LABORATORY EXERCISE 6: ANOVA OF THE RANDOMIZED COMPLETE BLOCK DESIGN (RCBD)

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Laboratory Section: J2L **Date:** 11/13/2024

Objectives At the end of this exercise, you should be able to:
1. Perform ANOVA for RCBD.
2. Perform multiple comparison test of means. Materials

1. Statistical software (Excel, PAST, R) Activity
1. A field experiment designed as a RCBD to investigate the effects of four different types of fungicides (F1, F2, F3, F4) on the yield of potatoes with untreated plots (negative control) was conducted. The following table shows the data:

Block	**Treatment**				
	Control	**F1**	**F2**	**F3**	**F4**
1	377	527	633	642	623
2	408	604	600	708	550
3	500	606	650	662	562
4	333	533	567	504	667

a.) Is there evidence of a difference in effects among four types of fungicides on the yield of potatoes at 5% level of significance? Perform ANOVA (from Ho to conclusion)

Univariate statistics

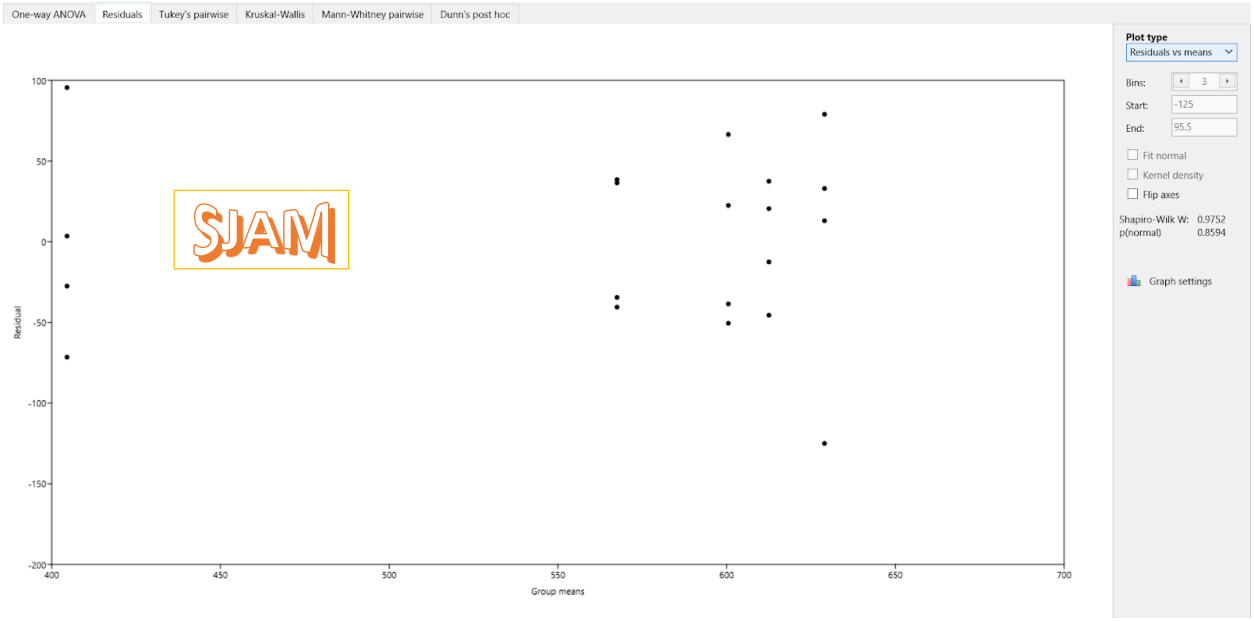
	Control	F1	F2	F3	F4
N	4	4	4	4	4
Min	333	527	567	504	550
Max	500	606	650	708	667
Sum	1618	2270	2450	2516	2402
Mean	404.5	567.5	612.5	629	600.5
Std. error	35.35652	21.68909	18.37798	43.89761	27.32673
Variance	5000.333	1881.667	1351	7708	2987
Stand. dev	70.71304	43.37818	36.75595	87.79522	54.65345
Median	392.5	568.5	616.5	652	592.5
25 prcntil	344	528.5	575.25	538.5	553
75 prcntil	477	605.5	645.75	696.5	656
Skewness	0.9138752	-0.01470169	-0.4672023	-1.400816	0.4884782
Kurtosis	1.14953	-5.894028	-1.693998	2.450714	-2.84735
Geom. mean	400.0405	566.2547	611.6639	624.0426	598.6572
Coeff. var	17.48159	7.643732	6.000972	13.9579	9.101325

Based on our table, control have the largest variance and F2 have the smallest variance, so we will compute this by dividing: largest variance/smallest variance.

Conclusion: First assumption is not met because the results of the ratio between the largest and smallest variance is 5.705, which does exceed 3.0.

7708 / 1351 =

5.70540340489



The residual plot shows no clear pattern, which suggests that the variances across the treatment means are uniform, this means that homoscedasticity assumption has been met in residual plot.

Lavene's test

One-way ANOVA | Residuals | Tukey's pairwise | Kruskal-Wallis | Mann-Whitney pairwise | Dunn's post hoc

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	133419	4	33354.8	8.811	0.0007231
Within groups:	56784	15	3785.6		**Permutation *p* (n=99999)**
Total:	190203	19			0.00138

Components of variance (only for random effects):

Var(group): 7392.3 **Var(error):** 3785.6 **ICC:** 0.661332

***omega*²:** 0.6097

Levene´s test for homogeneity of variance, from means ***p* (same):** 0.6275

Levene´s test, from medians ***p* (same):** 0.8597

Welch *F* test in the case of unequal variances: F=5.869, df=7.347, p=0.01958

To formally check the homogeneity of variance assumption, we used the Lavene's test. If the p value is greater than the level of significance, then the variances are homogenous. Since the p value is 0.9984 >0.5, the homogeneity of variances assumptions is met using Lavene's test.

Experimental Unit: Potatoes
Factor of Interest: Fungicides
Treatment Levels: Control (no fungicides), F1, F2, F3, F4 Four types of fungicides and negative control.
Blocking: Randomized Complete Block design, RCBD with 4 blocks
Response Variable: Yield of potatoes (measured in units based on data, e.g.,kg plot)

1. **State the null and alternative hypothesis.**

   - **H_o:** The mean yields for all treatments are equal.

   - **H_a:** At least one fungicide treatment has a mean yield significantly different from the others.

2. **Decision rule.**

   - **For Treatment (fungicides):** Reject H_o if p-value < 0.05, otherwise, fail to reject H_o.

   - **For Block:** Reject H_o if p-value < 0.05, otherwise, fail to reject H_o.

3. **Compute the p-value.**

Performing a parametric two-way ANOVA without replication:

The reason for using a parametric two-way ANOVA without replication is because the p-value we obtained from Levene's test is 0.6275, which is higher than the 0.05 threshold, this verifies that the homoscedasticity assumption is met.

One-way ANOVA | Residuals | Tukey's pairwise | Kruskal-Wallis | Mann-Whitney pairwise | Dunn's post hoc

Test for equal means

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Components of variance (only for random effects):

Var(group):	7392.3	**Var(error):**	3785.6	**ICC:**	0.661332

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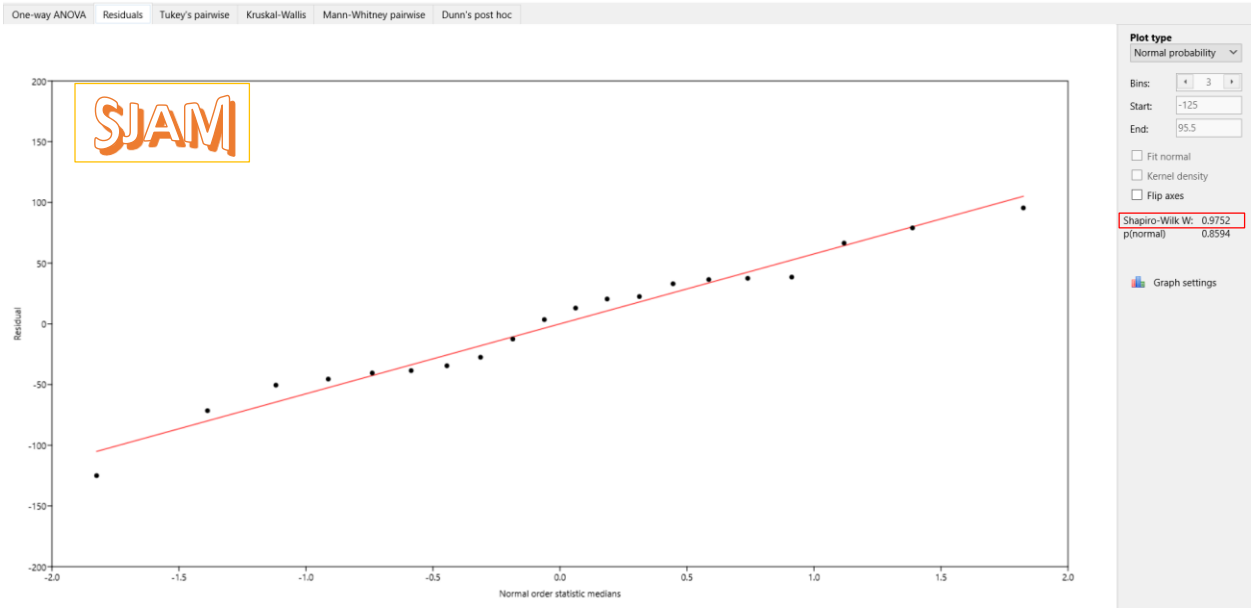
Levene´s test for homogeneity of variance, from means	***p* (same):**	0.6275
Levene´s test, from medians	***p* (same):**	0.8597

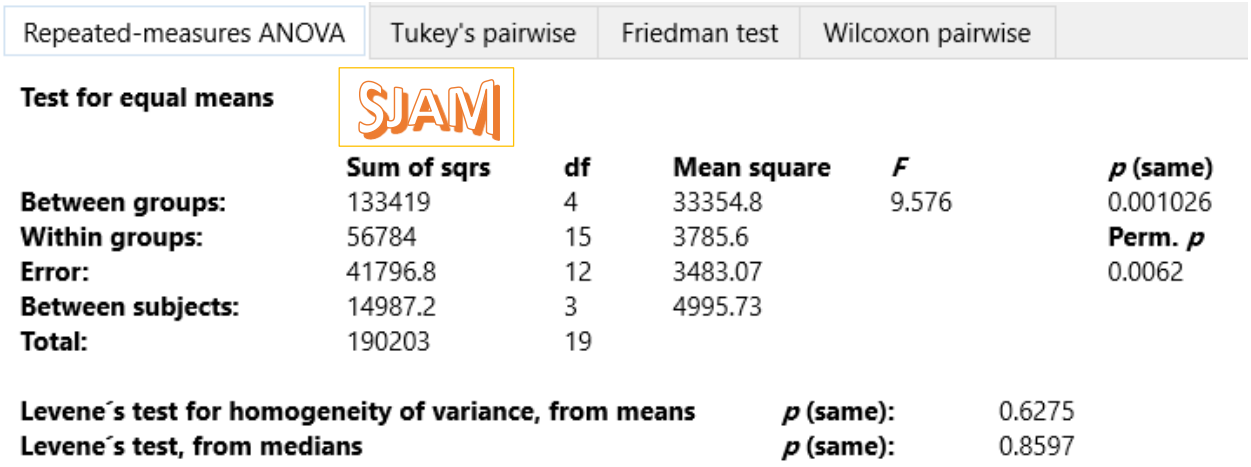
Welch *F* test in the case of unequal variances: F=5.869, df=7.347, p=0.01958

The normality assumption is met because we see that in Wilk-Shapiro test the p-value is 0.9752 which is greater than 0.05. Noticed also that the normal probability plot supports normality by displaying spots that closely match the diagonal line.



P-value computation through PAST.

- **For treatment:** p-value ≈ 0.001026.
  For block: p-value ≈ 0.2814



	Sum of sqrs	df	Mean square	*F*	*p* (same)
Between groups:	133419	4	33354.8	9.576	0.001026
Within groups:	56784	15	3785.6		**Perm. *p***
Error:	41796.8	12	3483.07		0.0062
Between subjects:	14987.2	3	4995.73		
Total:	190203	19			

Levene´s test for homogeneity of variance, from means	***p* (same):**	0.6275
Levene´s test, from medians	***p* (same):**	0.8597

P-value computation using PAST:

Treatment: p-value ≈ 0.001026

Block: p-value ≈ 0.2814

Two-way ANOVA without replication

Test for equal means

	Sum of sqrs	df	Mean square	*F*	*p* (same)
Rows:	14987.2	3	4995.73	1.434	0.2814
Columns:	133419	4	33354.8	9.576	0.001026
Error:	41796.8	12	3483.07		
Total:	190203	19			

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1 Make a Decision Treatment: Since p-value ≈ 0.001026 < 0.05, we reject Ho.
Block: Since p-value ≈ 0.2814 > 0.05, we fail to reject Ho.

2 Make a Conclusion

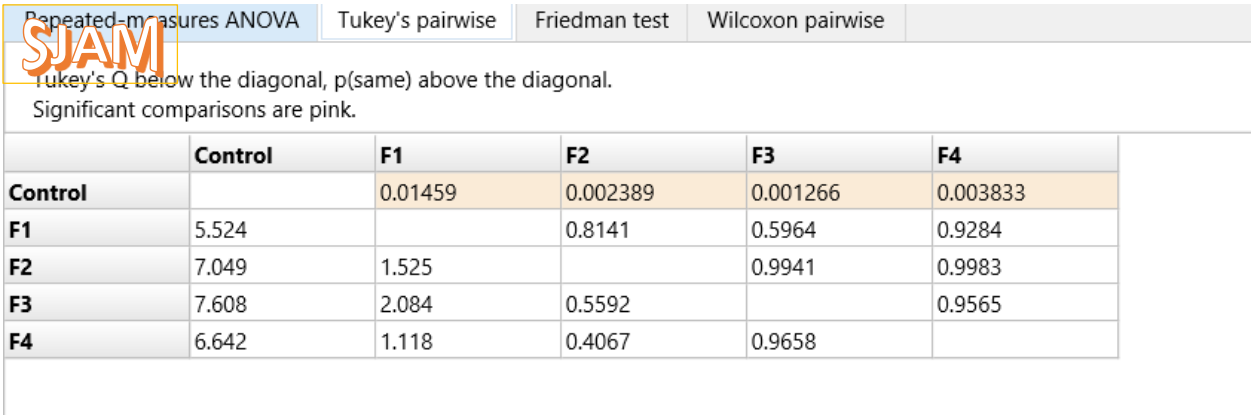
Treatment: At the 5% significance level, the data provide adequate evidence to indicate that the mean yields differ between the four fungicide types.

Block: At the 5% significance level, there is no sufficient evidence to suggest that the blocking factor has a notable impact on potato yield.

b. If necessary, perform Tukey's test. Write the summary table showing the mean per treatment and the appropriate superscripts. Write a short description about the test results.

Treatment	Mean
Control	404.5a
F1	567.5b

F2	612.5b
F3	629b
F4	600.5b



	Control	F1	F2	F3	F4
Control		0.01459	0.002389	0.001266	0.003833
F1	5.524		0.8141	0.5964	0.9284
F2	7.049	1.525		0.9941	0.9983
F3	7.608	2.084	0.5592		0.9565
F4	6.642	1.118	0.4067	0.9658	

According to Tukey's test, the control treatment produced much lower potato yields than the plots treated with fungicides, it clearly shows a clear difference between them. However, when we look at the four fungicide treatments (F1, F2, F3, and F4), we can see that there was no significant difference in yields at the 5% level, which means that all four fungicides worked similarly in improving the potato yield.

Repeated-measures ANOVA | Tukey's pairwise | Friedman test | Wilcoxon pairwise

Tukey's Q below the diagonal, p(same) above the diagonal.
Significant comparisons are pink.

	Control	F1	F2	F3	F4
Control		0.01459	0.002389	0.001266	0.003833
F1	5.524		0.8141	0.5964	0.9284
F2	7.049	1.525		0.9941	0.9983
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