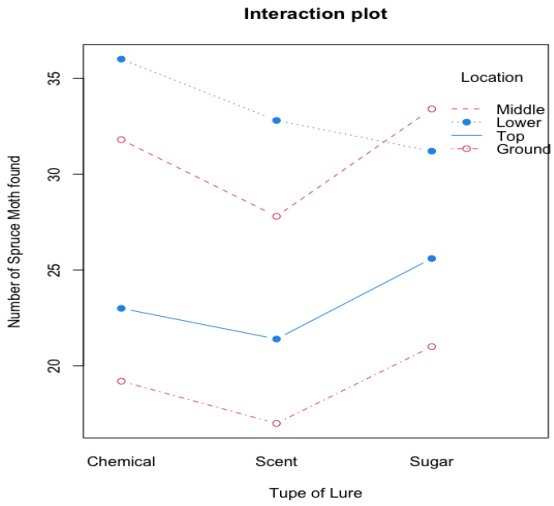

Fig9.2: Interaction Effect

The interaction plot shows how one factor depends on the other. Here there are non- parallel lines which indicate there is a possible interaction between “Location” and “Lure Type”. (It may be possible that the interaction plot is indicating the presence of interaction due to the small sample size.)

10. Tukey multiple pairwise-comparisons

i. Location:

	Difference	Lower	Upper	p- value
Lower-Ground	14.266667	6.541043	21.99229029	0.0000622
Middle-Ground	11.933333	4.207710	19.65895695	0.0008571
Top-Ground	4.266667	-3.458957	11.99229029	0.4633359
Middle-Lower	-2.333333	-10.058957	5.39229029	0.8523085
Top-Lower	-10.000000	-17.725624	-2.27437638	0.0063580
Top-Middle	-7.666667	-15.392290	0.05895695	0.0524653

Table 10.1: pair wise comparison for Location

The mean difference in the Number of Spruce Moths trapped with different Locations is significant as p value < 0.05 in all cases except for Top-Ground and Middle-Lower for which the p-value >0.05.

The number of Spruce moths trapped at the Lower part of tree increases by 14.266667 times than those at the Ground.

The number of Spruce moths trapped at the Middle part of tree increases by 11.933333 times than those at the Ground.

The number of Spruce moths trapped at the Top part of tree decreases by 10 times than those at the Lower.

The number of Spruce moths trapped at the Top part of tree decreases by 7.666667 times than those at the Middle.

We are 95% confidence that the true difference in the number of Spruce Moths trapped between the Location Lower and Ground lies in (6.541043, 21.99229029).

ii. Lure Type:

	Difference	Lower	Upper	p- value
Scent-Chemical	2.75	-8.829984	3.329984	0.5224665
Sugar-Chemical	0.30	-5.779984	6.379984	0.9921811
Sugar-Scent	3.05	-3.029984	9.129984	0.4512753

Table 10.2: pair wise comparison for Lure

The mean difference in the Number of Spruce Moths trapped with different Lure types is insignificant as p value > 0.05 in all cases.

iii. Interaction of Location & Lure Type:

	Difference	Lower	Upper	p- value
Lower:Chemical-Ground:Chemical	16.8	-0.4645333	34.064533	0.0631301
Middle:Chemical-Ground:Chemical	12.6	-4.6645333	29.864533	0.3609863
Top:Chemical-Ground:Chemical	3.8	-13.4645333	21.064533	0.9997696
Ground:Scent-Ground:Chemical	-2.2	-19.4645333	15.064533	0.9999991
Lower:Scent-Ground:Chemical	13.6	-3.6645333	30.864533	0.2551290
Middle:Scent-Ground:Chemical	8.6	-8.6645333	25.864533	0.8545753
Top:Scent-Ground:Chemical	2.2	-15.0645333	19.464533	0.9999991
Ground:Sugar-Ground:Chemical	1.8	-15.4645333	19.064533	0.9999999
Lower:Sugar-Ground:Chemical	12.0	-5.2645333	29.264533	0.4340989
Middle:Sugar-Ground:Chemical	14.2	-3.0645333	31.464533	0.2026008
Top:Sugar-Ground:Chemical	6.4	-10.8645333	23.664533	0.9787702

Middle:Chemical-Lower:Chemical	-4.2	-21.4645333	13.064533	0.9994060
Top:Chemical-Lower:Chemical	-13.0	-30.2645333	4.264533	0.3160173
Ground:Scent-Lower:Chemical	-19.0	-36.2645333	-1.735467	0.0198093
Lower:Scent-Lower:Chemical	-3.2	-20.4645333	14.064533	0.9999573
Middle:Scent-Lower:Chemical	-8.2	-25.4645333	9.064533	0.8887980
Top:Scent-Lower:Chemical	-14.6	-31.8645333	2.664533	0.1722356
Ground:Sugar-Lower:Chemical	-15.0	-32.2645333	2.264533	0.1454568
Lower:Sugar-Lower:Chemical	-4.8	-22.0645333	12.464533	0.9979999
Middle:Sugar-Lower:Chemical	-2.6	-19.8645333	14.664533	0.9999948
Top:Sugar-Lower:Chemical	-10.4	-27.6645333	6.864533	0.6462154
Top:Chemical-Middle:Chemical	-8.8	-26.0645333	8.464533	0.8355092
Ground:Scent-Middle:Chemical	-14.8	-32.0645333	2.464533	0.1584089
Lower:Scent-Middle:Chemical	1.0	-16.2645333	18.264533	1.0000000
Middle:Scent-Middle:Chemical	-4.0	-21.2645333	13.264533	0.9996243
Top:Scent-Middle:Chemical	-10.4	-27.6645333	6.864533	0.6462154
Ground:Sugar-Middle:Chemical	-10.8	-28.0645333	6.464533	0.5927962
Lower:Sugar-Middle:Chemical	-0.6	-17.8645333	16.664533	1.0000000
Middle:Sugar-Middle:Chemical	1.6	-15.6645333	18.864533	1.0000000
Top:Sugar-Middle:Chemical	-6.2	-23.4645333	11.064533	0.9833035
Ground:Scent-Top:Chemical	-6.0	-23.2645333	11.264533	0.9870483
Lower:Scent-Top:Chemical	9.8	-7.4645333	27.064533	0.7233229
Middle:Scent-Top:Chemical	4.8	-12.4645333	22.064533	0.9979999

Top:Scent-Top:Chemical	-1.6	-18.8645333	15.664533	1.0000000
Ground:Sugar-Top:Chemical	-2.0	-19.2645333	15.264533	0.9999997
Lower:Sugar-Top:Chemical	8.2	-9.0645333	25.464533	0.8887980
Middle:Sugar-Top:Chemical	10.4	-6.8645333	27.664533	0.6462154
Top:Sugar-Top:Chemical	2.6	-14.6645333	19.864533	0.9999948
Lower:Scent-Ground:Scent	15.8	-1.4645333	33.064533	0.1018215
Middle:Scent-Ground:Scent	10.8	-6.4645333	28.064533	0.5927962
Top:Scent-Ground:Scent	4.4	-12.8645333	21.664533	0.9990870
Ground:Sugar-Ground:Scent	4.0	-13.2645333	21.264533	0.9996243
Lower:Sugar-Ground:Scent	14.2	-3.0645333	31.464533	0.2026008
Middle:Sugar-Ground:Scent	16.4	-0.8645333	33.664533	0.0767434
Top:Sugar-Ground:Scent	8.6	-8.6645333	25.864533	0.8545753
Middle:Scent-Lower:Scent	-5.0	-22.2645333	12.264533	0.9971385
Top:Scent-Lower:Scent	-11.4	-28.6645333	5.864533	0.5122576
Ground:Sugar-Lower:Scent	-11.8	-29.0645333	5.464533	0.4597079
Lower:Sugar-Lower:Scent	-1.6	-18.8645333	15.664533	1.0000000
Middle:Sugar-Lower:Scent	0.6	-16.6645333	17.864533	1.0000000
Top:Sugar-Lower:Scent	-7.2	-24.4645333	10.064533	0.9509125
Top:Scent-Middle:Scent	-6.4	-23.6645333	10.864533	0.9787702
Ground:Sugar-Middle:Scent	-6.8	-24.0645333	10.464533	0.9669624
Lower:Sugar-Middle:Scent	3.4	-13.8645333	20.664533	0.9999220
Middle:Sugar-Middle:Scent	5.6	-11.6645333	22.864533	0.9925485
Top:Sugar-Middle:Scent	-2.2	-19.4645333	15.064533	0.9999991
Ground:Sugar-Top:Scent	-0.4	-17.6645333	16.864533	1.0000000

Lower:Sugar-Top:Scent	9.8	-7.4645333	27.064533	0.7233229
Middle:Sugar-Top:Scent	12.0	-5.2645333	29.264533	0.4340989
Top:Sugar-Top:Scent	4.2	-13.0645333	21.464533	0.9994060
Lower:Sugar-Ground:Sugar	10.2	-7.0645333	27.464533	0.6724526
Middle:Sugar-Ground:Sugar	12.4	-4.8645333	29.664533	0.3846628
Top:Sugar-Ground:Sugar	4.6	-12.6645333	21.864533	0.9986324
Middle:Sugar-Lower:Sugar	2.2	-15.0645333	19.464533	0.9999991
Top:Sugar-Lower:Sugar	-5.6	-22.8645333	11.664533	0.9925485
Top:Sugar-Middle:Sugar	-7.8	-25.0645333	9.464533	0.9176309

Table 10.3: pair wise comparison for Interaction

The difference in the Number of Spruce Moth trapped between the different interactions is non-significant as the p-value > 0.05 in all cases except for Ground: Scent - Lower: Chemical for which the p-value is 0.0198993<0.05.

The number of Spruce Moths trapped at the Lower part of the tree with lure-type Chemical are 16.8 times more than those at the Ground with lure-type Chemical.

11. Conclusion

Based on the analysis of the ***Spruce moths trap*** Data using a two-way factorial design, the following conclusions can be drawn:

1. The **location of the trap** significantly affects the number of moths found differences observed between locations in the tree.
2. The **type of lure** in the trap do not influence the number of moths.
3. There is **no interaction effect** between the location and type of lure indicating that different lures applied at different locations in the tree do not affect the number of moths found.

12. Future Analysis

1. **Environmental Factors:** Consideration of additional environmental variables that weren't included in the initial analysis could be valuable. Factors such as temperature, humidity, or even the presence of competing species might influence the effectiveness of traps. Incorporating these variables into the analysis could provide a more comprehensive understanding of trap effectiveness.

2. **Exploration of Lure Types:** While the current analysis didn't show significant differences among lure types, exploring a wider range of lure variations or formulations might be worthwhile. This could involve testing different concentrations, combinations of attractants, or exploring novel attractant compounds that could potentially yield more significant effects on moth attraction.

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