

AN ANALYSIS OF DATA, WITH AND WITHOUT CHECKS, FROM CORN PLOTS IN A RANDOMIZED COMPLETE BLOCK DESIGN

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A THESIS

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	Page
INTRODUCTION	1
REVIEW OF LITERATURE	2
METHODS AND MATERIALS	2
PRESENTATION AND DISCUSSION OF DATA	5
SUMMARY	8
BIBLIOGRAPHY	9
APPENDIX	10

TABLE OF CONTENTS

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INTRODUCTION

Uniform soil conditions are rarely, if ever, available for conducting field plot work. A soil may appear to be very uniform and yet two plots of the same crop variety grown side by side and treated alike may vary appreciably in yield. Many investigators have shown soil variability to be the chief source of error when comparing crop varieties and strains, fertilizer treatments, crop rotation practices, and other tests requiring the use of field plots.

Variability in plot yields due to soil heterogeneity has been reduced somewhat by increasing the number of replications, by decreasing plot size, by improving plot design, and by using statistical methods to analyze the data.

For a number of years a randomized complete block design without a check variety has been used in the Michigan overstate corn trials. In several instances this procedure gave satisfactory results, but there were tests where the differences in yield necessary for significance were so great that it was not possible to select the outstanding varieties with any degree of certainty.

In the 1942 Michigan overstate corn trials, a randomized complete block design with a check variety every other plot was used. The data obtained from three of these trials were analyzed without the use of checks and by three methods involving the use of checks. Comparisons were made to determine whether the inclusion of the checks had increased the precision of the trials.

The relative value of a particular plot design has been determined by comparing the error mean square of the new design with the error mean square of a randomized complete block involving the same number of varieties per replication, Cochran (1), Goulden (3), Weiss and Cox (5), Yates (6), (7), (8), and (9), Zuber (10).

Yates (6), in a design having a check every 5th or 6th plot, analyzed the differences between the actual yields and the calculated oheck yields in the same manner as in ordinary randomized block experiments. In a uniformity trial having 64 plots, he found a gain in precision of 11.9% for analysis of variance on the differences over analysis of variance on the actual yields alone. In another trial involving 49 plots there was a slight loss in precision for the differences over the actual yields alone. He also refers to expressing experimental yields as percentages of the corresponding fertility measures (calculated oheck yields) and analyzing these corrected values in the same manner as ordinary randomized block experiments.

METHODS AND MATERIALS

In 1942 a randomized complete block design with a check variety every other plot was used in Michigan overstate corn trials. Varieties competed with the same check throughout the field. Each plot was one row wide and ten hills long, and there were five replications of each variety. Plots were hand planted with five kernels per hill and were later thinned to three plants.

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The total area occupied by the plots was two-thirds the area occupied by the old system of three rows per plot and no checks. Slightly more labor was involved in harvesting since there were more individual plots to handle and more records to keep. In the Ingham County trial 40 varieties were tested, making 200 varietal plots and 205 check plots. Forty-two varieties were tested in the Monroe County trial, and 37 varieties in the St. Joseph County trial.

At harvest, all of the hills in each plot were husked, weighed, and then sampled for moisture by removing two rows of kernels from each of ten ears taken at random from every plot. The moisture samples were dried in steel driers until the moisture contents were uniform. Brown-Duval moisture tests were then made on samples selected at random to determine the average per cent of moisture remaining after drying. Field weights were converted to bushels per acre of shelled corn at 15.5% moisture.

Field weights were corrected for plots having missing hills. No corrections were made for an imperfect stand unless the entire hill was missing.

Four analyses of variance were made on the 1942 data from Ingham, Monroe, and St. Joseph Counties. They were: (1) analysis of variance on the actual yields, in which the checks were not included in the computations, (Table 5); (2) analysis of variance on the PK/C yields, in which the checks were used in arriving at the corrected yields but were not included in the sums of squares, (Table 6); (3) analysis of variance on the differences between actual yields and the calculated check yields, (Table 7); and (4) analysis of variance on the actual

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check yields alone, (Table 8).

The coefficient of yield as described by Spragg (4) was used in determining PK/C yields. In this method the two adjacent checks, one on either side of a variety, are averaged and this figure is taken as the theoretical or calculated check yield for the variety plot. This is illustrated in Table 1, using hypothetical figures. A coefficient of yield for each variety is obtained by dividing the actual yield of the variety plot by the calculated check yield for that plot. This gives the P/C values in the third column of Table 1. Corrected yields (PK/C yields) are determined by multiplying the coefficients of yield by the mean of all the checks in the field.

	P	C	P/C	PK/C
	Actual Yield	Calculated Check Yield	Coefficient	Corrected Yield
	Bu. Per Acre	Bu. Per Acre	of Yield	Bu. Per Acre
Check	60	60	1.000	63.3
Variety A	50	62		51.0
Check	64	64	1.000	63.3
Variety B	75	65	1.154	73.1
Check	66	66	1.000	63.3

Table 1. Illustration of method of determining PK/C yields.

K . Mean of all checks = 63.3 bu.

The differences between the actual yields and the calculated check yields were obtained in the manner shown in Table 2.

Table 2. Illustration of method of determining differences between actual yields and calculated check yields

	Actual Yield	Calculated Check Yield	Actual Yield Minus
	Bu. Per Acre	Bu. Per Acre	Calculated Check Yield
Check	60	60	
Variety 🛦	50	62	-12
Check	64	64	
Variety B	75	65	10
Check	66	66	

The fourth analysis of variance was made on only check yields. It was considered that the standard error of a variety was equal to the standard error of the check, Down, et al. (2).

Two procedures were used to determine whether the use of the checks had increased the precision of the trials. (1) The differences between variety means necessary for significance for the three methods using checks were compared with that for the actual yields. If these differences were lower than that for the actual yields, the precision was increased; if these were greater than that for the actual yields, the precision was decreased. (2) The precision was computed by comparing the error mean squares of the methods using checks with the error mean square of the actual yields. The error mean square of the actual yields was divided by the error mean square of the check method being compared. The quotients were obtained in percent and if they were greater than 100%, there was a gain in precision; if the quotient was less than 100%, there was a loss in precision for the method involving checks.

PRESENTATION AND DISCUSSION OF DATA

Tables 5, 6, 7, and 8 in the Appendix present the data for the 1942 Ingham County trial as a comparison of the methods used. The data from Monroe and St. Joseph Counties are on file with the Farm Crops Department.

Tables 3 and 4 present a summary of the pertinent results from the analyses of the data for the three counties.

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County	Ingham		Mon	roe	St. Joseph	
Method	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
	5%	1%	5%	1%	5%	1%
Actual Yields	9.98	13.18	8.42	11.11	7.15	9.44
PK/C Yields	7.09	9.37	9.03	11.92	8.36	11.04
Differences*	6.80	8.97	8.64	11.40	8.32	10.98
Check Yields	8.03	10.59	10.77	14.20	9.74	12.85

Table 3. Summary of the differences required for significance at 5% and 1% levels.

* Actual yield minus calculated check yield.

	Table	4.	Error	mean	squares	and	their	relative	precision
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County	Ĩ	ngham	M	onroe	St.	Joseph
Method	Error	Relative	Error	Relative	Error	Relative
	Mean	Precision	Mean	Precision	Mean	Precision
	Square	%	Square	%	Square	%
Actual Yields	63.70	100	45.23	100	32.75	100
PK/C Yields	31.33	203	52.26	87	44.78	73
Differences	29.44	216	47.82	95	44.36	74
Check Yields	41.27	154	74.61	60	61.03	54

The precision of the Ingham County trial was increased by the inclusion of a check every other plot. Analysis of variance on the three methods using checks gave lower differences necessary for significance than the analysis of actual yields, Table 3. On a percentage basis, Table 4, the increase in precision was 103% for PK/C yields, 116% for differences between actual yields and calculated check yields, and 54% for the checks, alone, over the analysis of actual yields. There was more variability within actual yields of varieties than within check yields. The fact that the checks were more uniform reduced the variability in the three methods using the checks, thereby increasing the precision of these methods over actual yields. The precision of the Monroe and St. Joseph County trials was not increased by the inclusion of the checks. The differences necessary for significance for the three methods using checks were greater than that for the actual yields, Table 3. Comparing the relative precisions, Table 4, there was a loss in precision for the three methods using checks over the actual yields in both counties. Variability within check yields was greater than variability within actual yields of varieties. This greater variability in checks caused the PK/C yields and the differences between actual yields and calculated check yields to become more variable than actual yields.

SUMMARY

The 1942 Michigan overstate corn trials were randomized complete blocks with a check variety every other plot. Each plot was one row wide and ten hills long. Analyses of variance were made on actual yields, PK/C yields, differences between actual yields and calculated check yields, and check yields for the Ingham, Monroe, and St. Joseph County trials. Comparisons were made to determine whether the inclusion of checks had increased the precision of the trials.

(1) The inclusion of the checks in the Ingham County trial increased the precision. This was due to the fact that the variability was greater in actual yields within varieties than within check yields.

(2) The inclusion of the checks in the Monroe and St. Joseph County trials did not increase the precision because the variability was greater in check yields than in actual yields within varieties.

(3) In a randomized complete block design where the variability is greater within variety yields than within check yields the precision of the trial can be increased by the inclusion of a check variety every other plot. However, where the variability is greater within check yields than within variety yields the precision of the trial cannot be increased by the inclusion of a check variety every other plot.

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APPENDIX

Tables 5, 6, 7, and 8

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Variety	Replication				Average	
No.	1	2	3	4	5	
1	74.75	75.17	83.84	80.95	74.75	77.89
2	71.49	74.62	79.53	82.21	83.10	78.19
3	79.89	80.76	87.71	84.23	72.51	81.02
4	72.22	53.31	73.94	73.51	69.21	68 .44
5	79.89	79.89	59.82	82.76	70.06	74.48
6	85.33	78.39	92.28	80.03	86.56	84.52
7	77.05	72.26	68 .34	86.19	62.25	73.22
8	80.71	91.77	63.91	74.57	85.63	79.32
9	78.20	79.81	90.29	87.07	84.65	84.00
10	88.02	78.92	82.38	70.68	75.45	79.09
11	79.66	85.44	65.42	83.66	67.20	76.28
12	75.30	56.70	63.50	73.94	81.19	70.13
13	83.98	70.61	74.37	85.65	84.81	79.88
14	76.55	83.03	51.03	68.85	90.32	73.95
15	83.87	79.06	83.47	82.67	95.11	84.84
16	80.78	80.78	95.90	94.61	83.38	87.09
17	72.52	77.02	70.88	62.27	67.60	70.06
18	54.32	70.03	70.45	74.27	51.78	64.17
19	61.20	58.19	78.01	66.37	70.25	66.80
20	78.90	75.52	78.90	78.47	68.35	76.03
21	81.95	82.39	71.82	74.02	88.12	79.66
22	80.64	79.36	81.48	78.94	78.51	79.79
23	66.85	68.59	69.47	73.84	70.34	69.82
24	74.20	56.79	63.83	75.02	83.73	70.71
25	86.42	85.22	82.82	63.22	78.82	79.30
26	84.64	63.48	83.39	84.22	91.69	81.48
27	79.43	78.53	64.99	76.72	76.27	75.19
28	83.63	63.31	81.29	94.18	70.73	78.63
29	65.66	47.95	76.90	72.14	79.06	68 .34
3 0	68.49	80.40	62.96	73.17	80.40	73.08
31	59.48	58.16	46.26	67.85	54.19	57.19
32	76.15	79.50	69.45	73.64	72.38	74.22
33	79.58	96.16	91.19	85.39	87.46	87 .96
34	73.09	86.56	90.64	75.94	85.33	82.31
35	82.11	90.71	79.10	94.15	84.26	86.07
36	85.99	80.15	91.44	83.27	73.93	82.96
37	73.35	68.69	72.57	76.46	61.32	70.48
38	81.12	69.24	80.30	86.45	63.50	76.12
39	85.48	71.83	67.42	83.07	89.49	79.46
4 0	85.47	86.76	90.20	86.76	72.59	84.36

Table 5. The actual yields in bushels per acre of the varieties in the 1942 corn trial in Ingham County, together with their analysis of variance.

Mean of all varieties: 76.66 bu.

Analysis of variance of actual yields.

Source of Variation	D. F.	Sum of Squares	Mean Square
Total	199	19,121.50	
Varieties	39	8,834.19	226.52
Replications	4	350.43	87.61
Error	156	9,936.88	63.70

Difference between means necessary for significance at 5% level = 9.98 bu.; at 1% level = 13.18 bu.

Variety	Replication					Averore
No		2		4	5	WARTERO
NO •	·					
1	73.51	78.01	76.33	81.18	69.66	75.74
2	69.54	71.41	73.36	74.28	75.84	72.89
3	77.71	83.33	81.10	82.15	74.18	79,69
4	71.81	60.25	69.08	82.20	75.12	71.69
5	79.00	76.45	69.36	77.53	76.98	75.86
6	82.10	84.31	82.75	79.14	79.22	81.50
7	74.94	68.05	70.11	79.69	71,96	72.95
8	83.28	90.49	76.34	81.42	84.68	83.24
9	81.39	80.72	84.37	78.47	83.94	81.78
10	85.14	79.14	76.17	72.93	73.19	77.31
11	76.85	81.32	80.29	75.97	70.36	76.96
12	75.09	72.60	64.22	67.83	81.18	72.18
13	85.17	90.75	73.14	83.77	81.16	82.80
14	78.07	76.57	59.95	73.38	83.95	74.38
15	87.05	78.18	88.96	83.13	90.29	85.52
16	83.35	78.36	88.67	95.14	83.38	85.78
17	71.32	73.11	68.01	71.28	69.76	70.70
18	53.13	63.44	67.06	67.10	56.72	61.49
19	61.90	56.60	68.57	57.62	67.58	62.45
20	75.50	67.55	81.41	80.97	76.52	76.39
21	77.59	88.08	87.04	82.35	79.72	82.96
22	79.52	77.40	73.24	75.94	73.74	75.97
23	66.66	64.60	64.57	71.81	81.30	69.79
24	75.04	62.98	64.91	79.72	75.74	71.68
25	86.66	82.26	78.83	70.55	80.40	79.74
26	79.71	75.33	73.47	81.25	87.98	79.55
27	70.52	81.28	84.13	74.41	68.23	75.71
28	74.99	81.66	77.69	89.40	71.12	78.97
29	60.72	54.33	74.80	78.77	71.99	68.12
3 0	69.47	78.85	67.92	81.91	79.94	75.62
31	68 . 97	57.04	51.95	63.73	53.74	59.09
32	85.51	75.49	85 .54	82.44	78.56	81.51
33	88 .26	93.02	82.81	81.06	82.15	· 85 .46
34	85.59	86.07	86.04	78.81	87.03	84.71
35	91.34	87.76	83.81	92.33	76.33	86.31
36	89.77	84.16	91.18	85.18	80.48	86.15
37	73.14	65.56	68.17	76.67	62.19	69.15
3 8	78.26	85.59	80 •53	76.18	65.71	77.25
39	82.92	81.18	86.04	81.47	82.10	82.74
40	85.46	83.48	86.07	87.99	81.00	84.80

Table 6. The PK/C yields in bushels per acre of the varieties in the 1942 corn trial in Ingham County, together with their analysis of variance.

Mean of all varieties: 76.91 bu.

Analysis of variance of PK/C yields.

Source of Variation	D. F.	Sum of Squares	Mean Square
	100	14 417 10	
TOTAL	199	14,417.10	
Varieties	39	9,373.15	240.34
Replications	4	156.10	39.03
Error	156	4,887.85	31.33

Difference between means necessary for significance at 5% level = 7.09 bu.; at 1% level = 9.37 bu.

in Ingh	am County,	together	with the	ir analys	is of va	riance.
Variety		Re	plication			Average
No.	, 1	2	3	4	5	
1	- 2.32	2.14	•59	5.37	- 6.58	16
2	- 6.43	- 4.58	- 2.64	- 1.67	•06	- 3.05
3	1.97	7.31	5.74	6.51	- 1.58	3.99
4	- 4.00	-13.75	- 7.18	5.89	62	- 3.93
5	3.24	•69	- 5.54	1.86	1.08	.27
6	6.56	7.92	7.76	3.39	3.74	5.87
7	87	- 8.22	- 5.54	4.22	- 3.32	- 2.75
8	7.26	14.91	.46	5.16	8.99	7.36
9	5.38	4.87	9.18	2.98	8.22	6.13
10	9.67	3.34	.41	- 2.77	- 2.68	1.59
11	1.10	5.81	3.67	.20	- 5.19	1.12
12	70	- 2.49	-11.44	- 8.67	5.39	- 3.58
13	9.25	11.64	- 2.70	8.16	5.61	6.39
14	2.24	.85	-13.48	- 2.26	8.78	77
15	10.85	2.42	12.36	7.30	15.27	9.64
16	7.33	2.65	13.93	19.24	7.59	10.15
17	- 4.55	- 2.82	- 8.11	- 3.94	- 5.85	- 5.05
18	-23.17	-13.64	- 9.17	- 9.61	-17.41	-14.60
19	-13.74	-19.73	- 8.21	-20.92	- 8.53	-14.23
20	30	- 9.21	4.45	5.02	.65	.12
21	1.90	11.50	9.28	5.89	4.34	6.58
22	3.78	1.65	- 2.83	.16	- 2.18	.12
23	- 9.15	-11.89	-12.07	- 4.09	4.77	- 6.49
[,] 24	74	-11,55	-10.69	3.70	05	- 3.89
25	10.84	7.08	3.19	- 4.69	4.52	4.19
26	4.16	39	- 2.63	5.66	12.70	3.90
27	- 5.94	5.30	6.44	- 1.42	- 8.46	82
28	89	4.55	1.99	14.34	- 4.64	3.07
29	-16.30	-18.69	- 1.02	2.73	- 4.18	- 7.49
30	- 6.23	3.12	- 7.30	5.47	4.18	15
31	- 5.88	-19.12	-21.23	-12.84	-22.24	-16.26
32	8.66	34	7.92	5.94	2.55	4.95
33	11.24	17.81	7.73	5.55	6.77	9.82
34	8.37	10.34	10.80	2.91	11.02	8.69
35	13.98	12.37	7.57	16.87	.59	10.28
36	13.39	7.97	15.43	9.18	4.31	10.06
37	- 2.66	-10.72	- 8.12	.88	-13.41	- 6.81
38	2.56	7.93	4.72	.44	- 9.74	1.18
39	7.35	4.77	8.03	5.79	6.88	6.56
40	9.67	7.99	10.78	12.03	4.67	9.03

Table 7. The differences between actual yields and calculated check yields in bushels per acre of the varieties in the 1942 corn trial in Ingham County, together with their analysis of variance.

Mean of all varieties: 1.03 bu.

Analysis of variance of the differences between actual yields and calculated check yields.

Source of Variation	D. F.	Sum of Squares	Mean Square
Total	199	14.065.73	
Varieties	39	9,333.33	239.34
Replications	4	140.33	35.08
Brror	156	4,592.07	29.44

Difference between means necessary for significance at 5% level = 6.80 bu.; at 1% level = 8.97 bu.

Check		Average				
No.	1	2	3	4	5	
1	75 .79	75.79	75.79	86.01	83.46	79.37
2	78.35	74.09	74.09	68.98	72.81	73.66
3	77.50	66.85	72.81	81.75	79.62	75.71
4	78.35	79.20	74.94	86.01	71.96	78.09
5	74.09	79.62	77.07	82.18	72.81	77.15
6	79.20	76.22	80.90	77.50	75.37	77.84
7	78.35	80.05	81.33	77.92	71.53	77.84
8	77.50	77.50	82.61	73.24	66.43	7 3.4 6
9	69.41	75.79	79.62	69.41	64.72	71.79
10	76.22	82.61	76.22	69.41	66.43	74.18
11	80.48	78.35	85.16	66.00	69.41	75.88
12	76.64	72.81	68.98	69.41	68.98	71.36
13	75.37	68.98	71.53	69.41	70.68	71.19
14	74.09	64.30	59.19	72.81	68.98	67.87
15	74.52	58.33	64.30	66.43	66.43	66.00
16	71.53	59.19	64.72	69.83	72.81	67.82
17	75.37	58.76	60.46	78.35	77.92	70.17
18	78.77	59.61	62.59	68.55	74.94	68.89
19	76.22	68.13	56.20	78.35	73.66	70.51
20	73.66	66.00	60.89	76.22	75.79	70.51
21	84.73	68.13	74.09	74.52	82.61	76.82
22	75.37	76.22	68.98	81.33	80.05	76.39
23	78.35	76.22	73.24	69.83	85.59	76.65
24	73.66	79.20	77.92	79.62	83.88	78.86
25	76.22	79.20	81.33	81.75	82.61	80.22
26	74.94	75.37	81.75	83.46	83.46	79.80
27	86.01	78.35	77.50	76.22	76.22	78.86
28	84.73	77.92	81.33	90.70	81.75	83.29
29	84.31	78.77	78.35	81.33	86.01	81.75
30	79.62	80.90	88.14	82.61	81.75	82.60
31	69.81	65.57	60.46	71.96	71.11	67.79
32	60.89	71.11	66.43	63.87	75.37	67.53
33	74.09	75.79	82.61	68.55	82.18	76.64
34	62.59	78.77	81.33	77.50	83.03	76.64
35	66.85	77.92	87.71	80.05	80.05	78.52
36	69.41	81.33	84.73	77.07	81.33	78.77
37	75.79	78.35	79.62	76.22	80.05	78.00
38	76.22	82.61	84.31	80.05	73.24	81.29
39	80.90	81.75	84.31	81.75	75.37	80.82
4 0	75.37	85.59	82.61	86.01	76.22	81.16
41	76.22	83.88	89.42	88.57	91.12	85.84

Table 8. The check yields in bushels per acre in the 1942 corn trial in Ingham County, together with their analysis of variance.

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Mean of all checks: 75.79 bu.

Analysis	of	variance	of	check	yields.

Source of Variation*	D. F.	Sum of Squares	Mean Square
Total Replications Error	204 4 200	9,906.68 1,652.66 8,254.02	413.17 41.27

* Since the data for checks are from the same variety, there is no variation due to varieties.

Difference between means necessary for significance at 5% level = 8.03 bu.; at 1% level = 10.59 bu.

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