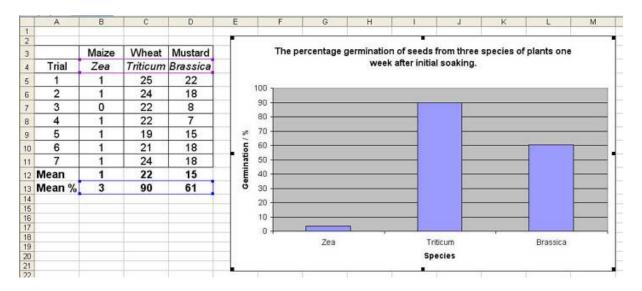
## Going further with graphs I Adding Error Bars

Error bars are way of showing the degree of uncertainty in a set of data. MS Excel can add them to your graphs.

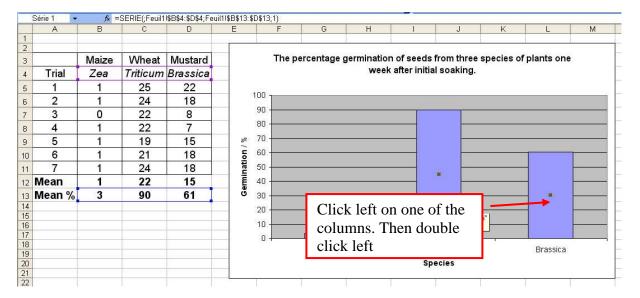
## **Error Bars Showing Precision**

The data below show the results from an experiment where the seeds from three species of plants were germinated for one week. At the end of the week the numbers of seeds germinating were counted. 25 seeds were used in each trial.

First the data is entered onto a spread sheet. The spread sheet is used to calculate the mean and the mean percentage germination. Then a bar chart is drawn using the graphing menu.



To enter the error bars first left click on one of the columns. This activates all the columns.



Double left click and a menu will appear. Select **error bars** (Fr *Barre d'erreur*). As this is a bar chart it will only offer to draw error bars on the y-axis.

	A	B	C		E	F	G G	H	- I	J	K	L	M
1	-												
: }		Maize	Wheat	Mustard	-	The p	ercentage g	ermination o	fseeds	from three	species of	plants one	;
1	Trial	Zea	Triticum	Brassica				week a	fter initi	al soaking.			
;	1	1	25	22									
6	2	1	24	18		00							
1	3	0	22	8	6	90	ART TRACK MERCET						
3	4	1	22	7	Fo	rmat de série	de données			100			
9	5	1	19	15		Étiquettes		Ordre des	séries	Options			
10	6	1	21	18	_	Motifs	Sé	lection de l'axe		Barre d'erreur Y			1
1	7	1	24	18	_ ] [	Affic <u>h</u> er				▲ 1		-	
-	Mean	1	22	15	_		t i				\$		·
	Mean %	3	90	61	_ 1	es deux Sup	érieure Inférie	ure Aucune		\ [	~ .		
4						Marge d'erreur				· · · ·	Selec	t error	bars
6						Précision :	10	0000			in the	menu	
7 8	-	Se	elect er	ror 🦌		Pourcentage	: 5	\$%					
9		h	ars abov	Ve		) É <u>c</u> art type :	1	\$				Brassica	
0						Erreur type			_				
2		ar	nd belov	W	(	Personnalisée			<u>.</u>				
3							-		<u>=</u>				
25			1	1								1	
26			1	· · · · · · · · · · · · · · · · · · ·					_			1	
27 28										OK Anr	uler	-	-

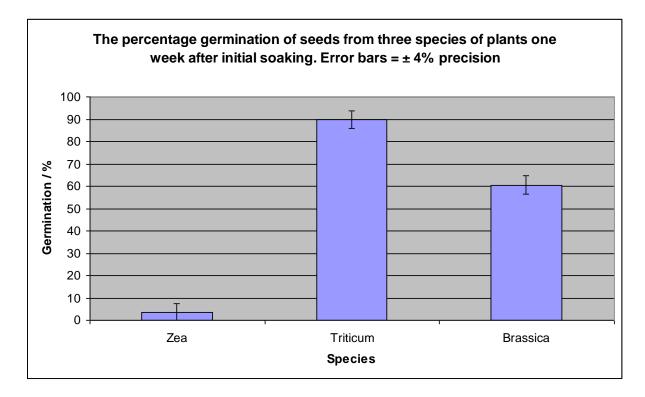
Select error bars above and below the data point.

Select **precision** and enter **4**. The data is calculated from samples of 25 seeds so the degree of precision is  $\pm 1$  seed. This means each seed represents 1/25 or 4% uncertainty.

A	В	Ċ	D	E	F	G	Н	L	J	К	L	
				Ĩ								_
	Maize	Wheat	Mustard		The pe	ercentage g	ermination	ofseeds	from three :	species	of plants one	9
Trial	Zea	Triticum	Brassica				weeka	after initia	l soaking.			
1	1	25	22									
2	1	24	18		100							
3	0	22	8		90			1				f
4	1	22	7	Fo	rmat de série	de données				<u> </u>		f
5	1	19	15		Étiquettes o		Ordre de		Options			f
6	1	21	18		Motifs	Sé	lection de l'axe		Barre d'erreur Y	-		h
7	1	24	18		Afficher		1				_	
Mean	1	22	15				-				_	1
Mean %	3	90	61		Les deux Sup	érieure Inférieu	ure Aucune					
					Marge d'erreur						_	
					Précision :	3	\$				_	
						5	\$ %					
		Sele	et	(	) Écart type :	1	\$				Brassica	
				- (	C Erreur type							
		prec	ision		O Personnalisée	: +		<b>1</b>				_
						-						ł
												t
												Ì
		-	· · · · · · · · · · · · · · · · · · ·					-		_		ŧ
									OK Ann	uler		ł

Press **Enter** or click **OK** and you will see the error bars appear on the graph.

Note: You will notice that you also have the possibility to enter percentage error, it should not be used this time as it will calculate 4% of each data point so the error bars will be proportional to the data (try it and you will see).



## **Error Bars Showing Standard Deviations**

If you want to show standard deviations as error bars then you need to use a slightly different approach.

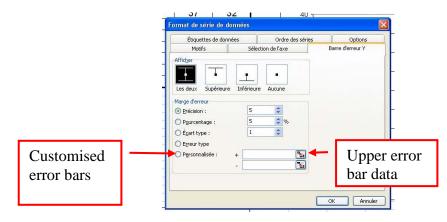
These data come from an investigation on the growth of moulds sampled from different parts of two cheeses (Camembert and Rocquefort) and grown on malt agar in a Petri dish. The growth of the mould was measured after one week.

The data is entered on a spread sheet. The spread sheet is used to calculate the mean and the standard deviations. A bar chart is drawn of the results.

	A	В	C	D	E	F	G	н	1	J	K	Ĺ	M	N	0
		Mould g	rowth / m	nm				_							
2	Cheese		Camem	bert		Rocque	fort		The	growth of t	ha maulda	Panaailliu	moomobo	tii fualla	
3	Sample	Crust	Inside	Middle	Crust	Inside	Middle			s) and Pen					
		25	29	23	35	30	40		10 01		erent levels			ampiou	
		27	25	20	33	30	32								
3		27	18	20	35	37	32		40 T						
2		32	24	29	32	31	35		012054						
		26	21	25	36	40	39		35			_	_	_	
		28	20	22	30	28	31		30						
)		33	25	26	35	40	40		30 +						
	Mean	28	23	24	34	34	36		<b>g</b> 25					-	
2	St Dev	3	4	3	2	5	4		<b>E</b> <sup>25</sup>	I I					
3									41 20 15					-	
4									0 15				•		
3									0 10						
7							Click	left c	n one	of the		•	-	-	
3															
0							colun	nns. 'I	Then d	ouble					
1							click	laft							
3							UNCK	ICIL				iddle C	rust in:	side	Middle
4									8	01000 11	INI MI		aust III:	alue	maule
5												Sample			
2															

Click left on one of the bars, then double click to get the data format menu.

Select error bars both above and below the data point and then select **Custom** (Fr: *Personnalisée*)



Now the data that is to be used for the error bars has to be selected. Click left on the upper bar (+) the menu will disappear and you will be left with the box in which you have to select the cells containing the data for the error bars (in this case the standard deviation).

	mple Crust Inside M						
Cheese		Camem	bert		Rocque	fort	The growth of the moulds Penecillium camebert
Sample	Crust	Inside	Middle	Crust	Inside	Middle	bars) and Penecillium roquefortii (blue bars) sa
	25	29	23	35	30	40	different levels from ripe cheeses.
	27	25	20	33	30	32	
	27	18	20	35	37	32	40
	32	24	29	32	31	35	Format de série de données - Personnalisé +
	26	21	25	36	40	39	=Feuil1!\$B\$12:\$G\$12
	28	20	22	30	28	31	30
	33	25	26	35	40	40	30
Mean	28	23	24	34	34	36	<b>E</b> 25
St Dev	3	4	3	2	5	4	
		******					
		down tl ull it ac				]	

Left click on the first cell and hold the button down whilst you run along the line for standard deviations. You will see the cell coordinates appear in the box.

Let go of the mouse button and the menu will reappear with the upper error bar box complete.

	A	В	С	D	E	F	G	Н	1		J	K	L	M
1		Mould g	rowth / m	nm				8						
2	Cheese		Camem	pert		Rocquet	fort		т	a aro	with of t	he moulde l	Popocilli	um camebert
3	Sample	Crust	Inside	Middle	Crust	Inside	Middle							blue bars) sa
4		25	29	23	35	30	40			/~		erent levels		
5		27	25	20	33	30	32						•	
6		27	18	20	35	37	32		40 -					
7		32	24	29	32	31	35	Format	de série de c	lonnées				
8		26	21	25	36	40	39	É	tiquettes de don	nées	1	Ordre des séries	Ĩ	Options
9		28	20	22	30	28	31	The second secon	Motifs		Sélection de	l'axe	Barre d'	CONTRACTOR OF A
10		33	25	26	35	40	40	Affiche	r					
11	Mean	28	23	24	34	34	36							
12	St Dev	3	4	3	2	5	4	Les de	- Supérieur	e Infér	ieure Auc			
13										a Tillel	ieure Auc	Julie		
14 15	5							- Marge O Pré	d'erreur	[	5	\$		
16									ircentage :			\$ %		
17 18	-							- 1985 E	rt type :			\$		
19								-	eur type	1				
20									sonnalisée :	+ =	Feuil11\$B\$12	2:\$G\$12 💽		
21 22								-	552935755550					
23										-				
24														3
25 26								-				ſ	ОК	Annuler
27												l	UK	Annuler

Repeat the procedure with the box for the lower error bar (-). Use the same cells for the standard deviations as before.

	A	В	С	D	E	F	G	Н	1	J	K	L.	M
1		Mould g	rowth / n	nm									
2	Cheese		Camem	bert		Rocque	fort		ть	o growth	of the moulds <i>I</i>	Papacilliu	maamabar
з	Sample	Crust	Inside	Middle	Crust	Inside	Middle				Penecillium roqu		
4		25	29	23	35	30	40			and a large	different levels t	10.00	
5		27	25	20	33	30	32						
6		27	18	20	35	37	32		40 -				
7		32	24	29	32	31	35	Format de	série de de	onnées			
8		26	21	25	36	40	39	Étia	uettes de donn	éer	Ordre des séries	1	Options
9		28	20	22	30	28	31		otifs	the second s	tion de l'axe	Barre d'ei	and the second se
10		33	25	26	35	40	40	Afficher					1
11	Mean	28	23	24	34	34	36						
12	St Dev	3	4	3	2	5	4						
13			*****					Les deux	: Supérieure	Inférieure	Aucune		
14 15								Marge d'e		1-			
16					1			O Précisi		5	\$		_
17								Pource	entage :	5	<b>*</b> %		
18								◯ É <u>c</u> art	type :	1	\$		
19	-							Erreur	type				
20 21			· · · · · · · · · · · · · · · · · · ·					Persor	nnalisée :	+ =Feuil1	!\$B\$12:\$G\$12 强		
22										12	!\$B\$12:\$G\$	Low	ver 🛛
23	1							-					. 1
24												erro	r bar
25												data	
26											(	uata	
27												-	

Press **Enter** or click **OK** and the error bars will appear on the graph.

	A	В	C	D	E	F	G	н	1		J	K	L	M		N	(
1		Mould g	rowth / m	nm													
2	Cheese		Camem	bert		Rocque	fort	-		-			_				
3	Sample	Crust	Inside	Middle	Crust	Inside	Middle		,			ne moulds					
4		25	29	23	35	30	40		(			<i>Penecilliu</i> ferent leve				)	
5		27	25	20	33	30	32			Sam		rs = 1 star			565.		
6		27	18	20	35	37	32				Liter be	iro i otai		nation			
7		32	24	29	32	31	35		45								
8		26	21	25	36	40	39										
9		28	20	22	30	28	31		40					1	Г	Ī	
10		33	25	26	35	40	40		35 -								_
11	Mean	28	23	24	34	34	36		30	Т			1				
12	St Dev	3	4	3	2	5	4	• •	30			7842					
13									25						-		
14 15	-		-			-	-	Growth	20 -						-	_	_
16								č	5								
17									15								
18 19									10 -				E				_
20									5						-		
21									0								
22 23	-								o 🗕		, .				<u> </u>		4
23										Crust	Inside	Middle	Crus	t Ins	side	Middle	9
25												S	ample				
26 27													se on daes sites				
27																	

## Entering error bars on a scatter plot

The same method can be used to put error bars on data with trend lines. This time however the menu gives you the option of x as well as y error bars.

In this example students were investigating the water potential of pieces of sweet potato tissue cut to a precise length (5 cm) and soaked in a range of sucrose solutions for 24 hours.

First the data is entered into the spread sheet. The spread sheet is then used to calculate the change in length of the tissue samples by setting up a second table.

	A	В	C	D	E	F
1	Sweet potato		Initial le	ength = 5.	0cm	
2		1				
3	Sucrose / mol dm <sup>-3</sup>		Final	lengths /	cm	
4	0	5.1	5.1	5.2	5.6	5.1
5	0.2	5.2	4.8	5.0	5.1	5.1
6	0.4	5.4	4.9	5.0	5.3	5.1
7	0.6	5.1	4.8	5.0	4.9	4.8
8	0.8	5.0	5.1	5.1	4.9	5.1
9	1.0	5.1	4.8	4.8	4.8	5.1
10						
11						
12	Sucrose / mol dm <sup>-3</sup>		Change	in length	/ cm	
13	0	=B4-5 🔸				
14	0.2	Ĭ				
15	0.4				To ca	lcuate the
16	0.6				ahana	in longt
17	0.8					ge in lengtl
18	1.0				enter	=B4-5
19						1

By entering the equation =B4-5 the cell will calculate the difference between the initial length (5cm) and the final length. Press **Enter** for the result. The same calculation can be repeated down the column by holding down the left mouse button and pulling down on the bottom right hand corner of the cell.

	A	В	С	D	E	F
1	Sweet potato		Initia	l length = 5	5.0cm	
2						
3	Sucrose / mol dm <sup>-3</sup>		Fin	al lengths	/ cm	
4	0	5.1	5.1	5.2	5.6	5.1
5	0.2	5.2	4.8	3 5.0	5.1	5.1
6	0.4	5.4	4.9	5.0	5.3	5.1
7	0.6	5.1	4.8	3 5.0	4.9	4.8
8	0.8	5.0	5.1	I 5.1	4.9	5.1
9	1.0	5.1	4.8	3 4.8	4.8	5.1
10						
11						
12	Sucrose / mol dm <sup>-3</sup>		Chan	ige in lengt	h/cm	
13		0.1				
14	0.2	0.2				
15	0.4	0.4				
16	0.6	0.1				
17	0.8	0				
18	1.0	0.1	•			
19			<b></b>			
20						

Then repeated for all the data by pulling this highlighted area across the table in the same way

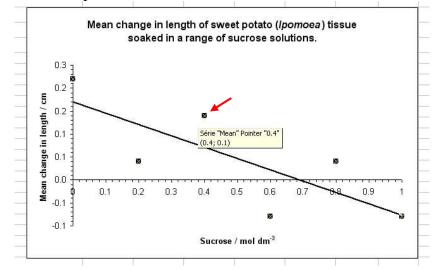
	A	В	C	D	E	F
1	Sweet potato		Initial I	ength = 5	.0cm	
2						
3	Sucrose / mol dm <sup>-3</sup>		Final	lengths /	cm	
4	0	5.1	5.1	5.2	5.6	5.1
5	0.2	5.2	4.8	5.0	5.1	5.1
6	0.4	5.4	4.9	5.0	5.3	5.1
7	0.6	5.1	4.8	5.0	4.9	4.8
8	0.8	5.0	5.1	5.1	4.9	5.1
9	1.0	5.1	4.8	4.8	4.8	5.1
10						
11						
12	Sucrose / mol dm <sup>-3</sup>		Chang	e in lengtl	h/cm	
13	0	0.1	0.1	0.2	0.6	0.1
14	0.2	0.2	-0.2	0	0.1	0.1
15	0.4	0.4	-0.1	0	0.3	0.1
16	0.6	0.1	-0.2	0	-0.1	-0.2
17	0.8	0	0.1	0.1	-0.1	0.1
18	1.0	0.1	-0.2	-0.2	-0.2	0.1
19						

Finally the mean change in length and the standard deviation of the samples can be calculated too. Note it is not necessary to calculate the percentage change in length as the tissues were all the same lengths to start with.

A scatter plot graph is drawn of the mean change in length against sucrose concentration and a trend line is added.

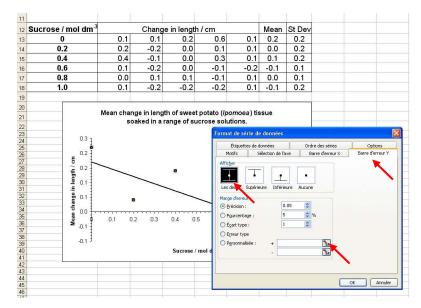
2 5	ucrose / mol	l dm <sup>-3</sup>		Change	in length /	/ cm		Mean	St Dev
13	0		0.1	0.1	0.2	0.6	0.1	0.2	0.2
4	0.2		0.2	-0.2	0.0	0.1	0.1	0.0	0.2
15	0.4		0.4	-0.1	0.0	0.3	0.1	0.1	0.2
16	0.6		0.1	-0.2	0.0	-0.1	-0.2	-0.1	0.1
7	0.8		0.0	0.1	0.1	-0.1	0.1	0.0	0.1
8	1.0		0.1	-0.2	-0.2	-0.2	0.1	-0.1	0.2
9									
20			a 20		10	77 (A. 1646)	C 231.442	·;	
21		N		nge in lengtl				sue	
22			SC	baked in a ra	ange of suc	rose soluti	ions.		
3									
		0.3 <sub>7</sub>							
24		×							
24 25		<sup>0.3</sup> ] × 0.2 ]							
24 25 26		×							
24 25 26 27		×							
24 25 26 27 28		0.2			×				
23 24 25 26 27 28 29 30		0.2			×				
24 25 26 27 28 29		0.2			×				
24 25 26 27 28 29 30 31		0.2	/		×				
24 25 26 27 28 29 30		0.2	_	×	×		×	s	
24 25 26 27 28 29 30 30 31 32 33		0.2 0.2 0.1 0.1	<u> </u>	×	×		×	<	
24 25 26 27 28 29 30 31 32 33 33 34		0.2				<u></u>	*****		
24 25 26 27 28 29 30 31 32 33 33 34 35	lean change in length / cm	0.2 0.2 0.1 0.1 0.1		× .2 0.3	× 0.4 0.5	0.6	× 0.7 6-	د ۹	<del></del> 1
24 25 26 27 28 29 30 30 31 32 33 33 34 35 36	lean change in length / cm	0.2 0.2 0.1 0.1				0.6	*****		1
24   25   26   27   28   29   30   31   32   33   34   35   36   37	Mean change in length / cm	0.2 0.2 0.1 0.1 0.0 -0.1				0.6 ×	*****		<b>∏</b> 1 ∕
14       15       16       17       18       19       10       11       12       13       14       15       16       17       18       17       18	Mean change in length / cm	0.2 0.2 0.1 0.1 0.1					*****		
14       15       16       17       18       19       10       11       12       13       14       15       16       17       18       19	Mean change in length / cm	0.2 0.2 0.1 0.1 0.0 -0.1				×	*****		
24 25 26 27 28 29 30 31 32	Mean change in length / cm	0.2 0.2 0.1 0.1 0.0 -0.1			0.4 0.5	×	*****		<b>∏</b> 1 ∕×

Click left on one of the data points to activate them.

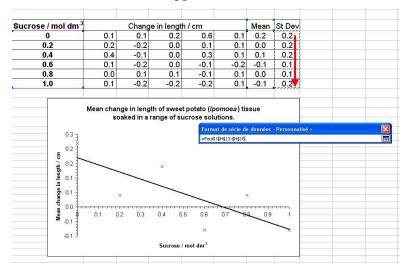


Double click on the data point to open the dialogue box. Select the Y error bar menu.

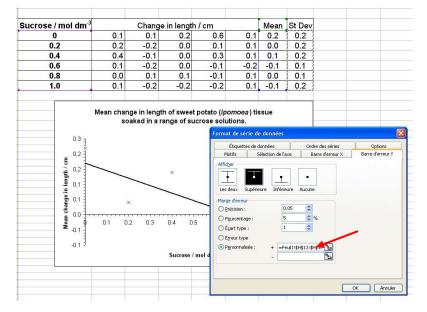
Note this time for the scatter plot you will see an X error bar menu too. So you can put in horizontal error bars too.



Select error bars both above and below the data point and then select Custom (Fr: *Personnalisée*) Select the data that is to be used for the upper error bar. Click left on the upper bar (+) the menu will disappear and you will be left with the box in which you have to select the cells containing the data for the error bars (in this case the standard deviation). Left click on the first cell and hold the button down whilst you run along the line for standard deviations. You will see the cell coordinates appear in the box.



Let go of the mouse button and the menu will reappear with the upper error bar box complete.



Repeat the procedure with the box for the lower error bar (-). Use the same cells for the standard deviations as before.

	A	В	C	D	E	F	G	Н	1	J	K	L	M
1		Mould g	rowth / n	nm									
2	Cheese		Camem	pert		Rocque	fort		Th	o arouth	of the moulds F	Damaailliu	maamaham
3	Sample	Crust	Inside	Middle	Crust	Inside	Middle				Penecillium roqu		
4		25	29	23	35	30	40				different levels f		
5		27	25	20	33	30	32					~~~~ <b>.</b> ~~~	
6		27	18	20	35	37	32		40 <del>-</del>				
7		32	24	29	32	31	35	Format de	e série de do	onnées			X
8		26	21	25	36	40	39	Élia	uettes de donn	dae 1	Ordre des séries		otions
9		28	20	22	30	28	31		otifs		on de l'axe	Barre d'er	
10		33	25	26	35	40	40	Afficher					1
11	Mean	28	23	24	34	34	36		T				
12	St Dev	3	4	3	2	5	4			L			
13								Les deux	and the second second	Inférieure	Aucune		
14 15								Marge d'e		_			
15	-							O Précis		5	\$		
17								O Pouro	202 C 202 C	5	\$ %		
18								○ Écart	type :	1	\$		
19 20								C Erreur	type			-	
20								Perso	nnailsée :	+ =Feuil1	\$B\$12:\$G\$12		
22										- =Feuilt	\$B\$12:\$G\$12 5		
23													
24													
25								_				-	
26											(	OK	Annuler
27													

