The $5.50 per acre Experiment

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Introduction

Articles such as the one presented in Figure 1 find their way into the popular magazines or newspapers summarizing the hard work by well-meaning and dedicated scientists. By the way the article in Figure 1 is indeed a fictitious story, but it is based on real field data. The article appears as a credible encounter of a scientifically designed and executed set of experiments. An independent scientist (in this case a professor) is involved, and experimentation has been carried out with apparently a generally accepted and widely understood design.

One of the aspects that can be frustrating to the scientific community when scientific data is disseminated is the lack of understanding and/or employment of statistical rules in much of the work reported in popular magazines.

New treatment helps canola beat the weather

by Fantasia Fictitious

Now we are all aware that crop yields took a beating in 2001either because of drought or too much moisture. Frankly, I never understood this business of reporting normals for weather or crop production. All these years I have spent in agricultural reporting have taught me that each year is a normal in its own. In any event, one of the worst hit crops in 2001 was canola. Preliminary estimates of the 2001 harvest show that canola production may be as much as 27 to 30% lower compared to 2000.

When Professor Factual and I discussed the new treatment to address canola resistance to really dry or really wet conditions, we were very excited about the prospect of improving canola yields under extreme conditions. The best way to assess its impact was to set field experiments.

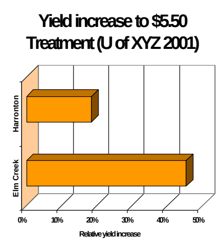
Differences in the high of the canola crop were already evident when we visited the sites in July.

We selected a site at Elm Creek, Manitoba at one of the most challenging soil types, Almassippi sandy loam, and a site at Herronton, Alberta in the middle of the drought belt to assess the impact of the $5.50 per acre treatment under the harshest possible conditions. To compound the problem, the intense heat of July had a damaging impact on this as well as all canola crops in the area. The experiments were set up in a completely randomized block design with six replicates. We applied all nutrients according to soil test recommendations and herbicide treatments as required for each area.

At a farmer tour on August 23, both farmers and retail staff were impressed with the intense visual response to the $5.50 per acre treatment. "I'd sure would like to know what's in this treatment", exclaimed Mr. Farmer, the farmer co-operator at the site. The impact of the treatment was not as pronounced at our Herronton site.

There were no surprises when the final results from the plots came in. A whopping 45.3 % yield increase at Elm Creek and a moderate but still significant increase of 18.4 % at Herronton. Although the increase at Herronton was much lower, it provided over a 2:1 return on the investment for the treatment.

"This treatment deserves further attention", remarked Professor Factual, although he admitted that the mode of operation of the treatment is not quite clear as yet. Farmer co-operator Farmer commented, "it's worth the money invested", when he saw the results this fall.



Yield increase to the $5.50 per acre treatment from replicated field experiments by U of F at Elm Creek, Manitoba and Herronton, Alberta.

Figure 1. A fictitious article based on real data.

Granted, the general public has no interest in statistics and inclusion of statistics can be confusing and cause the reader to abandon an otherwise interesting article. However, does this, constitute a reason for omitting or misusing statistics? Can omission of statistical analysis lead to answers and conclusions that may be inconsistent or greatly different from what is apparently so obvious by just looking at the experimental results?

The objectives of this paper was to utilize the results from a series of experiments on which the article in Figure 1 was based to illustrate uses and misuses of statistics for the benefit of all those involved in agronomic research.

Materials and Methods

Eight experiments with SW Rider and one with Q2 canola (*Brassica napus* L.), five with AC Barrie wheat (*Triticum aestivum* L.), five with Harrington barley (*Hordeum vulgarae* L.) and four with Logan peas (*Pisum sativum* L.) were set in the three Prairie Provinces in 2001. Two experimental designs were used, namely, the simplest form of experimental design, i.e., two treatments, namely, a control and the $5.50 per acre treatment and rate experiments with eight rates, namely, 0, $2.75, $5.50, $8.25, $11.00, $13.75, $16.50, and $19.25 per acre. All treatments/rates were replicated six times at each site. Both control and treatment received the fertilizer rates described in Tables 1, 2 3 and 4, except two one cent (1¢) coins were randomly thrown on each of the six replicates of the treated plot prior to seeding for the $5.50 acre treatment and 0, 1, 2, 3, 4, 5, 6 and 7 one cent (1¢) coins for the rate experiments.

Table 1. Location and brief plan of experimental sites of canola.

Test No.	Location	Province	Seeding date	Harvest date	Implement	Nutrient application rate, lb/ac			
						N	P	K	S
1733	Herronton 1[a]	AB	May-01	Aug-28	Hoedrill	72	22	13	7
1734	Herronton 2[a]	AB	May-01	Aug-28	Hoedrill	72	22	13	7
1739	Balzac 1[a]	AB	May-10	Sept-06	Airseeder	72	22	13	7
1740	Balzac 2[a]	AB	May-10	Sept-06	Airseeder	72	22	13	7
1743	Red Deer	AB	May-04	Sept-17	Hoedrill	79	27	0	0
1752	Wetaskiwin	AB	May-04	Sept-26	DD Drill	79	27	0	0
1772	Choiceland	SK	May-10	Sept-05	Hoedrill	77	22	67	22
1795	Elm Creek	MB	May-25	Aug-22	Hoedrill	78	27	46	15
1803	Miami	MB	May-12	Aug-21	Hoedrill	77	22	80	27

[a] Indicates sites where a rate experiment was carried out.

Table 2. Location and brief plan of experimental sites of wheat.

Test No.	Location	Province	Seeding date	Harvest date	Implement	Nutrient application rate, lb/ac			
						N	P	K	S
1742	Red Deer	AB	May-04	Sept-12	Hoedrill	79	27	0	0
1769	Smeaton	SK	May-09	Sept-06	Hoedrill	78	27	67	22
1775	Choiceland	SK	May-10	Sept-06	Hoedrill	78	27	67	22
1791	Elm Creek	MB	May-25	Aug-23	Hoedrill	78	27	46	15
1802	Miami	MB	May-12	Aug-21	Hoedrill	78	27	53	18

Table 3. Location and brief plan of experimental sites of barley.

Test No.	Location	Province	Seeding date	Harvest date	Implement	Nutrient application rate, lb/ac N	P	K	S
1733	Herronton 1[a]	AB	May-01	Aug-14	Hoedrill	67	22	21	0
1734	Herronton 2[a]	AB	May-01	Aug-14	Hoedrill	67	22	21	0
1739	Balzac 1[a]	AB	May-10	Aug-15	Airseeder	67	22	21	0
1740	Balzac 2[a]	AB	May-10	Aug-15	Airseeder	67	22	21	0
1803	Ellerslie	AB	May-03	Aug-29	DD drill	0	0	0	0

[a] Indicates sites where a rate experiment was carried out.

Table 4. Location and brief plan of experimental sites of peas.

Test No.	Location	Province	Seeding date	Harvest date	Implement	Nutrient application rate, lb/ac N	P	K	S
1733	Herronton 1[a]	AB	May-01	Aug-14	Hoedrill	5	22	0	0
1734	Herronton 2[a]	AB	May-01	Aug-14	Hoedrill	5	22	0	0
1739	Balzac 1[a]	AB	May-10	Aug-15	Airseeder	5	22	0	0
1740	Balzac 2[a]	AB	May-10	Aug-15	Airseeder	5	22	0	0

[a] Indicates sites where a rate experiment was carried out.

Each site received all the weed control treatments that were necessary and appropriate for the area as recommended. Each plot was 6 feet (1.35 m) wide and 25 feet (7.6 m) long and crops were seeded with the implement indicated in Tables 1 to 4 at 9 inch (22.5-cm) spacing. At maturity, the plots were harvested using a Wintersteiger Nurserymaster Elite experimental combine and the grain samples were dried at 60 ^{o}C by forced air and weighed to determine grain yield.

All data were subject to Basic Statistics or Analysis of Variance as appropriate using SYSTAT 8.0 (SPSS Inc. 1998).

Results

The article in Figure 1 raises a number of issues. Some of them have been intentionally created for discussion sake; others were merely raised through the nature of this article. For example, there is no mention of seven other experiments with canola or the experiments with wheat, peas and barley, although a number of experiments with these crops were also carried out. Observing responses to a treatment with one crop but not with others is not unusual. For example, certain crops (e.g., wheat) are more sensitive to a certain micronutrient (e.g., copper), while others (canola) are not. The choice of showing one crop is therefore probably justified, however, the choice of only the experiments where there was an "apparent" response is not.

Response of Canola to the $5.50 per acre Treatment

The response of canola to the $5.50 per acre or “two penny” per plot treatment was statistically significant at Elm Creek (Table 5), however, the 18.4 % yield increased referred to in the article of Figure 1 is the $5.50 per acre rate of the rate experiment at the Herronton 2 site (Table 8). This difference apparently is not significant. Furthermore, separating a single rate out of a rate experiment is not appropriate.

Table 5. The effect of the $5.50 per acre treatment on canola

Location	Control	$5.50/acre	ANOVA (P) [a]	LSD
Red Deer	47.2	47.9	NS	5.5
Wetaskiwin	50.3	50.6	NS	7.1
Choiceland	42.0	41.5	NS	1.3
Elm Creek	17.6	25.5	*	6.7
Miami	26.9	31.2	NS	20.2

[a] ,*,** Significant at P 0.10, 0.05, and 0.01 respectively; NS, not significant

Response of Wheat and Barley to the $5.50 per acre Treatment

There was no significant response of either wheat or barley to the $5.50 per acre treatment (Tables 6 and 7). Normally, field experiments are designed to assess the impact of “something” on the yield and characteristics of crops. In this case, we examined the impact of “nothing” on the yield of various crops. Statistical analysis of data is commonly expected to demonstrate the impact of something 18 to 19 out of 20 times (90 to 95 % probability). We, therefore, expected to obtain the same result for the impact of “nothing” on the yield of crops. Therefore, out of the eleven single rate experiments described above, only one produced a significant response. Should the remaining twelve rate experiments are included in this logic, then only one in twenty-three experiments produced a significant response.

Table 6. The effect of the $5.50 per acre treatment on wheat

Location	Control	$5.50/acre	ANOVA (P) [a]	LSD
Red Deer	50.4	49.2	NS	5.1
Smeaton	20.9	21.6	NS	2.1
Choiceland	29.4	28.5	NS	2.5
Elm Creek	29.8	30.2	NS	4.8
Miami	54.3	55.6	NS	5.3

[a] ,*,** Significant at P 0.10, 0.05, and 0.01 respectively; NS, not significant

Table 7. The effect of the $5.50 per acre treatment on barley

Location	Control	$5.50/acre	ANOVA (P) [a]	LSD
Ellerslie	52.1	51.4	NS	3.6

[a] ,*,** Significant at P 0.10, 0.0 5, and 0.01 respectively; NS, not significant

Response of Canola, Barley and Peas to rates of $$'s per acre

The results from the penny rate experiment are shown in Table 8.

Table 8. The effect of rates of $$'s per acre or pennies per plot on peas, barley and canola.

	$ Treatment per acre [c,d]								
Crop	$0.00	$2.75	$5.50	$8.25	$11.00	$13.75	$16.50	$19.25	crop means [a]
					Herronton 1				
Field Pea	14.3	14.0	15.8	14.5	15.8	16.1	14.7	15.1	15.0
Barley	37.2	39.2	39.5	36.4	36.6	38.8	38.4	39.0	38.1
Canola	11.0	11.0	10.9	9.9	11.2	9.7	10.3	11.0	10.6
$$ means [b]	20.8	21.4	22.0	20.3	21.2	21.6	21.1	21.7	26.6
					Herronton 2				
Field Pea	14.7	13.8	13.3	14.9	13.9	13.6	13.9	12.8	13.9
Barley	35.9	39.2	35.8	36.2	37.7	38.1	34.1	34.3	36.4
Canola	10.3	11.3	12.2	10.9	11.1	10.1	10.4	12.0	11.1
$$ means [b]	20.3	21.4	20.4	20.7	20.9	20.6	19.5	19.7	25.1
					Balzac 1				
Field Pea	46.7	49.4	51.2	49.0	48.5	44.5	46.9	47.6	48.0
Barley	91.9	93.5	92.4	90.0	90.8	95.8	94.3	93.9	92.8
Canola	33.8	36.4	35.5	34.4	34.7	34.2	34.5	35.6	34.9
$$ means [b]	57.5	59.8	59.7	57.8	58.0	58.2	58.5	59.0	70.4
					Balzac 2				
Field Pea	44.6	42.9	42.1	45.8	48.1	46.2	44.0	47.4	45.1
Barley	87.9	83.9	86.0	87.0	83.7	85.3	86.1	85.9	85.7
Canola	33.2	33.2	33.5	34.0	34.7	32.3	30.8	32.8	33.1
$$ means [b]	55.2	53.3	53.9	55.6	55.5	54.6	53.6	55.4	65.4

	Significance [e]			
Contrasts	Herronton 1	Herronton 2	Balzac 1	Balzac 2
Pea Yield vs Canola Yield (PC)		**	**	**
Barley Yield vs avg Pea & Canola Yield (B vs P & C)	**	**	**	**
Linear Response to Pennies (PL)	NS	NS	NS	NS
Quadratic Response to Pennies (PQ)	NS	NS	NS	NS
Cubic Response to Pennies (PCu)	NS	NS		NS
Residual Response to Pennies (PR)	NS	**	NS	**
PC x PL Interaction	NS	*	NS	*
PC x PQ Interaction	NS	NS	NS	NS
PC x PCu Interaction	NS	NS	NS	NS
PC x PR Interaction	NS	NS	NS	NS
(B vs P & C) x PL Interaction	NS	NS		NS
(B vs P & C) x PQ Interaction	NS	NS	NS	NS
(B vs P & C) x PCu Interaction	NS	NS	*	NS
(B vs P & C) x PR Interaction		NS	NS	NS

[a] LSD, 5%: between crop means, 4.8

[b] LSD, 5%: between penny rate means, 1.7

[c] LSD, 5%: between penny rate means at the same crop, 2.9

[d] LSD, 5%: between penny rate means at different crops, 5.5

[e] ,*,** Significant at P   0.10, 0.05 and 0.01 respectively; NS,   not significant

Discussion

Yield Increases of 18.4% - Why is it not Real?

Looking at the Table in Figure 1 the researcher has shown the two experiments with canola where he obtained the highest yields. Percent yield increases were obviously a convenient way to hide the fact that yields, especially at Herronton, were extremely low due to drought in this latter case. Nevertheless an 18.4% yield increase (1.9 bu/acre) in this case begs the question why it is not real (significant)?

A scientist will require all the individual data or the statistical analysis carried out on the results to ascertain whether the differences are real. A layman may argue that he/she don't care about the statistics. Just under two bushels is a good enough difference for them. Let's analyze this thinking.

Suppose one uses the ruler in Figure 2 to measure the length of two golden chains, so they can decide which one to buy. The chains look pretty much the same length, but the buyer wants to make sure. Ten measurements of the each chain are taken (Table 2).

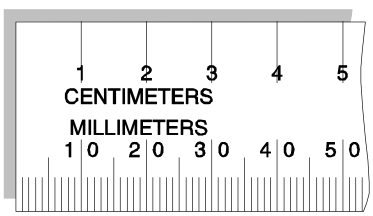


Figure 2. Portion of the metric ruler used to compare the length of two chains.

Table 9. Measurement (in mm) of the length of two chains using the ruler in Figure 1.

	1	2	3	4	5	6	7	8	9	10	Average in mm	Difference in µm
Chain 1	20	20	19.9	20	20.1	20	20	20	20	20	20	+20
Chain 2	20	20	20	19.9	20	19.9	20	20	20	20	19.98	

Can the buyer conclude that chain 1 was longer than chain 2 and, therefore, he/she should prefer to buy it? To a layman the answer is obvious: of course; it is 20 µm longer after all. However, to a scientist the answer is also obvious: the smallest unit we could measure is 1 mm or 1000 µm. Therefore, anything less than that cannot be seen and cannot be measured, although it can be mathematically calculated. The eye cannot see 20 µm differences anyway and we did use our eyes as an instrument to measure in addition to the ruler, therefore, the answer is no. The scientist has used the element of "uncertainty" in providing his/her answer. It is so easy to be out by one mm when we measure something so many times.

The above example begs the question: Is there an "eye" that allows us to see yield differences in experiments? The answer is, of course, yes and it is known as Variance. Although the intention of this paper is not to cover statistical analysis in detail, examples of determining the "experimental eye" is afforded in Table 3 in the form of the required replicates to detect a difference (Cochran and Cox 1992). The procedure to derive the number of replicates can be also found in Little and Hill (1978). Once an experiment has been carried out, the examples in Table 4 show the real "experimental eye".

Table 10. Examples of number of replicates required based on anticipated variance (two-tailed test with 4 treatments).

Parameter	Value	Explanation/Comments
		Example 1
Difference to be detected (% of mean):	5.0	This is the difference between the treatment mean and overall mean
Coefficient of Variation CV (% of mean):	5.0	This is the typical coefficient of variance associated with the test
Required probability:	0.95	This is a measure of the minimum certainty required to detect the difference inputted above (i.e., 5%)
Number of replicates required	27	
		Example 2
Difference to be detected (% of mean):	5.0	This is the difference between the treatment mean and overall mean
Coefficient of Variation CV (% of mean):	5.0	This is the typical coefficient of variance associated with the test
Required probability:	0.80	This is a measure of the minimum certainty required to detect the difference inputted above (i.e., 5%)
Number of replicates required	17	
		Example 3
Difference to be detected (% of mean):	5.0	This is the difference between the treatment mean and overall mean
Coefficient of Variation CV (% of mean):	10.0	This is the typical coefficient of variance associated with the test
Required probability:	0.95	This is a measure of the minimum certainty required to detect the difference inputted above (i.e., 5%)
Number of replicates required	105	

Table 11. Examples of differences that can be detected based on the experimental variance (two-tailed test at desired significance level of 5%).

Parameter	Example 1	Example 2	Example 3	Example 4	Example 5
Measured CV (% of mean)	10	15	15	15	15
Required probability	0.95	0.95	0.8	0.8	0.95
Number of treatments	5	5	5	5	2
Number of replicates	6	6	6	4	6
Difference that can be detected (% of mean)	±23%	±34%	±26%	±33%	±40%

Often scientists combine the results from a number of sites in support of the performance of a treatment. Analysis of the results of a series of experiments is quite a bit more complicated, so the reader is referred to Cochran and Cox (1992) for further information. An example of such analysis is demonstrated for the $5.50 per acre treatment with canola in Table 5. The analysis of variance is based on Cochran and Cox (1992) that includes all nine canola tests, in other words the $5.50 treatment from the rate experiments has been separated and included (Table 5).

Table 12. Analysis of variance for the series of nine experiments carried out with canola in 2001.

Rate	Test #									Averages
	1733	1734	1739	1740	1743	1752	1772	1795	1803	
0	11.0	10.3	33.8	33.2	47.2	50.3	42.0	17.6	26.9	30.3
$5.50	10.9	12.2	35.5	33.5	47.9	50.6	41.5	25.5	31.2	32.1
ANOVA (P) [a]	NS	NS	NS	NS	NS	NS	NS	*	NS	NS

[a] *,** Significant at P 0.05, and 0.01 respectively; NS, not significant

Analysis of Variance

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
PLACE	3343.031111	8	417.878889	115.118151	0.000000
TRT	15.125000	1	15.125000	4.166667	0.075528
Error	29.040000	8	3.630000		

The difference in the yield between the $5.50 per acre treatment and the control at one site (Elm Creek, Manitoba) was significant at 95% probability level (P<0.05). The difference in the remaining sites was not significant and overall the difference of 2.1 bu/acre of canola or 6.4% yield increase was below what our “experimental eye” could see.

The objective of many projects that employ agricultural field experimentation is to hopefully derive results that can be applied to practical farming. The results thus derived must be valid for at least several seasons and over a reasonably large farming area. It would be just as wrong to selectively present the data from the one experiment where the statistical significance was obtained and “bury” the rest as it would reporting all nine with the intention of proposing a new treatment without having the data statistically analyzed. A single experiment, however well conducted, supplies information for only one location and one season and in any event according to the statistical rules applied can represent the one case out of the twenty times that this experiment may be carried out (95 % probability) that results do not fit the overall conclusions.

Genetic and environmental variations are normally beyond the control of the experimenter and represent what is known as “experimental error”. These will occur almost always in agricultural research. As Little and Hill (1978) observe “No matter how much scientists know about nutrition and physiology, they cannot predict precisely what will be the gain in weight of a steer or the yield of a plot of potatoes under given sets of conditions”. The purpose of statistics according to Finney (1968) is to provide an objective basis for the analysis of problems in which the data depart from the laws of exact causality.

Conclusions

This set of data can be utilized in a multitude of ways to illustrate uses and misuses of statistical principles. One of these approaches was followed here to illustrate some simple principle of agricultural experimentation. We provide an Appendix with the raw data from the canola experiments for those who wish to carry out further analysis.

References

Cochran, W.G. and Cox, G.M. 1992. Experimental designs. Second edition, John Wiley & Sons, Inc., Toronto.

Little, T.M. and Hill, F.J. 1978. Agricultural experimentation. Design and analysis. John Wiley & Sons, Inc., Toronto.

SPSS Inc. 1998. SYSTAT 8.0. Chicago, IL.

APPENDIX

Raw data for each one treatment experiment; rate is 0 (1) and $5.50 per acre (2); yield in bu/acre

1742		1743		1752		1756		1769		1772		1775		1791		1975		1802		1803	
Rate	Yield	Rate	Yield	Rate	Yield	Rate	Yield	Rate	Yield	Rate	Yield	Rate	Yield	Rate	Yield	Rate	Yield	Rate	Yield	Rate	Yield
1	54.5	1	48.8	1	40.7	1	56.1	1	18.0	1	40.6	1	27.9	1	36.0	1	17.0	1	57.4	1	12.3
2	54.9	2	47.3	2	42.7	2	51.6	2	20.7	2	41.2	2	27.4	2	30.5	2	20.9	2	54.4	2	31.1
1	51.8	1	41.6	2	58.9	1	50.8	1	15.6	2	41.6	1	23.4	2	37.2	1	27.7	2	56.0	1	24.6
2	44.5	2	37.3	1	53.8	2	52.4	2	13.8	1	43.2	2	26.9	1	33.2	2	30.6	1	56.3	2	35.7
2	53.4	1	46.4	1	52.3	2	55.2	2	21.0	1	37.4	2	25.2	2	30.5	2	18.1	2	59.1	1	25.0
1	52.4	2	45.1	2	60.0	1	53.3	1	18.9	2	38.9	1	28.8	1	31.1	1	18.2	1	57.1	2	41.5
2	54.1	1	47.9	2	47.1	1	53.6	2	28.6	1	47.4	2	27.4	2	38.6	1	8.6	1	54.2	1	21.0
1	48.6	2	46.6	1	44.6	2	48.1	1	26.7	2	46.8	1	28.7	1	35.3	2	21.7	2	52.4	2	40.7
1	48.4	2	50.5	1	58.0	2	48.3	2	22.6	1	41.8	1	33.8	1	29.4	1	14.0	1	55.7	2	19.6
2	42.0	1	48.9	2	48.6	1	48.7	1	24.3	2	40.5	2	32.7	2	25.1	2	28.8	2	55.8	1	36.5
2	46.5	2	60.4	2	46.0	2	52.7	1	22.0	2	40.0	2	31.3	2	19.0	1	19.9	2	55.8	2	18.6
1	46.6	1	49.7	1	52.8	1	50.2	2	22.7	1	41.5	1	33.6	1	13.7	2	33.0	1	44.8	1	41.8

Raw data for each rate experiment; crops: 1=peas, 2=barley, 3=canola; rates: rate X $2.75; yields are in bu/acre

BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield
1	1	1	12.0	1	1	1	16.3	1	1	1	12.0	1	1	1	50.5
1	1	2	12.8	1	1	2	15.0	1	1	2	12.8	1	1	2	48.8
1	1	3	14.0	1	1	3	14.9	1	1	3	14.0	1	1	3	48.8
1	1	4	16.5	1	1	4	15.7	1	1	4	16.5	1	1	4	52.7
1	1	5	15.1	1	1	5	15.2	1	1	5	15.1	1	1	5	51.5
1	1	6	14.8	1	1	6	12.1	1	1	6	14.8	1	1	6	51.8
1	1	7	15.8	1	1	7	13.4	1	1	7	15.8	1	1	7	54.5
1	1	8	14.0	1	1	8	14.1	1	1	8	14.0	1	1	8	53.3
1	2	1	29.8	1	2	1	30.1	1	2	1	29.8	1	2	1	84.3
1	2	2	31.0	1	2	2	35.7	1	2	2	31.0	1	2	2	86.0
1	2	3	30.3	1	2	3	30.3	1	2	3	30.3	1	2	3	88.7
1	2	4	31.7	1	2	4	31.9	1	2	4	31.7	1	2	4	89.6
1	2	5	37.1	1	2	5	30.1	1	2	5	37.1	1	2	5	79.8
1	2	6	36.8	1	2	6	31.1	1	2	6	36.8	1	2	6	83.6
1	2	7	39.7	1	2	7	30.4	1	2	7	39.7	1	2	7	83.6
1	2	8	36.1	1	2	8	31.1	1	2	8	36.1	1	2	8	87.8
1	3	1	10.1	1	3	1	13.4	1	3	1	10.1	1	3	1	35.5
1	3	2	11.5	1	3	2	11.4	1	3	2	11.5	1	3	2	32.8
1	3	3	10.2	1	3	3	10.8	1	3	3	10.2	1	3	3	35.6
1	3	4	9.3	1	3	4	9.9	1	3	4	9.3	1	3	4	36.6
1	3	5	7.5	1	3	5	10.7	1	3	5	7.5	1	3	5	35.8
1	3	6	6.5	1	3	6	9.1	1	3	6	6.5	1	3	6	33.7
1	3	7	8.7	1	3	7	10.1	1	3	7	8.7	1	3	7	30.9
1	3	8	9.5	1	3	8	12.1	1	3	8	9.5	1	3	8	33.5
4	1	2	11.9	4	3	5	11.6	4	1	2	11.9	4	3	2	33.4
4	1	3	12.0	4	3	7	11.0	4	1	3	12.0	4	3	5	37.1
4	1	7	10.7	4	3	1	12.1	4	1	7	10.7	4	3	3	33.3
4	1	4	12.6	4	3	2	11.8	4	1	4	12.6	4	3	6	31.1
4	1	6	11.0	4	3	6	13.2	4	1	6	11.0	4	3	1	30.2
4	1	1	11.0	4	3	3	10.8	4	1	1	11.0	4	3	7	29.6
4	1	5	14.7	4	3	4	9.8	4	1	5	14.7	4	3	8	29.7

Raw data for each rate experiment; crops: 1=peas, 2=barley, 3=canola; rates: rate X $2.75; yields are in bu/acre

BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield
4	1	8	12.9	4	3	8	10.7	4	1	8	12.9	4	3	4	31.2
4	3	6	16.8	4	1	3	6.7	4	3	6	16.8	4	2	7	83.3
4	3	1	16.2	4	1	4	8.6	4	3	1	16.2	4	2	2	77.7
4	3	8	17.6	4	1	1	9.0	4	3	8	17.6	4	2	6	84.1
4	3	2	17.2	4	1	6	9.1	4	3	2	17.2	4	2	4	87.0
4	3	5	19.1	4	1	2	9.7	4	3	5	19.1	4	2	5	88.3
4	3	3	16.1	4	1	8	7.8	4	3	3	16.1	4	2	3	89.3
4	3	7	16.7	4	1	5	9.3	4	3	7	16.7	4	2	8	86.9
4	3	4	14.9	4	1	7	10.3	4	3	4	14.9	4	2	1	93.5
4	2	1	44.9	4	2	7	32.4	4	2	1	44.9	4	1	7	39.5
4	2	8	51.7	4	2	5	33.1	4	2	8	51.7	4	1	4	39.9
4	2	3	54.1	4	2	1	35.2	4	2	3	54.1	4	1	5	42.9
4	2	6	54.1	4	2	2	37.3	4	2	6	54.1	4	1	1	35.4
4	2	2	49.3	4	2	3	33.0	4	2	2	49.3	4	1	3	33.8
4	2	7	44.7	4	2	8	29.9	4	2	7	44.7	4	1	8	35.2
4	2	5	46.3	4	2	4	32.3	4	2	5	46.3	4	1	6	30.7
4	2	4	41.4	4	2	6	30.6	4	2	4	41.4	4	1	2	35.0
2	2	8	29.5	2	3	2	13.4	2	2	8	29.5	2	3	8	40.2
2	2	5	29.5	2	3	7	15.0	2	2	5	29.5	2	3	4	40.5
2	2	7	27.5	2	3	6	13.4	2	2	7	27.5	2	3	3	37.7
2	2	3	33.9	2	3	5	11.6	2	2	3	33.9	2	3	6	35.6
2	2	2	33.0	2	3	3	15.6	2	2	2	33.0	2	3	7	33.9
2	2	4	31.9	2	3	8	14.9	2	2	4	31.9	2	3	1	40.3
2	2	1	30.6	2	3	4	12.9	2	2	1	30.6	2	3	2	39.1
2	2	6	33.4	2	3	1	10.1	2	2	6	33.4	2	3	5	39.9
2	1	5	14.6	2	2	4	37.7	2	1	5	14.6	2	1	7	36.5
2	1	2	13.2	2	2	2	36.0	2	1	2	13.2	2	1	4	47.6
2	1	7	12.3	2	2	7	35.7	2	1	7	12.3	2	1	3	54.4
2	1	4	12.7	2	2	8	37.8	2	1	4	12.7	2	1	6	50.8
2	1	3	15.0	2	2	6	40.7	2	1	3	15.0	2	1	2	47.4
2	1	8	14.3	2	2	3	36.4	2	1	8	14.3	2	1	5	52.7
2	1	1	15.2	2	2	5	35.2	2	1	1	15.2	2	1	1	53.2
2	1	6	20.5	2	2	1	40.6	2	1	6	20.5	2	1	8	53.3
2	3	5	10.1	2	1	3	13.2	2	3	5	10.1	2	2	4	89.8
2	3	2	7.5	2	1	2	12.7	2	3	2	7.5	2	2	7	90.6
2	3	4	6.2	2	1	6	12.3	2	3	4	6.2	2	2	3	91.3
2	3	7	6.8	2	1	7	15.6	2	3	7	6.8	2	2	6	91.1
2	3	8	8.3	2	1	5	13.2	2	3	8	8.3	2	2	2	90.5
2	3	1	8.6	2	1	1	13.1	2	3	1	8.6	2	2	1	89.7
2	3	3	8.2	2	1	4	14.4	2	3	3	8.2	2	2	8	88.5
2	3	6	5.6	2	1	8	11.9	2	3	6	5.6	2	2	5	88.9
5	2	5	32.8	5	1	7	12.7	5	2	5	32.8	5	2	3	78.1
5	2	4	35.9	5	1	4	14.2	5	2	4	35.9	5	2	5	85.3
5	2	6	34.8	5	1	5	13.6	5	2	6	34.8	5	2	2	89.4
5	2	3	37.9	5	1	6	12.5	5	2	3	37.9	5	2	6	85.4
5	2	1	41.4	5	1	8	12.7	5	2	1	41.4	5	2	8	86.6
5	2	8	37.4	5	1	2	11.5	5	2	8	37.4	5	2	7	93.0
5	2	2	40.6	5	1	3	12.8	5	2	2	40.6	5	2	1	96.5
5	2	7	40.3	5	1	1	14.8	5	2	7	40.3	5	2	4	91.2
5	3	8	13.4	5	3	2	6.6	5	3	8	13.4	5	1	2	41.6
5	3	3	12.6	5	3	6	6.9	5	3	3	12.6	5	1	1	41.7

Raw data for each rate experiment; crops: 1=peas, 2=barley, 3=canola; rates: rate X $2.75; yields are in bu/acre

BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield
5	3	2	13.2	5	3	8	8.4	5	3	2	13.2	5	1	4	46.0
5	3	1	13.4	5	3	4	9.3	5	3	1	13.4	5	1	6	49.3
5	3	7	13.0	5	3	3	8.1	5	3	7	13.0	5	1	8	49.1
5	3	5	13.3	5	3	5	8.9	5	3	5	13.3	5	1	3	40.5
5	3	6	10.3	5	3	1	7.6	5	3	6	10.3	5	1	7	44.9
5	3	4	11.1	5	3	7	7.7	5	3	4	11.1	5	1	5	45.5
5	1	8	14.8	5	2	1	36.3	5	1	8	14.8	5	3	3	32.9
5	1	6	16.6	5	2	8	37.0	5	1	6	16.6	5	3	2	32.6
5	1	3	15.7	5	2	7	31.0	5	1	3	15.7	5	3	6	30.8
5	1	2	13.7	5	2	6	31.1	5	1	2	13.7	5	3	5	35.4
5	1	1	14.8	5	2	3	35.2	5	1	1	14.8	5	3	4	31.2
5	1	4	15.7	5	2	5	31.4	5	1	4	15.7	5	3	8	31.9
5	1	7	15.6	5	2	2	38.0	5	1	7	15.6	5	3	1	27.8
5	1	5	16.4	5	2	4	35.4	5	1	5	16.4	5	3	7	23.3
3	1	1	15.6	3	2	1	35.5	3	1	1	15.6	3	2	5	80.5
3	1	2	16.1	3	2	7	37.1	3	1	2	16.1	3	2	2	79.8
3	1	7	18.7	3	2	8	35.2	3	1	7	18.7	3	2	6	86.5
3	1	3	20.1	3	2	3	37.0	3	1	3	20.1	3	2	8	86.0
3	1	6	18.2	3	2	4	40.4	3	1	6	18.2	3	2	7	85.2
3	1	5	18.6	3	2	2	49.3	3	1	5	18.6	3	2	4	83.9
3	1	8	17.7	3	2	5	56.4	3	1	8	17.7	3	2	1	85.7
3	1	4	17.6	3	2	6	57.6	3	1	4	17.6	3	2	3	91.6
3	3	2	11.2	3	3	2	10.5	3	3	2	11.2	3	1	4	49.0
3	3	5	7.9	3	3	4	9.6	3	3	5	7.9	3	1	1	48.0
3	3	7	7.3	3	3	7	9.3	3	3	7	7.3	3	1	5	53.9
3	3	1	10.0	3	3	5	13.9	3	3	1	10.0	3	1	2	51.0
3	3	8	7.0	3	3	3	15.3	3	3	8	7.0	3	1	8	48.3
3	3	6	8.9	3	3	6	11.8	3	3	6	8.9	3	1	7	46.1
3	3	3	10.1	3	3	1	8.6	3	3	3	10.1	3	1	6	48.8
3	3	4	11.0	3	3	8	13.4	3	3	4	11.0	3	1	3	45.1
3	2	5	38.8	3	1	7	15.4	3	2	5	38.8	3	3	2	32.3
3	2	6	36.9	3	1	1	16.1	3	2	6	36.9	3	3	8	32.3
3	2	4	38.7	3	1	4	14.7	3	2	4	38.7	3	3	4	32.8
3	2	2	39.9	3	1	2	16.6	3	2	2	39.9	3	3	7	33.5
3	2	3	40.5	3	1	6	16.6	3	2	3	40.5	3	3	3	33.7
3	2	7	48.6	3	1	3	16.4	3	2	7	48.6	3	3	5	30.7
3	2	8	43.3	3	1	8	15.5	3	2	8	43.3	3	3	1	32.3
3	2	1	35.7	3	1	5	16.6	3	2	1	35.7	3	3	6	33.0
6	3	4	6.6	6	1	5	15.5	6	3	4	6.6	6	3	7	33.4
6	3	2	5.6	6	1	8	14.9	6	3	2	5.6	6	3	1	32.9
6	3	7	9.3	6	1	6	19.1	6	3	7	9.3	6	3	2	28.9
6	3	5	9.1	6	1	7	15.8	6	3	5	9.1	6	3	8	29.5
6	3	6	10.4	6	1	1	18.6	6	3	6	10.4	6	3	6	29.5
6	3	3	8.1	6	1	4	21.7	6	3	3	8.1	6	3	4	31.6
6	3	1	7.8	6	1	3	15.7	6	3	1	7.8	6	3	5	29.3
6	3	8	10.0	6	1	2	17.2	6	3	8	10.0	6	3	3	28.0
6	1	6	15.5	6	2	5	39.8	6	1	6	15.5	6	1	3	29.9
6	1	8	16.7	6	2	8	34.7	6	1	8	16.7	6	1	2	33.6
6	1	5	15.6	6	2	7	38.1	6	1	5	15.6	6	1	5	42.1
6	1	3	17.7	6	2	3	42.8	6	1	3	17.7	6	1	4	39.5
6	1	2	16.2	6	2	1	37.8	6	1	2	16.2	6	1	1	39.0

Raw data for each rate experiment; crops: 1=peas, 2=barley, 3=canola; rates: rate X $2.75; yields are in bu/acre

BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield	BLK	Crop	Rate	Yield
6	1	1	17.3	6	2	6	37.3	6	1	1	17.3	6	1	6	45.7
6	1	7	15.4	6	2	2	38.9	6	1	7	15.4	6	1	8	45.2
6	1	4	12.0	6	2	4	39.5	6	1	4	12.0	6	1	7	42.1
6	2	7	29.5	6	3	7	9.4	6	2	7	29.5	6	2	6	81.1
6	2	1	40.8	6	3	3	12.5	6	2	1	40.8	6	2	7	81.1
6	2	8	36.1	6	3	1	9.9	6	2	8	36.1	6	2	2	79.9
6	2	4	38.6	6	3	5	9.9	6	2	4	38.6	6	2	5	79.5
6	2	2	41.3	6	3	2	14.2	6	2	2	41.3	6	2	3	77.3
6	2	5	35.0	6	3	4	14.2	6	2	5	35.0	6	2	4	80.7
6	2	6	37.0	6	3	8	12.8	6	2	6	37.0	6	2	8	79.8
6	2	3	40.4	6	3	6	6.1	6	2	3	40.4	6	2	1	77.7