

Investigating Seed Germination.

Results

Table of Results

TEMP. (°c)	PERCENTAGE GERMINATED					
	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	MEAN
-10	0	0	0	0	0	0.0
4	8	4	12	6	10	8.0
22	80	100	74	86	100	88.0
30	60	74	8	96	94	81.0
40	10	6	0	10	2	5.6

CONTROL	0	0	0	0	0	0.0
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NB. Numbers in bold italics are anomalous. They have not been included in the mean.

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TEMP. (°c)	MEAN PERCENTAGE GERMINATED
-10	0.0
4	8.0
22	88.0
30	81.0
40	5.6

CONTROL	0.0
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These results can now be used to perform statistical analysis and to plot a graph.

Analysis

To determine whether temperature has had an effect I shall use the Chi-Squared (χ^2) Test for Goodness of Fit.

The Chi-Squared Test is used to determine whether the actual results of the experiment confirm the null hypothesis stated.

For this investigation, the null hypothesis would be; '*temperature has no effect on the percentage of seeds that germinate*'

Whereas the alternative hypothesis would be; '*temperature does have an effect on the percentage of seeds that germinate*'

We will now determine whether the results fit the null hypothesis:

The following results were obtained:

	-10°C	4°C	22°C	30°C	40°C
% Germinated	0.0	8.0	88.0	81.0	5.6

By using these results we can determine the expected frequencies if the null hypothesis is correct:

⇒ Total percentage of seeds that germinate / Number of different categories

⇒ $(0.0 + 8.0 + 88.0 + 81.0 + 5.6) / 5 = 36.52$

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	-10°C	4°C	22°C	30°C	40°C
Observed % Germinate (O)	0.0	8.0	88.0	81.0	5.6
Expected % Germinate (E)	36.52	36.52	36.52	36.52	36.52

For each category work out; $(O - E)^2/E$ and add the values together to work out the χ^2 value.

$$(0.0 - 36.52)^2/36.52 + (8.0 - 36.52)^2/36.52 + (88.0 - 36.52)^2/36.52 + (81.0 - 36.52)^2/36.52 + (5.6 - 36.52)^2/36.52$$

$$= 36.52 + 22.3 + 72.6 + 54.2 + 26.2$$

$$= 211.82 = \chi^2$$

$$\text{Degrees of Freedom} = (\text{Number of Categories} - 1) = (5 - 1) = 4$$

Using a chi-squared table, look up value for the appropriate significance level (5%) and the degrees of freedom. The 5% level for four degrees of freedom = 9.488

As our chi-squared value is greater than this we are able to reject our null hypothesis and accept our alternative hypothesis. Temperature does have an effect on number of seeds that germinate.

The Chi-Squared Test has shown that, with certainty, we can assume that temperature is directly linked to the number of seeds that germinate. I feel it is necessary, however, to carry out confidence limits on the graph to determine whether any of the individual results are due to chance. For example, the difference between the percentage of seeds that germinate between the range of 22c to 30c has little significant difference. These results may, therefore be due to chance.

We find the confidence limits for each point on the graph by following the following steps:

Take the standard deviation of the group of data for that point using the equation

$\Rightarrow \sqrt{(\sum(x - \bar{x})^2)/n}$ where; x = an individual sample in the group of data, \bar{x} = the mean of the group of data and n = number of samples used.

Standard error is then found by:

$\Rightarrow \text{Standard Deviation}/(n - 1)$

NB. If 'n' is greater than 30 we can just use 'n' in the above formula.

To work out 95% confident limits we simply multiply our value for the standard error by two. These are then used to plot error bars on the graph. Should the error bars overlap we can assume that the difference between the points is due to chance.

For example, at 4c our range of data is; 8, 4, 12, 6 and 10.

Standard Deviation = $\sqrt{((16 + 16 + 4 + 4)/5)} = 2.8$

Standard Error = $2.8/\sqrt{5} = 1.25$

95% Confidence Limits = $1.25 \times 2 = 2.5$

See following table of data and graph for results of confidence limit testing on each of the five groups of data.

From the graph, plotted with error bars, we can see that two pairs of error bars overlap. The error bars at 4c overlap with those at 40c and the error bars at 22c overlap with those at 30c.

These overlaps indicate that there is either significantly different results possible within the range of temperatures separating the points or that there is a range of optimal temperatures for germination of seed germination.

The overlap of error bars between 4c and 40c is due to the fact that there are significantly different results within the range of temperatures from 4c to 40c.

The overlap of error bars between 22c and 30c, however, may be due to either of the situations mentioned above. Further tests would be required to determine whether there are significantly different results within this temperature range or that the difference in results is due to the seeds having a range of optimal germination temperatures, ie, the difference is due to chance.