

Parametric Test

1. t-test
2. One way ANOVA
3. Regression
4. Correlation

t-Test

- a. One-Sample t-Test or Difference between population and sample means
 - A one sample t-test compares the mean of one sample to a fixed estimate, usually 0.
 - A significant result indicates that the group's mean differs from the fixed value

Understanding the output

One-Sample Test test value

	Test Value = 5					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Q1	2.540	24	.018	1.1200	.2100	2.0300

t-value degrees of
freedom p-value difference from
test value

t-Test

b. Independent Sample t-Test or Difference between two independent means

- An independent sample t-test compares the means of two independent groups. e.g. data from two different groups.
- The null hypothesis would be that the means are the same.

Understanding the output

a. Test of Normality

		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
WEIGHT	Female	.165	9	.200*	.946	9	.615
	Male	.162	13	.200*	.961	13	.727

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The p-values of 0.615 and 0.727 from Shapiro-Wilk test of normality are both greater than 0.05 which implies that it is acceptable to assume that the weight distribution for male and female are both normal (bell-shape)

b. Test of Equality of Variance

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
hours of work - S	Equal variances assumed	1.153	.286	-3.388	77	.001	-1.120	.3305	-1.7779	-.4617
	Equal variances not assumed			-3.326	66.811	.001	-1.120	.3367	-1.7919	-.4477

test for equal variances
 p-value: should be higher than .05

t-value

degrees of freedom

p-value

difference between sample means

The Levene's Test for Equality of Variances tests whether the variances from your two samples are different - a p-value of less than .05 means that they are probably different and you should use another test or modify this one.

A value of greater than .05, such as in this example, means you've met your assumption of equal variances - good work!

t-Test

c. Paired Sample t-Test or t-Test for dependent means

- evaluates two groups that are related to each other.
- data from a group of participants who are tested before and after a procedure

Understanding the output

Paired Samples Test

		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower				Upper
Pair 1	Q1 - Q10	1.4400	2.64701	.52940	.3474	2.5326	2.720	24	.012

difference
between sample
means

t-value

degrees of
freedom

p-value

Analysis of Variance

- Analysis of variance (ANOVA) is the analysis to use when you have *more than two means* to compare
- ANOVA is a procedure that partitions the total variance into sub-component variances.
- It enables us to determine whether such variances or differences are:
 - a. due to chance alone or sampling error or
 - b. indeed as a result of the effects of the independent variable on the dependent variable.

Analysis of Variance

- The *F value* should be computed only when the *error df* is large enough for a reliable estimate of the error variance.
- As general guideline, the value should be computed only when the *error df* is six (6) or more

Completely Randomized Design (CRD) or One-Way ANOVA

- This is the simplest of all the designs and it is also the basic design upon which all other designs are built.
- This design is commonly used in laboratory and greenhouse experiments because the experimental units usually have, more or less, similar properties; and the environmental conditions in which the experiments are being carried out can be made as uniform as possible.

Advantages

1. any number of treatments and replications may be used and the number replication may be different from one treatment to another
2. statistical analysis is extremely simple.
3. missing observation do not present any difficulty in the mode of analysis

Disadvantages

1. accuracy is low compared to other designs
2. since the experimental units are not grouped in any way, all of the variations between the units enters into the experimental error.

Understanding the output

Descriptive Statistics

Dependent Variable: yield

trt	Mean	Std. Deviation	N
Var A	6.0960	.47141	5
Var B	6.3080	.70379	5
Var C	5.3640	.89388	5
Var D	4.7140	.19282	5
Var E	3.9320	.54389	5
Total	5.2828	1.05542	25

- It tells us that there were 5 replicates in each variety.
- It gives us the means and standard deviations for each variety

Levene's Test of Equality of Error Variances

Dependent Variable: yield

F	df 1	df 2	Sig.
2.201	4	20	.106

Tests the null hypothesis that the error variance the dependent variable is equal across groups.

a. Design: Intercept+trt

- This gives us the results of a homogeneity of variance test.
- Remember, this is an assumption for a valid ANOVA (that the variances of each group/condition are the same).

Tests of Between-Subjects Effects

Dependent Variable: yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	19.336 ^a	4	4.834	13.068	.000
Intercept	697.699	1	697.699	1886.102	.000
trt ←	19.336	4	4.834	13.068	.000
Error	7.398	20	.370		
Total	724.433	25			
Corrected Total	26.734	24			

Treatment is significant because $p < 0.05$ and 0.01

a. R Squared = .723 (Adjusted R Squared = .668)

- According to the last column, the p -value is $< .001$ (SPSS rounds, so when you see “.000” in this box, always report it as $p < .001$, or as less than the alpha you are using).
- Thus, at either alpha (.05 or .01), we can reject the null; the groups are different.

Comparison of Treatment Means

yield

Duncan^{a,b}

trt	N	Subset			
		1	2	3	4
Var E	5	3.9320			
Var D	5	4.7140	4.7140		
Var C	5		5.3640	5.3640	
Var A	5			6.0960	6.0960
Var B	5				6.3080
Sig.		.056	.107	.072	.588

Means for groups in homogeneous subsets are displayed.

Based on Type III Sum of Squares

The error term is Mean Square(Error) = .370.

a. Uses Harmonic Mean Sample Size = 5.000.

b. Alpha = .05.

The means that differ from each other are in separate boxes (other post hoc tests show differences between groups in different ways, sometimes by an *).

Randomized Complete Block Design

- This design is extensively used in agricultural experiments.
- The primary distinguishing feature of the RCBD is the presence of blocks of equal sizes, each of which contains all the treatments.
- The main purpose of blocking is to reduce the experimental error by eliminating the known source of variation among experimental units.
- This is done by grouping the experimental units into block such that variability within each block is minimized and variability among blocks is maximized

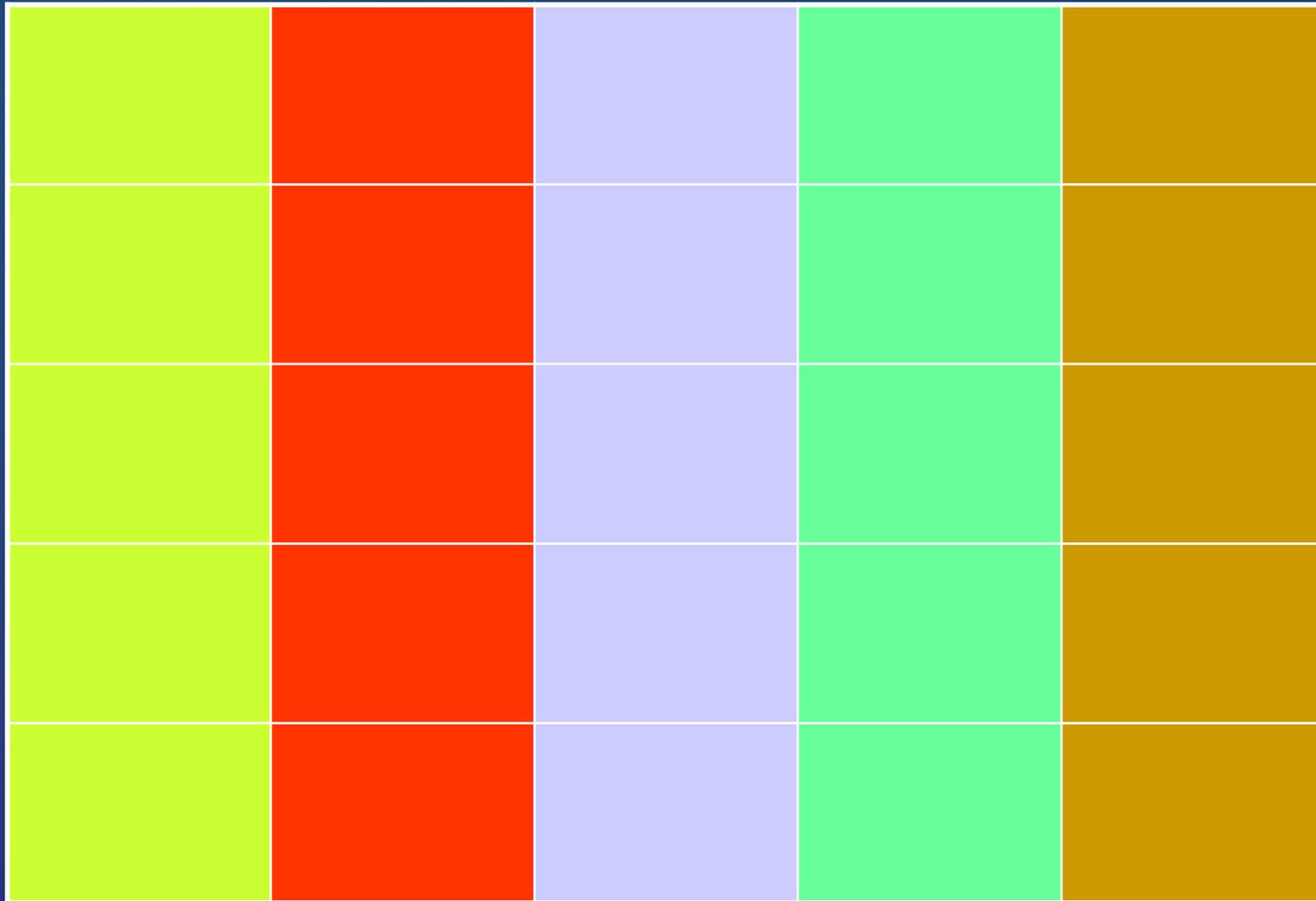
Block I

Block II

Block III

Block IV

Block V



Low



High

Regression Analysis

- Regression analysis describes the effect of one or more variables (designated as independent or **predictor variables**, *IV*) on a single variable (designated as dependent variable, *DV*) by expressing the latter as a function of the former.
- In this analysis, it is important to distinguish between the dependent and independent variables.
- Regression analysis is particularly useful in handling several variables simultaneously

Simple Linear Regression

- The simple linear regression analysis deals with the estimation and test of significance concerning the two parameters α and β in the equation:

$$Y = \alpha + \beta X + \varepsilon$$

- The estimated linear regression is given by:

$$\hat{Y} = a + bX$$

Example

y = grain yield

x = number of tillers

a = Y-intercept or value of Y when X is 0

b (slope) = change in DV associated with one unit increase in IV

Understanding the output

Variables Entered/Removed^a

Model	Variables Entered	Variables Removed	Method
1	tiller ^a	.	Enter

a. All requested variables entered.

b. Dependent Variable: yield

- This box is telling you that the number of tillers was entered to predict grain yield
- (this box is meaningless for this example, but would be important if you were using multiple predictor (X) variables and using a method of entering these into the equation that was not the default).

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.835 ^a	.697	.647	402.594

a. Predictors: (Constant), tiller

- The second column gives you the correlation coefficient (0.835 – a strong, positive, linear relationship).
- The next column gives you a measure of effect R^2 : 69.7% of the variation in grain yield is accounted for by the number of tillers (this is a strong effect!).
- Adjusted R^2 adjusts for the fact that you are using a sample to make inferences about a population; some people report R^2 and some report the adjusted R^2 .
- The standard error of the estimate (think of this as the standard deviation around the regression line).

Don't let the word "ANOVA" fool you here. The word ANOVA comes from the fact that the table partitions the variance in the regression model and is therefore technically an Analysis of Variance.

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2239012	1	2239012.410	13.814	.010 ^a
	Residual	972491.1	6	162081.848		
	Total	3211504	7			

a. Predictors: (Constant), tiller

b. Dependent Variable: yield

The ANOVA part of the output is not very useful for our purposes.

It basically tells us whether the regression equation is explaining a statistically significant portion of the variability in the dependent variable from variability in the independent variables.

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	
	B	Std. Error	Beta			
1	(Constant)	1375.476	1402.493		.981	.365
	tiller	310.525	83.548	.835	3.717	.010

a. Dependent Variable: yield

The Coefficients part of the output gives us the values that we need in order to write the regression equation.

The regression equation will take the form:

$$\text{Grain yield} = 1375.5 + 310.5 * \text{tillers}$$

An increase of 1 unit in tillers results in a 310.5 increase in grain yield

Multiple Linear Regression

Multiple regression is a statistical technique that allows us to predict someone's score on one variable on the basis of their scores on several other variables.

It allows us to identify a set of **predictor variables** which together provide a useful estimate of a participant's likely score on a criterion variable.

Understanding the output

Descriptive Statistics

	Mean	Std. Deviation	N
yield	6561.25	677.338	8
height	96.200	15.8282	8
tiller	16.700	1.8213	8
spikelets	286.300	20.4277	8

The first table describes the descriptive statistics

Correlations

	yield	height	tiller	spikelets	
Pearson Correlation	yield	1.000	-.869	.835	.608
	height	-.869	1.000	-.776	-.635
	tiller	.835	-.776	1.000	.398
	spikelets	.608	-.635	.398	1.000
Sig. (1-tailed)	yield	.	.003	.005	.055
	height	.003	.	.012	.045
	tiller	.005	.012	.	.165
	spikelets	.055	.045	.165	.
N	yield	8	8	8	8
	height	8	8	8	8
	tiller	8	8	8	8
	spikelets	8	8	8	8

The second table gives the details of the correlation between each pair of variables

Variables Entered/Removed^a

Model	Variables Entered	Variables Removed	Method
1	spikelets, tiller, ^a height	.	Enter

a. All requested variables entered.

b. Dependent Variable: yield

The third table tells us about the predictor variables and the method used

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.914 ^a	.835	.712	363.695

a. Predictors: (Constant), spikelets, tiller, height

This table is important. The Adjusted R^2 value tells us that our model accounts for 83.5% of the variation in grain yield – **a very good model**

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2682408	3	894135.893	6.760	.048 ^a
	Residual	529095.8	4	132273.955		
	Total	3211504	7			

a. Predictors: (Constant), spikelets, tiller, height

b. Dependent Variable: yield

This table reports an ANOVA, which assesses the overall significance of our model. As $p < 0.05$, our model is significant

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3960.810	4969.722		.797	.470		
	height	-17.937	16.688	-.419	-1.075	.343	.271	3.692
	tiller	165.068	122.094	.444	1.352	.248	.382	2.617
	spikelets	5.482	8.884	.165	.617	.571	.574	1.743

a. Dependent Variable: yield

The Standardized Beta coefficients give a measure of the of each predictor variable to the model. A large value indicates that a unit change in this predictor variable has a large effect on the criterion variable.

The ***t*** and ***Sig (p)*** values give rough indication of the impact of each predictor variable (a ***large t*** and ***small p*** values suggest that a predictor variable is having a large impact on the criterion variable

The **tolerance values** are a measure of the correlation between the predictor variables and can vary between 0 and 1. The closer to zero the tolerance value is for a variable, the stronger the relationship between this and the other predictor

Reporting the results

When reporting the results of a multiple regression analysis, you want to inform the reader about

1. the proportion of the variance accounted for by your model,
2. the significance of your model and
3. the significance of the predictor variables.

Selection methods

There are different ways that the relative contribution of each predictor variable can be assessed.

1. **Enter Method**, the researcher specifies the set of predictor variables that make up the model.

The success of this model in predicting the criterion variable is then assessed.

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	spikelets, tiller, height ^a	.	Enter

a. All requested variables entered.

b. Dependent Variable: yield

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.914 ^a	.835	.712	363.695

a. Predictors: (Constant), spikelets, tiller, height

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2682408	3	894135.893	6.760	.048 ^a
	Residual	529095.8	4	132273.955		
	Total	3211504	7			

a. Predictors: (Constant), nitro, tiller, height

b. Dependent Variable: yield

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3960.810	4969.722		.797	.470
	height	-17.937	16.688	-.419	-1.075	.343
	tiller	165.068	122.094	.444	1.352	.248
	nitro	5.482	8.884	.165	.617	.571

a. Dependent Variable: yield

In “statistical” methods, the order in which the predictor variables are entered into (or taken out of) the model is determined according to the **strength of their correlation with the criterion variable.**

Actually there are several versions of this method, called **forward selection, backward selection and stepwise selection.**

2. Forward selection, SPSS enters the variables into the model one at a time in an order determined by the strength of their correlation with the criterion variable.

The effect of adding each is assessed as it is entered, and variables that do not significantly add to the success of the model are excluded.

Variables Entered/Removed^a

Model	Variables Entered	Variables Removed	Method
1	height		Forward (Criterion: Probability-of- F-to-enter ≤ .050)

a. Dependent Variable: yield

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.869 ^a	.755	.714	362.385

a. Predictors: (Constant), height

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2423567	1	2423566.838	18.455	.005 ^a
	Residual	787936.7	6	131322.777		
	Total	3211504	7			

a. Predictors: (Constant), height

b. Dependent Variable: yield

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10137.455	842.265		12.036	.000
	height	-37.175	8.653	-.869	-4.296	.005

a. Dependent Variable: yield

Excluded Variables^b

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	tiller	.404 ^a	1.341	.238	.514	.397
	spikelets	.094 ^a	.333	.753	.147	.597

a. Predictors in the Model: (Constant), height

b. Dependent Variable: yield

3. Backward selection, SPSS enters all the predictor variables into the model.

The **weakest predictor** variable is then removed and the regression re-calculated.

If this significantly weakens the model then the predictor variable is re-entered – otherwise it is deleted.

This procedure is then repeated until **only useful predictor variables** remain in the model.

Variables Entered/Removed^b

Model	Variables Entered	Variables Removed	Method
1	spikelets, tiller, height ^a		Enter
2		spikelets	Backward (criterion: Probability of F-to-remove >= .100).
3		tiller	Backward (criterion: Probability of F-to-remove >= .100).

a. All requested variables entered.

b. Dependent Variable: yield

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.914 ^a	.835	.712	363.695
2	.905 ^b	.820	.747	340.428
3	.869 ^c	.755	.714	362.385

a. Predictors: (Constant), spikelets, tiller, height

b. Predictors: (Constant), tiller, height

c. Predictors: (Constant), height

ANOVA^d

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2682408	3	894135.893	6.760	.048 ^a
	Residual	529095.8	4	132273.955		
	Total	3211504	7			
2	Regression	2632048	2	1316024.076	11.356	.014 ^b
	Residual	579455.3	5	115891.069		
	Total	3211504	7			
3	Regression	2423567	1	2423566.838	18.455	.005 ^c
	Residual	787936.7	6	131322.777		
	Total	3211504	7			

a. Predictors: (Constant), spikelets, tiller, height

b. Predictors: (Constant), tiller, height

c. Predictors: (Constant), height

d. Dependent Variable: yield

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3960.810	4969.722		.797	.470
	height	-17.937	16.688	-.419	-1.075	.343
	tiller	165.068	122.094	.444	1.352	.248
	spikelets	5.482	8.884	.165	.617	.571
2	(Constant)	6335.596	2942.931		2.153	.084
	height	-23.748	12.895	-.555	-1.842	.125
	tiller	150.313	112.069	.404	1.341	.238
3	(Constant)	10137.455	842.265		12.036	.000
	height	-37.175	8.653	-.869	-4.296	.005

a. Dependent Variable: yield

Excluded Variables^c

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
2	spikelets	.165 ^a	.617	.571	.295	.574
3	spikelets	.094 ^b	.333	.753	.147	.597
	tiller	.404 ^b	1.341	.238	.514	.397

a. Predictors in the Model: (Constant), tiller, height

b. Predictors in the Model: (Constant), height

c. Dependent Variable: yield

4. **Stepwise method** is the most sophisticated of these statistical methods.

Each variable is entered in sequence and its value assessed.

If adding the variable contributes to the model then it is retained, but all other variables in the model are then re-tested to see if they are still contributing to the success of the model.

If they no longer contribute significantly they are removed.

Thus, this method should ensure that you end up with the **smallest possible set of predictor variables** included in your model.

Variables Entered/Removed^a

Model	Variables Entered	Variables Removed	Method
1	height		Stepwise (Criteria: Probability-of- F-to-enter ≤ .050, Probability-of- F-to-remove ≥ .100).

a. Dependent Variable: yield

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.869 ^a	.755	.714	362.385

a. Predictors: (Constant), height

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10137.455	842.265		12.036	.000
	height	-37.175	8.653	-.869	-4.296	.005

a. Dependent Variable: yield

Excluded Variables^b

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics
						Tolerance
1	tiller	.404 ^a	1.341	.238	.514	.397
	spikelets	.094 ^a	.333	.753	.147	.597

a. Predictors in the Model: (Constant), height

b. Dependent Variable: yield

How to choose the appropriate method?

Enter method is the safest to use if you have no theoretical model in mind, and/or you have relatively low number of cases

Statistical procedures should be used with caution and only when you have a large number of cases.

This is because minor variations in the data due to sampling errors can have a large effect on the order in which variables are entered and therefore the likelihood of them being retained.

Stepwise method is of advantage because it should always result in the most economical model.

This could be important if you wanted to know the **minimum number of variables** you would need to measure to predict the criterion variable.

Tip on what method to use

Validate your results with a second independent set of data.

This can be done either by conducting a second study, or by randomly splitting your data set into two halves

Only results that are common to both analyses should be used and reported.

Understanding the output

Descriptive Statistics

	Mean	Std. Deviation	N
yield	6561.25	677.338	8
height	96.200	15.8282	8
tiller	16.700	1.8213	8
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The first table describes the descriptive statistics

Correlations

		yield	height	tiller	spikelets
Pearson Correlation	yield	1.000	-.869	.835	.608
	height	-.869	1.000	-.776	-.635
	tiller	.835	-.776	1.000	.398
	spikelets	.608	-.635	.398	1.000
Sig. (1-tailed)	yield	.	.003	.005	.055
	height	.003	.	.012	.045
	tiller	.005	.012	.	.165
	spikelets	.055	.045	.165	.
N	yield	8	8	8	8
	height	8	8	8	8
	tiller	8	8	8	8
	spikelets	8	8	8	8

The second table gives the details of the correlation between each pair of variables

Variables Entered/Removed^a

Model	Variables Entered	Variables Removed	Method
1	spikelets, tiller, height ^a	.	Enter

a. All requested variables entered.

b. Dependent Variable: yield

The third table tells us about the predictor variables and the method used

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
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a. Predictors: (Constant), spikelets, tiller, height

This table is important. The Adjusted R^2 value tells us that our model accounts for 83.5% of the variation in grain yield – **a very good model**

ANOVA^b

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a. Predictors: (Constant), spikelets, tiller, height

b. Dependent Variable: yield

This table reports an ANOVA, which assesses the overall significance of our model. As $p < 0.05$, our model is significant

Coefficients^a

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3960.810	4969.722		.797	.470		
	height	-17.937	16.688	-.419	-1.075	.343	.271	3.692
	tiller	165.068	122.094	.444	1.352	.248	.382	2.617
	spikelets	5.482	8.884	.165	.617	.571	.574	1.743

a. Dependent Variable: yield

The Standardized Beta coefficients give a measure of the of each predictor variable to the model. A large value indicates that a unit change in this predictor variable has a large effect on the criterion variable.

The ***t*** and ***Sig (p)*** values give rough indication of the impact of each predictor variable (a ***large t*** and ***small p*** values suggest that a predictor variable is having a large impact on the criterion variable

The **tolerance values** are a measure of the correlation between the predictor variables and can vary between 0 and 1. The closer to zero the tolerance value is for a variable, the stronger the relationship between this and the other predictor

In the results section, we would write:

Using the enter method, a significant model emerged ($F_{3,4}=60.417$, $p < 0.05$. Adjusted $R^2 = 0.712$).

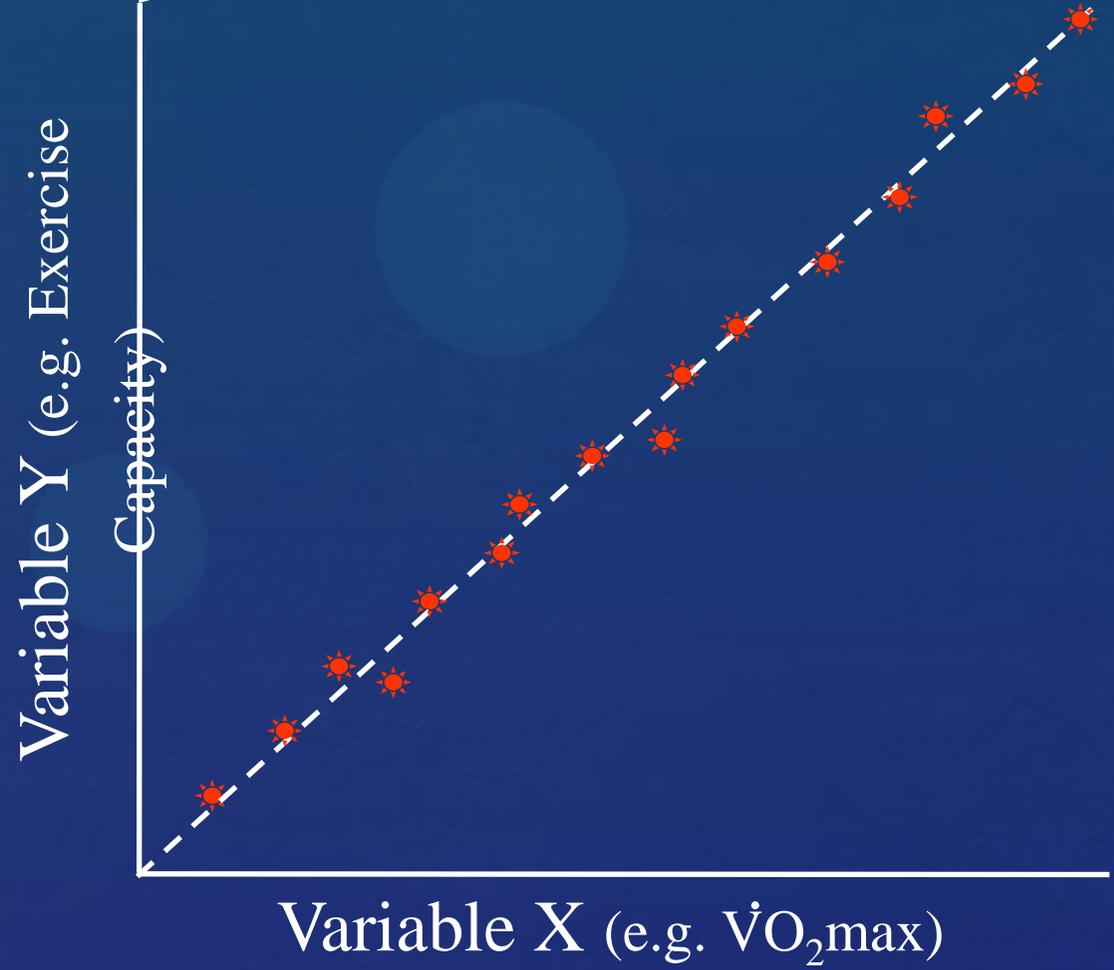
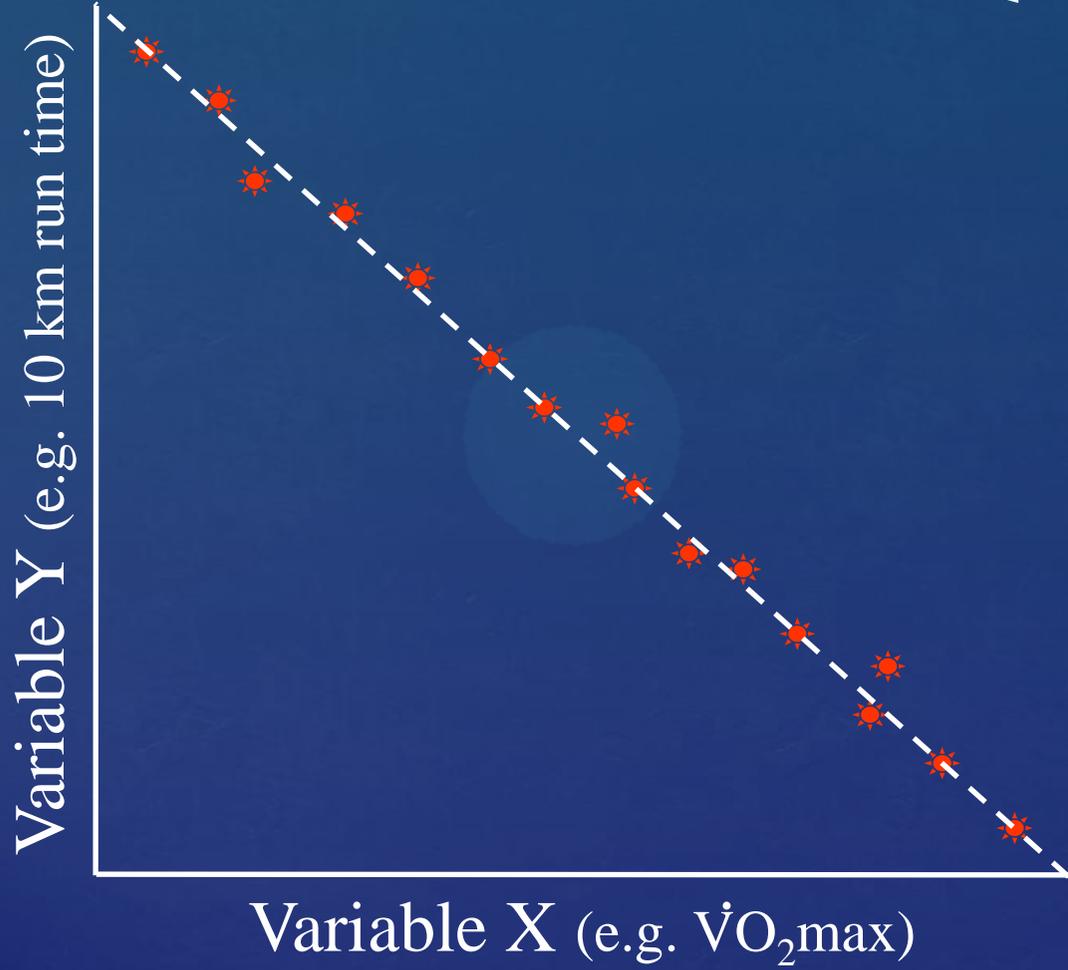
All variables are not significant predictors of grain yield.

Correlation Analysis

Simple linear correlation analysis deals with the estimation and test of significance of the simple linear correlation coefficient (r), which is a measure of the degree of linear association between two variables X and Y

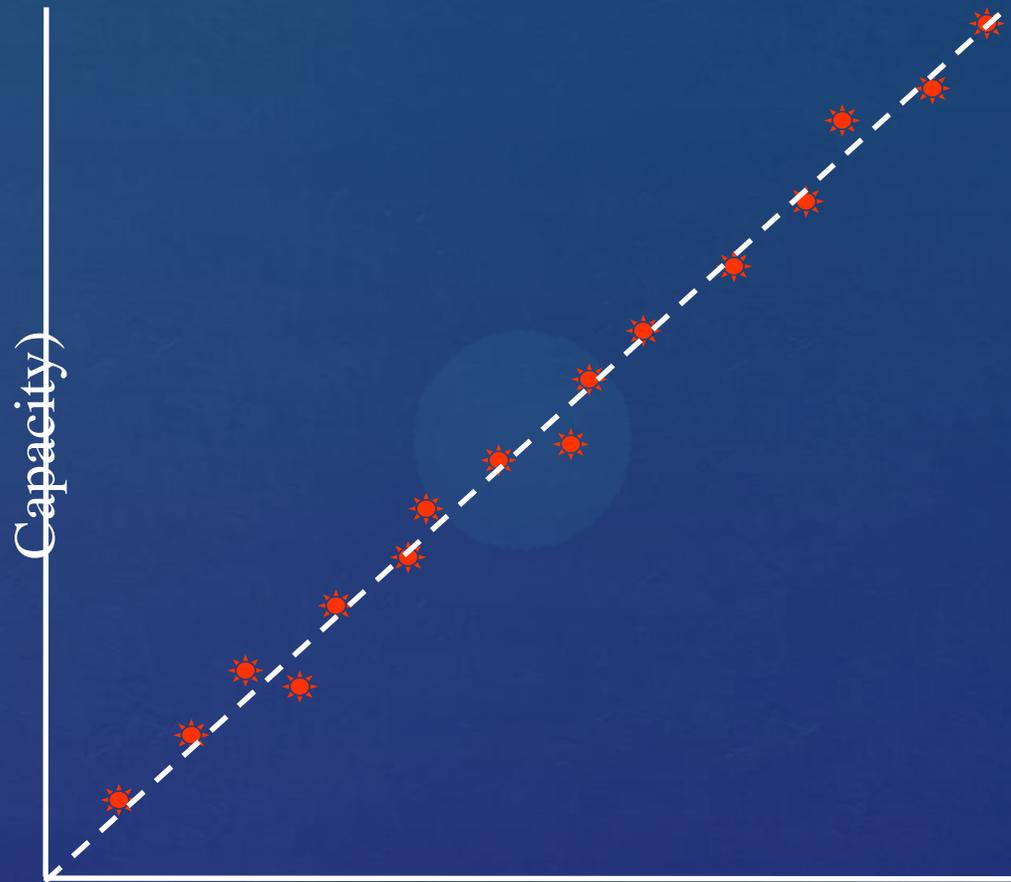
This technique is used when you have two variables (measured on the same person or thing) that are quantitative in nature and measured on an interval or ratio scale

Direction



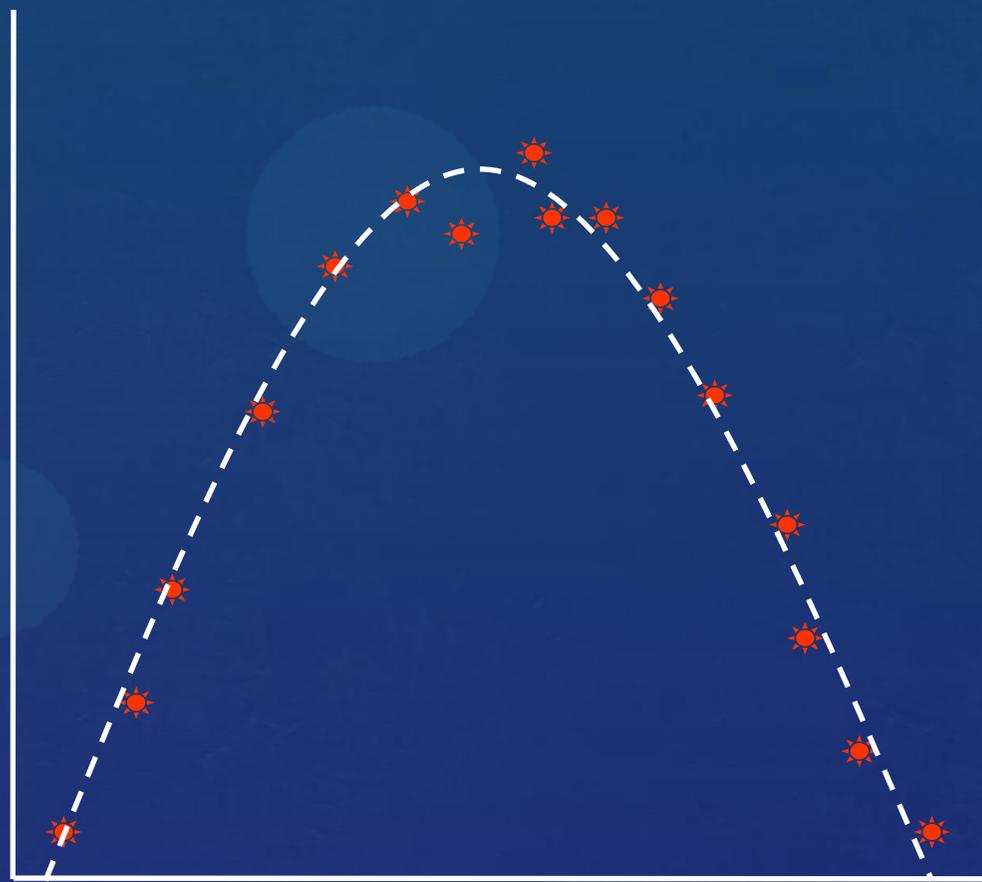
Form

Variable Y (e.g. Exercise Capacity)



Variable X (e.g. $\dot{V}O_2\text{max}$)

Variable Y (e.g. Strength)



Variable X (e.g. Age)

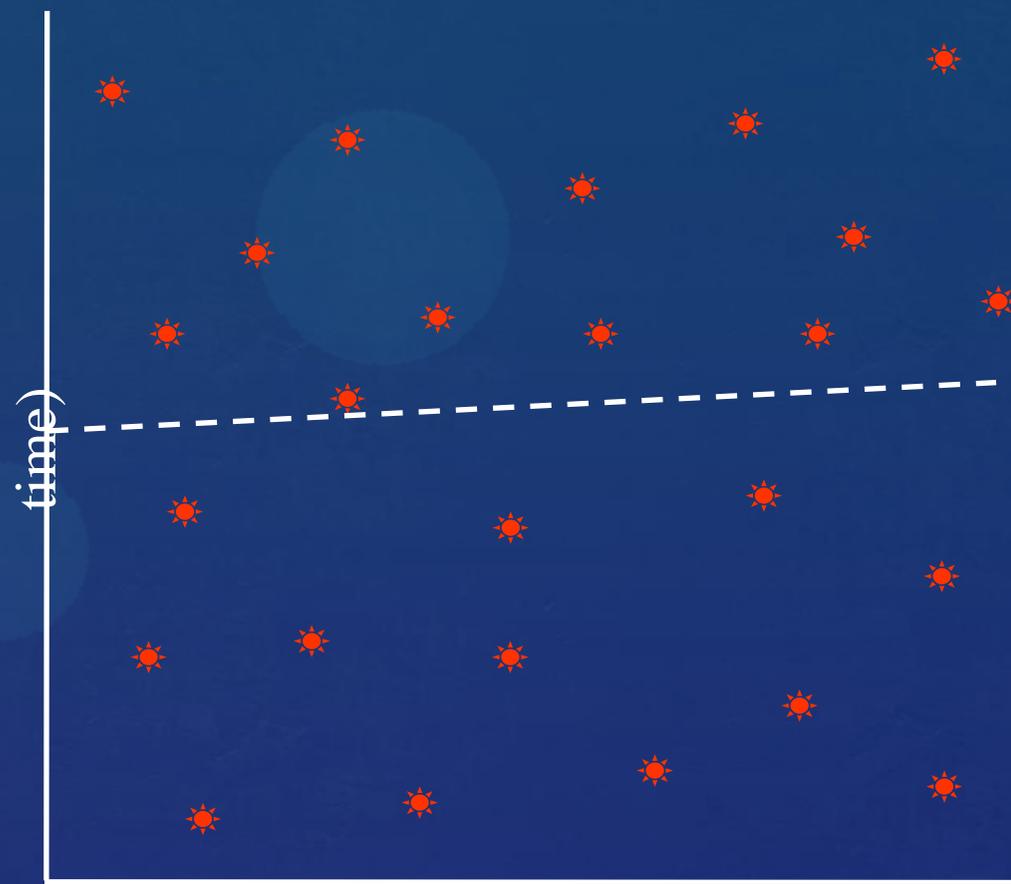
Significance

Variable Y (e.g. Exercise Capacity)



Variable X (e.g. $\dot{V}O_2\text{max}$)

Variable Y (e.g. 100 m Sprint time)



Variable X (e.g. $\dot{V}O_2\text{max}$)

Correlation **does not necessarily prove** causation.

A correlation coefficient (r) is an index number that measures ...

- a. the magnitude and
- b. the direction of the relationship between two variables

It is designed to range in value between 0.0 and 1.0

Understanding the output

		score	time
score	Pearson Correlation	1	.083
	Sig. (2-tailed)		.745
	N	18	18
time	Pearson Correlation	.083	1
	Sig. (2-tailed)	.745	
	N	18	18



The correlation coefficient in the last column, first row is 0.083 which is a small correlation

The p -value is 0.745 which exceeded α (0.05 and 0.01) – which is not statistically significant

To be continued



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