END-BORDER EFFECTS IN FALL-SOWN IRRIGATED BARLEY YIELD TRIALS

by

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INTRODUCTION

Competition and border effects are recognized as sources of error in agronomic experiments. It has been observed (11, 14, 20) that a vigorous and fast growing variety grown next to a poor and slow growing variety yields higher and also depresses the yield of the slow growing plants. Plants in border rows adjacent to alleys yield higher than those in the inner rows. If varieties respond differently in the border rows, it is necessary to remove these outside rows to achieve precise and accurate results. This aspect of field plot technique has been studied by many workers (1, 2, 3). In small grains research it is a standard procedure to exclude border rows when estimating yields (9).

Border effects on plants are influenced by plot shape and size, the experimental material, and the environmental conditions. It is believed that border effects are more intense in moisture deficient areas. Conclusions drawn from research in one region, therefore, may not be applicable to a different area.

Most research regarding border effects has been conducted in non-irrigated areas. An experiment was initiated to study the end-border effects in barley in two irrigated areas in Arizona. The objectives were to determine if there was any appreciable change in yield due to end-border effects, and if so, how far these effects extended into the plots. The problem was approached from the view point of experimental variability, and the end-border effects were measured by determining their influence on the experimental error.

REVIEW OF LITERATURE

Many workers have studied border effects and recommend exclusion of border rows in estimating the true yield of varieties being compared. The American Society of Agronomy Committee on the standardization of field experiments stated that in small grains, rows adjoining an alley space may show as much as 100% increase over the inner rows. The committee recommended the removal of one or two border rows in small grain experiments to achieve accurate results (1). Love (13) in discussing border effects stated: "If it seems necessary to remove borders they should be removed all around the plot and not as some have done, on the sides of the plots only." Border effects have been studied in a number of different crops. Green (7), Drapala and Johnson (5), and Hartwig _et al._ (8) reported significant border effects in cotton, millet and sudangrass, and soybeans, respectively. In grain sorghum, Ross (20) found no difference in behaviour or yield between guarded and unguarded plots.

"End-border" effects have been reported in safflower and soybean nursery plots. Probst (17) found that such effects were present one foot within the rows adjacent to a three foot alley. Draper (6) conducted an experiment to determine optimum plot size and end-border effects for safflower yield tests. He concluded that 12 inches should be removed from each end of each plot to minimize the end-border effects. In his experiment, when the border rows adjacent to the alley and 12-

inch end-borders were removed, the coefficient of variability decreased from 28.3 to 13.8%.

Border effects in small grains, in their various aspects have been studied by a number of workers. Arny and Hayes (3) reported significant side border effects in wheat, oats, and barley yield trials. Their data indicated that such border effects were operative at least 12 inches within plots separated by 18-inch alleys. They found that for the three crops there was an average yield increase of 102.1 and 41.0% for the outside and the inside border rows, respectively, over the 13 middle rows. Together the two border rows showed a yield increase of 143.1%. The standard deviation decreased with the removal of border rows. It was concluded that removal of two border rows was necessary to obtain accurate results. Arny (2), McCelland (16), and Hulbert (10) obtained significant border effects that extended to at least 12 inches within plots.

Inability of varieties to equally utilize the alley space necessitates the removal of borders. Arny and Hayes (3) found that all small grain varieties did not respond the same to the bordering alley. Brown and Weible (4) obtained a significant variety x border interaction, indicating that the border effects were not the same for every selection.

It has been observed that intensity of border effects is influenced by the alley width and the condition of the alley. McCelland (15) working with winter oats, reported a significant average yield increase of 52.5% in rows bordering a 16-inch alley as compared to a lesser increase of 24.9% in rows next to an 8-inch alley. The border effects due to a 16-inch alley extended to the second row. The coefficient of variability increased from 16.7 to 19.3% when wider alleys were used in Appler, winter oats. Army (2) found the yield of the outer and inner border rows surrounded by a cropped alley to be lower than the yield obtained from two rows adjacent to a bare alley. He concluded that the intensity of the border effects was reduced when the alley was cropped.

Critical moisture conditions, and seasonal changes have been suggested as factors influencing border effects. Klages (12) observed that border effects in small grains were intensified under drought conditions. Hulbert _et al_. (10) studied border effects in three spring wheat varieties for a two year period. In 1926, they found that for three varieties there was an average yield increase of 204.6 and 120.0% for the outside and inside border rows, respectively. In 1927, the yield increase for the same varieties at the same location was 220.7 and 117.0% for the outside and inside border rows, respectively. They concluded that seasonal changes and growth habits of a variety influence border effects.

Seeding rate and spacing influence the intensity of border effects. Hulbert _et al_. (10) found a positive correlation between rate of seeding and intensity of border effects in winter and spring wheat. Shear and Miller (21), working with jumbo runner peanuts, reported that border effects were greater for a close spacing of 6 x 6 inches than for wider spacings.

One of the ways by which border effects adversely affect the accuracy of experimental results is, that such effects increase the error by introducing greater variability. Experiments conducted by Draper (6), McCelland (15), and Arny and Hayes (3) showed an increase in variability when border rows were included in yield estimates. Panse and Sukhatme (19) in discussing plot shape and size noted that border effects inflate the error by increasing the heterogeneity between plots.

It is of interest to study the response of different yield components to the border effects. Brown and Weible (4) suggested that the increased yield in the border rows of wheat and oats was probably due to excessive tillering.

The author was unable to find any report in the literature on the end-border effects in small grains grown in the irrigated areas of the Southwest.

MATERIALS AND METHODS

Experiments were conducted at two locations in Arizona (Mesa and Yuma) in 1959 and 1960 to study the end-border effects in fall-sown irrigated barley. The experiments consisted of barley variety yield tests with 12 varieties and selections: (1) Arivat, (2) Harlan, (3) California Mariout, (4) Vaughn, (5) Atlas 57, (6) Atlas 54, (7) California 1096, (8) Rojo, (9) Winter Tennessee, (10) Glacier, (11) Naked Barley Bulk, and (12) White Barley from Composite Cross II. The experimental design was a randomized complete block with four replications. Plots were laid out in an irrigation border that was 30 x 300 feet in size and each plot consisted of 4 rows 12 feet long with a one-foot spacing between rows. A five-foot bare alley or border was adjacent to each end of each plot.

The soil was a Cajon Sandy Clay Loam at Yuma and a Laveen Loam at Mesa. The seed was planted in December at the rate of 100 pounds per acre and the grain was harvested in June of the following year. At Yuma, the seed was planted in dry soil and later irrigated and at Mesa it was planted in moist soil. After seedling emergence, the experiment was irrigated as needed throughout the growing season. One hundred pounds per acre of elemental nitrogen fertilizer were applied at planting time in the form of ammonium nitrate.

At maturity, the two middle rows in each plot were hand-harvested with a sickle in 12 one-foot sections. The one-foot sections are referred to as sections 1 through 12 in this study. Sections 1 and 12 were adjacent to the bare-alley or border and sections 6 and 7 were farthest from the alley. At harvest, the following data were obtained for each section in each plot: (1) total yield of grain, (2) number of tillers that produced heads, (3) average number of seeds per head, and (4) weight of 400 seeds.[1]

Three analyses of variance, with different sources of variation, were calculated to evaluate the data. They are referred to as (1) Analysis without sub-sampling, (2) Analysis with sub-sampling, and (3) Replication analysis. The object of these analyses was to determine the extent of end-border effects within a row, and their consequent effects on the experimental error in the analysis of variance. In these analyses, the experimental variability was the focal point because end-border effects, even if present, were of no concern if they did not inflate the experimental error and thus did not reduce the precision of the experiment.

In the analysis without sub-sampling, the coefficients of variability were calculated for six row lengths: (1) 2 feet, (2) 4 feet, (3) 6 feet, (4) 8 feet, (5) 10 feet, and (6) 12 feet. Each row length was obtained by combining successive pairs of one-foot sections that were an equal distance from the alley, beginning in the middle of the plot. For example, the 2-foot row included sections 6 and 7 that were 5 feet from the alley and the 4-foot row included sections 5, 6, 7, and 8.

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[1]The field data were obtained by G. D. Massey and R. K. Thompson at Yuma and Mesa, respectively.

The sources of variation in the analyses for different plot lengths were expressed by the following linear additive model:

$$X_{ij} = \mu + \tau_i + \beta_j + \epsilon_{ij}$$

where μ = Mean, τ_i = treatment effects 1 to 12, β_j = block effects, 1 to 4, and ϵ_{ij} = random error with a zero mean and variance, σ_e^2.

In the model, it was assumed that the treatment effects were fixed, the block effects were random and there was no treatment x block interaction. Coefficients of variability for different plot lengths indicated the variability associated with each plot length. A decrease in the coefficient of variability was expected as the plot length was increased. However, if end-border effects of any consequence were present, the coefficient of variability would increase when sections with exaggerated data, due to end-border effects, entered the row length.

In the sampling analysis, an additional source of variation was considered. Six analyses of variance were calculated for 2, 4, 6, 8, 10, and 12 sections. Variance was calculated between sections in each case to give the sampling error. The following linear additive model was used:

$$X_{ijk} = \mu + \tau_i + \beta_j + \epsilon_{ij} + \delta_{ijk}$$

where δ_{ijk} = sampling error. Since block effects were random, the experimental error was considered random, therefore appropriate for testing treatment effects.

The extent of end-border effects within a row was determined by comparing the sampling error of the six analyses. If end-border effects did not exist, the sampling error would be expected to decrease as the number of sections increase from 2 to 6. Increase in the sampling error variance due to inclusion of end-border sections would indicate the presence of end-border effects.

In the sampling analysis, the variance component due to experimental error was calculated from the following equation:

$$\hat{\sigma}_e^2 = \frac{MS_E - MS_S}{S}$$

where $\hat{\sigma}_e^2$ = variance component due to experimental error.

MS_S = sampling error variance.

MS_E = experimental error variance.

S = number of samples per plot.

The variance component due to experimental error provided the estimate of the variability introduced because of the presence of end-border effects.

In the replication analysis, the variation within four replications for each variety was estimated for different row lengths, as described previously. The coefficient of variability in this case indicated the within replication variation which should be at a minimum to provide unbiased estimate of the treatments in the experiment. The variation would increase with the inclusion of sections that exhibit an end-border effect. Since within replication variation was estimated separately for each variety, the influence of end-borders on individual varieties was studied.

EXPERIMENTAL RESULTS

The grain yield, number of tillers per unit area, average number of seeds per head, and the weight of 400 seeds for each individual one-foot section for the 12 barley varieties and the 2 locations are contained in Appendices I through VIII.

The average yield increase per plot, due to the inclusion of the outside and the inside end-border sections (outside sections = 1 and 12, inside sections = 2 and 11), expressed as a percentage of the yield of the middle 8 sections, is presented in Tables 1 and 5. Increases in the number of tillers per unit area, the average number of seeds per head, and in the weight of 400 seeds are reported in Tables 2 through 4, and 6 through 8 for the experiments conducted at Mesa and Yuma, respectively.

For the data obtained at Mesa, the average yield and the three yield components (number of tillers, average number of seeds per head, and weight of 400 seeds) were over-estimated by 24, 10, 4, and 3%, respectively, without removal of the outside end-border sections. The increase, in the same order, with the removal of sections 1 and 12 was less than 2% in all cases. At Yuma, the comparable increases in yield and number of tillers were 3 and 16%, and 2 and 8%, respectively, with and without the removal of sections 1 and 12. Both head size and seed weight increased by 3% when totals were calculated for the entire plot. No increases were apparent in these two yield components when the two outside end-border sections were removed. These increases indicated the presence of end-border effects in the plots. (Figure 1).

Table 1. Average yields per plot, in lbs. per acre, for 12 barley varieties, calculated for plots 8, 10, and 12 feet long, for a barley variety yield test grown at Mesa, Arizona in 1960.

Variety	Yield for 8-ft. plots (lb./acre)	Yield for 10-ft. plots (lb./acre	Increase in yield for 10-ft. plots over 8-ft. plots (%)	Yield for 12-ft. plots (lb./acre)	Increase in yield for 12-ft. plots over 8-ft. plots (%)
Arivat	7338	7385	1	9181	25
Harlan	7036	7105	1	8619	22
California Mariout	7744	7625	0	9204	19
Vaughn	6978	7030	1	8763	26
Atlas 57	7087	7302	3	8831	25
Atlas 54	6758	6798	1	8449	25
California 1096	7406	7571	2	9428	27
Rojo	7996	8106	1	9705	21
Winter Tennessee	6764	6682	0	8352	23
Glacier	7596	7820	3	9035	19
Naked Barley Bulk	4039	3965	0	5011	24
White Barley from Composite Cross II	6877	7138	4	8840	29
Average	6968	7044	1	8618	24

Table 2. Average number of tillers per one-foot section for 12 barley varieties, calculated for plots 8, 10, and 12 feet long, for a barley variety yield test grown at Mesa, Arizona in 1960.

Variety	No. of tillers for 8-ft. plots (per 1-ft. section)	No. of tillers for 10-ft. plots (per 1-ft. section)	Increase in No. of tillers for 10-ft. plots over 8-ft. plots (%)	No. of tillers for 12-ft. plots (per 1-ft. section)	Increase in No. of tillers for 12-ft. plots over 8-ft. plots (%)
Arivat	90	89	0	97	8
Harlan	89	90	1	100	12
California Mariout	86	84	0	91	6
Vaughn	85	86	1	95	12
Atlas 57	83	84	1	92	11
Atlas 54	81	82	0	90	11
California 1096	87	87	0	94	8
Rojo	78	79	1	86	10
Winter Tennessee	74	74	0	83	12
Glacier	79	80	1	89	13
Naked Barley Bulk	58	57	0	64	10
White Barley from Composite Cross II	65	65	0	73	12
Average	80	80	0	89	10

Table 3. Average number of seeds per head per one-foot section for 12 barley varieties, calculated for plots 8, 10, and 12 feet long, for a barley variety yield test grown at Mesa, Arizona in 1960.

Variety	No. of seeds per head for 8-ft. plots	No. of seeds per head for 10-ft. plots	Increase in No. of seeds per head for 10-ft. plots over 8-ft. plots (%)	No. of seeds per head for 12-ft. plots	Increase in No. of seeds per head for 12-ft. plots over 8-ft. plots (%)
Arivat	26	26	0	27	4
Harlan	22	22	0	23	5
California Mariout	26	26	0	27	4
Vaughn	22	22	0	24	9
Atlas 57	27	27	0	28	4
Atlas 54	25	25	0	26	4
California 1096	26	26	0	28	8
Rojo	30	29	0	30	0
Winter Tennessee	30	29	0	31	3
Glacier	25	25	0	26	4
Naked Barley Bulk	24	23	0	25	4
White Barley from Composite Cross II	30	31	3	32	7
Average	26	26	0	27	4

Table 4. Average weight of 400 seeds in grams per one-foot section for 12 barley varieties calculated for plots 8, 10, and 12 feet long, for a barley variety yield test grown at Mesa, Arizona in 1960.

Variety	Weight of 400 seeds for 8-ft. plots (per 1-ft. section)	Weight of 400 seeds for 10-ft. plots (per 1-ft. section)	Increase in weight of 400 seeds for 10-ft. plots over 8-ft. plots (%)	Weight of 400 seeds for 12-ft. plots (per 1-ft. section)	Increase in weight of 400 seeds for 12-ft. plots over 8-ft. plots (%)
Arivat	13.4	13.6	1	14.1	5
Harlan	15.3	15.4	1	15.7	3
California Mariout	14.8	15.1	2	15.5	5
Vaughn	15.1	15.7	4	16.1	7
Atlas 57	13.5	13.7	1	14.0	4
Atlas 54	13.9	14.2	2	13.7	5
California 1096	13.8	14.0	1	14.7	7
Rojo	15.0	15.3	2	15.7	5
Winter Tennessee	13.0	13.0	0	13.2	2
Glacier	16.3	16.3	0	16.5	2
Naked Barley Bulk	12.4	12.5	1	12.6	2
White Barley from Composite Cross II	15.2	15.4	1	15.7	3
Average	14.3	14.5	1	14.8	3

Table 5. Average yields per plot, in lbs. per acre, for 12 barley varieties, calculated for plots 8, 10, and 12 feet long, for a barley variety yield test grown at Yuma, Arizona in 1960.

Variety	Yield for 8-ft. plots (lb./acre)	Yield for 10-ft. plots (lb./acre)	Increase in yield for 10-ft. plots over 8-ft. plots (%)	Yield for 12-ft. plots (lb./acre)	Increase in yield for 12-ft. plots over 8-ft. plots (%)
Arivat	7542	7931	5	8613	14
Harlan	5324	5390	1	6136	15
California Mariout	7542	7960	6	9149	21
Vaughn	5875	6138	5	6911	18
Atlas 57	5095	5236	3	5961	17
Atlas 54	5431	5658	4	6400	18
California 1096	9316	9206	0	10083	8
Rojo	6415	6608	3	7471	17
Winter Tennessee	5348	5409	1	6184	15
Glacier	5515	5792	5	6784	23
Naked Barley Bulk	3249	3328	3	3819	18
White Barley from Composite Cross II	6354	6464	1	7095	12
Average	6087	6260	3	7051	16

Table 6. Average number of tillers per one-foot section for 12 barley varieties, calculated for plots 8, 10, and 12 feet long, for a barley variety yield test grown at Yuma, Arizona in 1960.

Variety	No. of tillers for 8-ft. plots (per 1-ft. section)	No. of tillers for 10-ft. plots (per 1-ft. section)	Increase in No. of tillers for 10-ft. plots over 8-ft. plots (%)	No. of tillers for 12-ft. plots (per 1-ft. section)	Increase in No. of tillers for 12-ft. plots over 8-ft. plots (%)
Arivat	71	72	1	73	3
Harlan	71	71	0	74	4
California Mariout	67	70	4	73	9
Vaughn	64	66	3	71	11
Atlas 57	62	65	5	70	11
Atlas 54	54	56	4	62	11
California 1096	73	74	1	77	11
Rojo	62	63	2	67	8
Winter Tennessee	64	64	0	67	5
Glacier	68	70	3	75	11
Naked Barley Bulk	41	43	5	47	11
White Barley from Composite Cross II	58	59	2	62	7
Average	63	64	2	68	8

Table 7. Average number of seeds per head per one-foot section for 12 barley varieties, calculated for plots 8, 10, and 12 feet long, for a barley variety yield test grown at Yuma, Arizona in 1960.

Variety	No. of seeds per head for 8-ft. plots	No. of seeds per head for 10-ft. plots	Increase in No. of seeds per head for 10-ft. plots over 8-ft. plots (%)	No. of seeds per head for 12-ft. plots	Increase in No. of seeds per head for 12-ft. plots over 8-ft. plots (%)
Arivat	39	40	3	40	3
Harlan	35	36	3	36	3
California Mariout	42	42	0	42	0
Vaughn	36	36	0	37	3
Atlas 57	35	36	3	37	6
Atlas 54	35	35	0	36	3
California 1096	40	40	0	40	0
Rojo	34	34	0	35	3
Winter Tennessee	39	39	0	41	5
Glacier	35	35	0	36	3
Naked Barley Bulk	44	44	0	45	2
White Barley from Composite Cross II	40	40	0	41	3
Average	38	38	1	39	3

Table 8. Average weight of 400 seeds in grams per one-foot section for 12 barley varieties calculated for plots 8, 10, and 12 feet long, for a barley variety yield test grown at Yuma, Arizona in 1960.

Variety	Weight of 400 seeds for 8-ft. plots (per 1-ft. section)	Weight of 400 seeds for 10-ft. plots (per 1-ft. section)	Increase in weight of 400 seeds for 10-ft. plots over 8-ft. plots (%)	Weight of 400 seeds for 12-ft. plots (per 1-ft. section)	Increase in weight of 400 seeds for 12-ft. plots over 8-ft. plots (%)
Arivat	10.6	11.3	7	11.7	10
Harlan	9.0	8.7	0	8.9	0
California Mariout	11.3	11.5	2	12.0	6
Vaughn	10.9	10.8	1	11.0	1
Atlas 57	10.1	9.8	0	9.8	0
Atlas 54	11.7	11.7	0	11.8	1
California 1096	13.2	13.2	0	13.5	2
Rojo	12.7	12.8	1	13.2	4
Winter Tennessee	9.3	9.3	0	9.5	2
Glacier	10.1	10.1	0	10.6	5
Naked Barley Bulk	7.0	6.9	0	7.3	4
White Barley from Composite Cross II	11.4	11.5	1	11.6	1
Average	10.6	10.6	0	10.9	3

Figure 1. The increased plant growth produced at each end of the plots in the barley variety yield test grown at Mesa, Arizona in 1960.

42
36
30
24
18

The results of the analysis of variance without sub-sampling are reported in Tables 9 and 10. The coefficients of variability for the six row lengths showed a general decrease as the plot length increased. In all cases, the lowest coefficient of variability was obtained when all 12 sections comprised the row length. Since the over-estimation of the yield and the three yield components (Tables 1-8) suggested end-border effects in sections 1 and 12, one would expect the coefficient of variability to rise when the estimate of the experimental error was based on all 12 sections. The influence of the end-border effects on the experimental error, however, might not be apparent if the data obtained exhibited a large variation. This may be a partial explanation for the results obtained at Yuma. The Yuma data showed a relatively large variation and the coefficient of variability for the 10-foot row was 17.46%. The same, however, could not be said of the Mesa experiment. A coefficient of variability of 8.19% for the 10-foot row indicated a lower inherent variability at Mesa.

A more plausible explanation for the failure of the coefficient of variability to rise, with the inclusion of the end-border sections, might be the equal efficiency with which the 12 varieties utilized the extra nutrients and moisture provided by the bare alleys. The presence of end-border effects would not increase the experimental error if all of the varieties showed the same increase due to the excessive growth in the end-border sections. Although the yield increases per plot for the 12 varieties, without the removal of the outside end-border sections, ranged from 19 to 29% at Mesa (Table 1) and 18 to 23% at Yuma

Table 9. Coefficients of variability for yield, number of tillers per unit area, number of seeds per head, and weight of 400 seeds for different plot lengths for a barley variety yield test grown at Mesa, Arizona in 1960.

Plot Length (feet)	Coefficient of Variability (%)			
	Yield	No. of Tillers	No. of seeds per head	Wt. of 400 seeds
2	15.19	9.74	16.17	6.70
4	9.95	7.53	10.84	6.96
6	9.41	6.98	10.69	6.53
8	8.72	3.93	10.16	6.15
10	8.19	5.62	10.37	5.47
12	6.03	5.31	8.61	4.94

Table 10. Coefficients of variability for yield, number of tillers per unit area, number of seeds per head, and weight of 400 seeds for different plot lengths for a barley variety yield test grown at Yuma, Arizona in 1960.

Plot Length (feet)	Coefficient of Variability (%)			
	Yield	No. of Tillers	No. of seeds per head	Wt. of 400 seeds
2	23.66	12.02	9.87	24.19
4	18.38	10.32	7.96	22.40
6	17.65	10.13	6.33	16.70
8	18.43	10.10	6.34	16.24
10	17.46	9.58	5.56	15.24
12	16.66	8.89	5.12	14.92

(Table 5), these differences probably were not large enough to cause an inflation in the error.

Lower coefficients of variability could have resulted because of the greater increase in the general mean relative to the standard deviation when sections 1 and 12 were added to the row length. The coefficient of variability is the standard deviation expressed as a percentage of the mean. Therefore, to obtain higher values for the coefficient of variability, the increase in the standard deviation should have been greater than the increase in the mean, as a result of the introduction of the data obtained from the outside end-border sections. For example, in the analysis of variance for the yield obtained at Mesa, the mean increased by 47%, whereas the standard deviation showed an 8% increase with the inclusion of sections 1 and 12. This resulted in a lower coefficient of variability.

Tables 11 and 12 contain the sampling error and the variance component due to the experimental error obtained from the analysis with sub-sampling. In general, the sampling error showed an increase when the error was estimated for all 12 sections. At Mesa, the sampling error of the yield analysis showed an increase of 6%, due to the inclusion of sections 2 and 11 and a seven-fold increase when sections 1 and 12 were considered. The respective increases for the experiment at Yuma, in the same order, were 18 and 200%. The sampling error variance calculated for the variable number of sections indicated the average variation between sections included in the analyses. One can conclude from the increase in the sampling error with the inclusion of sections

Table 11. The effect of including end-border sections on the sampling error variance per section and on the experimental error variance component for yield, number of tillers per unit area, number of seeds per head, and weight of 400 seeds, for a barley variety yield test grown at Mesa, Arizona in 1960.

	Sampling error variance per section				Variance Component due to experimental error			
No. of one-foot sections	Yield	No. of tillers per unit area	No. of seeds per head	Wt. of 400 seeds	Yield	No. of tillers per unit area	No. of seeds per head	Wt. of 400 seeds
2	225.69	75.20	20.78	1.13	2.84	16.41	7.00	0.41
4	270.60	114.84	24.07	1.40	0*	7.17	1.97	0.64
6	248.76	128.30	22.29	1.56	6.07	9.36	3.87	0.61
8	237.24	127.03	21.21	1.86	10.79	0*	4.50	0.54
10	252.66	124.93	21.56	1.29	11.16	7.64	5.3	0.53
12	1918.15	515.18	30.27	2.21	0*	0*	3.10	0.35

*The estimate of variance component obtained was negative and was assumed as 0.

Table 12. The effect of including end-border sections on the sampling error variance per section and on the experimental error variance component for yield, number of tillers per unit area, number of seeds per head, and weight of 400 seeds for a barley variety yield test grown at Yuma, Arizona in 1960.

	Sampling Error Variance per Section				Variance Component due to experimental error			
No. of one-foot sections	Yield	No. of tillers per unit area	No. of seeds per head	Wt. of 400 seeds	Yield	No. of tillers per unit area	No. of seeds per head	Wt. of 400 seeds
2	280.02	92.10	14.18	6.36	72.14	9.09	6.66	3.15
4	219.59	78.15	11.87	5.32	73.56	21.87	5.87	2.37
6	219.71	79.30	10.94	4.82	85.26	27.11	4.43	2.31
8	232.10	80.07	11.58	5.16	96.46	30.56	3.68	2.32
10	273.86	93.01	11.40	5.64	100.87	28.95	3.20	2.17
12	733.77	208.97	15.95	6.07	102.87	19.87	2.63	1.89

1 and 12, and 2 and 11 that end-border effects were present in these sections. At Mesa, it was observed that the inclusion of sections 1 and 12 caused a higher percentage increase in the sampling error for yield, number of tillers per unit area and the average number of seeds per head analyses. This indicated that the border effects were more intense at Mesa. The increase in intensity, however, did not affect the seed weight. At Mesa, excessive plant growth in sections 1 and 12 appeared to affect the yielding capacity of the plants in sections 2 and 11. This was shown by the comparison of the sampling errors calculated for Mesa and Yuma. A seven-fold increase in the sampling error variance of the yield analysis for the 12 sections at Mesa consisted of a 6% increase in the error due to sections 2 and 11. Whereas, at Yuma there was a 200% increase in the error with 18% of it being contributed by sections 2 and 11.

The sampling error of the three yield components also increased with the inclusion of the two outside end-border sections. For the experiment at Mesa, the sampling errors for number of tillers, head size, and seed weight increased by 300, 43, and 18%, respectively (Table 11). The respective increases for the experiment at Yuma were160, 38, and 17% (Table 12). The exclusion of sections 1 and 12, however, lowered the sampling error to such an extent that the increase in the error was not apparent. The comparison of the increases in the sampling error of the yield components suggested that excessive tillering contributed the most to the increase in yield.

The variance component due to the experimental error was of comparatively small magnitude and in the case of the yield analysis increased slightly with each increase in the row length. For the data obtained at Yuma, the inclusion of sections 1 and 12 increased the variance component by 2%. The variance component for the Mesa data was assumed to be zero.

The variance component calculated for the three yield components did not show any definite pattern of increase or decrease with an increase in the plot length. However, the variance component in all cases was lowest when all 12 sections were included. It would appear that the end-border effects when average over varieties, did not inflate the experimental error, or the end-border effects did not bias the experimental error for the two experiments.

In the replication analysis, since the variation between four replications of each variety was estimated separately, the coefficient of variability measured the within replication variation or variation between sections of each variety. Thus, it was possible to study the influence of border effects on individual varieties. Tables 13 through 16 and 17 through 20 show the coefficients of variability when sections of each variety were combined into various plot lengths for Mesa and Yuma, respectively. In all cases, the highest coefficients of variability were obtained with the inclusion of sections 1 and 12. The coefficient of variability for the yield data obtained at Mesa, averaged over the 12 varieties, increased from 21.54 to 48.27% when sections 1 and 12 were not removed. A smaller increase of 11.00% in the

Table 13. The coefficients of variability for yield for different plot lengths for 12 barley varieties calculated from the replication analysis of a barley yield test grown at Mesa, Arizona in 1960.

Variety	Plot length in feet 2	4	6	8	10	12
	Coefficient of Variability in percent					
Arivat	13.31	14.08	17.43	17.72	17.54	50.56
Harlan	16.79	26.73	23.49	22.35	20.95	43.98
California Mariout	15.93	13.89	17.10	17.27	21.16	44.45
Vaughn	32.93	25.93	24.34	26.21	25.98	51.38
Atlas 57	28.29	28.32	22.89	21.07	22.28	46.81
Atlas 54	22.51	22.66	18.05	17.63	20.04	51.26
California 1096	15.29	15.61	22.38	20.20	20.30	49.47
Rojo	22.05	24.38	26.48	24.98	23.05	41.82
Winter Tennessee	20.65	19.39	17.30	13.76	16.26	48.33
Glacier	9.19	17.25	16.51	16.83	17.64	44.14
Naked Barley Bulk	31.87	36.51	35.67	34.92	33.99	56.19
White Barley from Composite Cross II	24.01	21.65	17.87	17.21	19.37	50.92
Average	21.06	22.20	21.62	20.84	21.54	48.27

Table 14. The coefficients of variability for number of tillers per unit area for different plot lengths for 12 barley varieties calculated from the replication analysis of a barley yield test grown at Mesa, Arizona in 1960.

	Plot length in Feet					
	2	4	6	8	10	12
Variety	Coefficient of Variability in percent					
Arivat	10.15	7.87	11.22	10.34	9.88	23.39
Harlan	9.99	13.28	12.86	12.93	12.22	25.99
California Mariout	7.50	12.46	15.33	13.70	15.20	22.95
Vaughn	10.68	17.83	16.54	16.69	15.76	25.92
Atlas 57	16.31	14.48	14.24	12.79	12.07	24.80
Atlas 54	5.45	10.15	11.48	11.62	11.71	23.86
California 1096	5.60	10.49	10.66	12.96	12.92	22.87
Rojo	8.73	14.67	12.80	11.59	12.57	21.86
Winter Tennessee	11.36	12.36	13.45	12.13	11.97	28.31
Glacier	18.95	14.86	13.36	13.66	15.62	28.24
Naked Barley Bulk	10.04	10.16	18.26	19.32	19.26	32.93
White Barley from Composite Cross II	17.30	18.13	18.78	20.19	21.33	34.41
Average	11.00	13.06	14.08	13.99	14.38	26.29

Table 15. The coefficients of variability for average number of seeds per head for different plot lengths for 12 barley varieties calculated from the replication analysis of a barley yield test grown at Mesa, Arizona in 1960.

Variety	Plot length in Feet 8	10	12
	Coefficient of Variability in percent		
Arivat	15.17	14.08	19.54
Harlan	17.85	17.66	19.21
California Mariout	15.41	18.65	19.92
Vaughn	24.60	20.33	20.38
Atlas 57	19.49	21.10	20.92
Atlas 54	17.89	21.39	21.35
California 1096	13.65	14.11	18.43
Rojo	16.44	16.07	15.95
Winter Tennessee	9.49	13.23	16.62
Glacier	14.94	16.18	15.87
Naked Barley Bulk	30.60	29.03	30.90
White Barley from Composite Cross II	17.59	18.39	19.86
Average	17.75	18.35	19.91

Table 16. The coefficients of variability for weight of 400 seeds for different plot lengths for 12 barley varieties calculated from the replication analysis of a barley yield test grown at Mesa, Arizona in 1960.

Variety	Plot length in Feet 8	10	12
	Coefficient of Variability in percent		
Arivat	6.44	8.13	12.18
Harlan	8.01	7.54	9.64
California Mariout	7.11	7.46	9.38
Vaughn	7.00	6.28	8.99
Atlas 57	9.96	9.67	11.04
Atlas 54	10.50	10.29	12.74
California 1096	6.57	9.28	10.76
Rojo	10.40	6.83	10.11
Winter Tennessee	14.15	13.99	13.39
Glacier	9.10	8.33	8.52
Naked Barley Bulk	5.86	4.82	5.62
White Barley from Composite Cross II	5.42	5.72	7.40
Average	8.37	8.19	9.98

Table 17. The coefficients of variability for yield for different plot lengths for 12 barley varieties calculated from the replication analysis of a barley yield test grown at Yuma, Arizona in 1960.

	Plot length in Feet					
	2	4	6	8	10	12
Variety	Coefficient of Variability in percent					
Arivat	35.07	31.07	23.88	26.08	28.56	39.39
Harlan	15.40	27.62	32.46	28.03	27.04	37.90
California Mariout	18.94	16.36	14.54	15.48	18.85	39.09
Vaughn	18.30	24.75	21.37	21.99	25.64	34.17
Atlas 57	26.06	26.41	28.40	31.68	30.40	40.83
Atlas 54	43.32	31.96	26.46	25.21	24.31	37.76
California 1096	10.55	9.76	13.85	16.54	20.72	28.54
Rojo	29.87	24.94	27.86	24.29	25.78	35.54
Winter Tennessee	12.85	20.91	20.07	22.35	24.02	34.09
Glacier	38.68	28.58	28.00	27.54	26.10	40.77
Naked Barley Bulk	39.00	33.73	32.25	35.85	34.48	49.86
White Barley from Composite Cross II	32.02	27.13	24.87	25.43	24.35	34.74
Average	26.67	25.26	24.50	25.03	26.68	37.68

Table 18. The coefficients of variability for number of tillers per unit area for different plot lengths for 12 barley varieties calculated from the replication analysis of a barley yield test grown at Yuma, Arizona in 1960.

	Plot length in Feet					
	2	4	6	8	10	12
Variety	Coefficient of Variability in percent					
Arivat	20.62	17.13	22.43	13.61	14.00	26.38
Harlan	12.92	13.04	14.21	15.02	14.88	21.22
California Mariout	10.70	8.45	10.15	9.58	10.93	17.39
Vaughn	11.14	10.49	14.30	15.75	17.87	23.60
Atlas 57	14.59	20.08	20.34	20.55	21.21	26.51
Atlas 54	34.59	23.13	20.11	18.26	29.62	27.21
California 1096	5.90	6.5	9.35	8.65	8.60	14.71
Rojo	17.00	14.70	12.89	11.93	13.38	17.93
Winter Tennessee	10.86	12.48	13.38	14.84	16.04	20.19
Glacier	15.28	11.21	11.46	11.75	14.55	21.55
Naked Barley Bulk	22.98	21.58	19.11	19.84	20.15	24.95
White Barley from Composite Cross II	4.07	12.51	10.64	11.70	13.94	22.18
Average	15.05	13.78	14.86	14.29	15.43	24.68

Table 19. The coefficients of variability for average number of seeds per head for different plot lengths for 12 barley varieties calculated from the replication analysis of a barley yield test grown at Yuma, Arizona in 1960.

Variety	Plot length in Feet 8	10	12
	Coefficient of Variability in percent		
Arivat	7.43	7.57	9.36
Harlan	9.06	8.81	10.56
California Mariout	7.22	5.76	5.93
Vaughn	6.86	7.84	9.36
Atlas 57	10.44	7.73	12.46
Atlas 54	8.07	7.46	8.54
California 1096	6.48	6.60	7.17
Rojo	8.11	7.60	10.45
Winter Tennessee	7.52	9.18	12.88
Glacier	7.90	7.95	9.54
Naked Barley Bulk	11.18	11.44	11.68
White Barley from Composite Cross II	8.54	9.60	9.61
Average	8.23	8.12	9.73

Table 20. The coefficients of variability for weight of 400 seeds for different plot lengths for 12 barley varieties calculated from the replication analysis of a barley yield test grown at Yuma, Arizona in 1960.

Variety	Plot length in Feet 8 Coefficient of Variability in percent	10	12
Arivat	25.63	26.63	26.77
Harlan	16.29	18.14	18.26
California Mariout	17.34	14.13	17.34
Vaughn	19.46	19.20	18.65
Atlas 57	26.01	27.73	25.84
Atlas 54	18.42	18.12	17.94
California 1096	14.79	19.90	16.50
Rojo	23.39	28.22	31.14
Winter Tennessee	22.98	23.92	25.77
Glacier	21.14	19.70	22.82
Naked Barley Bulk	27.69	30.52	30.88
White Barley from Composite Cross II	17.66	18.98	19.22
Average	20.90	22.09	22.59

coefficient of variability was observed at Yuma. In general, the coefficients of variability showed an insignificant increase when the plot length was increased from 8 to 10 feet. Most varieties appeared to be more or less similar in their response to the bare alley, but in certain cases the inclusion of sections 1 and 12 caused higher within replication variation. The increase in the coefficient of variability, for the 12 varieties ranged from 19 to 33% at Mesa (Table 13) and from 8 to 20% at Yuma (Table 17). At Mesa, the coefficient of variability for Arivat, White Barley from Composite Cross II, Atlas 54, and Winter Tennessee increased by more than 30%, whereas, the increase for Rojo was only 18%. At Yuma, the inclusion of sections 1 and 12 caused the highest increase in the coefficient of variability for California Mariout and the least for California 1096. It was observed from these results, that the varieties that ranked high at Mesa, on the bases of their ability to utilize the bare alley, did not fare as well at Yuma. The number of tillers was the only yield component that appeared to have been affected appreciably by the end-border effects. The coefficients of variability for head size and seed weight increased slightly due to the presence of the end-border effects at both localities.

The replication analysis confirmed the results of the other analyses. It appeared that the end-border effects extended to about two feet and varied in their intensity at the two locations. However, the removal of one foot from each end of the row eliminated most of the bias. The remaining end-border effects, when averaged over replications and varieties, were of little consequence.

DISCUSSION

Yield trials are conducted to compare the yield potential, and other plant characteristics of a number of varieties for the purpose of selecting outstanding entries. Among other factors, end-border effects influence the accuracy of these experiments, depending upon the experimental materials and their interactions with their environments. The presence of end-border effects can cause serious errors if the varieties are variable in their response to the bordering alleys. Where the number of varieties or selections included in the trial is large the influence of the end-border effects on the experimental error may not be apparent, even though one or two varieties show a differential response. Errors may be made in the detection of differences between varieties when employing the standard tests of significance. For the Mesa experiment, the results of the various analyses indicated that the end-border effects, averaged over varieties, did not influence the experimental error. However, when the varieties were ranked in the order of their yielding ability, change in rank occured with the removal of the outside end-border sections. For example, Glacier ranked fifth when the yield was based on all 12 sections, but rose to second place with the exclusion of sections 1 and 12. This shows the importance of removing end-borders from each end of the plots. At Yuma, there was a negligible increase in the experimental error and the varieties did not change ranks when the end-borders were removed.

This, however, does not preclude the necessity of removing end-borders in future experiments.

The comparison of the results from the two experiments suggested that environments influence the intensity of end-border effects. The environment x variety interaction makes it difficult to predict the affect of end-border effects on individual varieties. The results showed that varieties within themselves, varied in their efficiency to utilize the bare alley from one locality to the other. Unfortunately, a combined analysis to determine the border effect x locality interaction could not be calculated because of the heterogeneity of variances. However, higher increases in the sampling error variance and in the coefficients of variability, calculated from the replication analyses, indicated that the end-border effects were more intense at Mesa. This may be partially explained by the more favorable environmental conditions at Mesa than at Yuma, as evidenced by the higher grain yields obtained in the Mesa area. In addition, the Mesa Experiment Station had been in operation for a number of years with a more favorable cropping history. Field crop experiments were initiated on the Yuma Experiment Station in 1956. If the soil fertility at Mesa were higher than at Yuma, the plants adjacent to the alleys may have had more available nutrients. Since climatic factors at Mesa were more favorable for plant growth, higher end-border yields were obtained at that location.

Of the three yield components (1. Number of tillers per unit area, 2. number of seeds per head, and 3. seed weight), the number of tillers per unit area was influenced the most by the end-border effects. However, number of tillers per unit area may not have been the only yield component that contributes to the increase in yield due to end-border effects. It is believed, however, that varieties with a high inherent tillering potential would benefit most from bare alleys adjacent to the ends of the plots. End-border effects, therefore, would be relatively unimportant in experiments concerned with the study of head size and seed weight.

For the two experiments, although the end-border effects extended beyond the first foot in some instances, they were never observed beyond two feet. It is the opinion of the author, that the removal of one foot from each end of the plots would be sufficient to eliminate most end-border effects in Arizona barley yield trials. Since end-border effects are greatly influenced by the availability of nutrients and moisture, it is suggested that it may be advisable to remove a greater length of plot ends to eliminate end-border effects in fertilizer and irrigation experiments.

SUMMARY AND CONCLUSIONS

Experiments were conducted at two locations in Arizona (Mesa and Yuma) to determine the extent of end-border effects in fall-sown irrigated barley yield trials. The experiments consisted of 12 barley varieties sown in plots 4 feet wide and 12 feet long in a randomized complete block design. A five-foot bare alley separated plots at each end. The two middle rows in each plot were hand-harvested in 12 one-foot sections. Data were recorded for total grain yield, number of tillers, average number of seeds per head, and weight of 400 seeds for each section.

End-border effects were measured by determining their influence on the experimental variability.

The sampling error variance calculated for variable numbers of sections showed an increase when inside and outside end-border sections were included. Most variation, however, occured with the inclusion of outside end-border sections. It was observed that end-border effects extended to about two feet within each end of the plots. Removal of one foot from each plot end was sufficient to eliminate most end-border effects at both localities.

Of the three yield components, the number of tillers per unit area was influenced most by the end-border effects. Head size and seed weight increased slightly indicating that end-border effects were relatively unimportant for these two yield components.

At Mesa, although the end-border effects averaged over varieties did not increase the experimental error, some varieties changed ranks when yields were calculated with and without end-borders. At Yuma, end-borders were not a source of error.

Replication analyses were calculated to study the influence of end-border effects on individual varieties. Most varieties reacted similarly to end-border effects. Although the number of tillers per unit area increased the most, it was not the only yield component that contributed to the increase in yield due to the end-border effects. The response of the varieties to the bare alley was influenced by environment. End-border effects were more intense at Mesa.

It is the opinion of the author, that the removal of one-foot from each end of the plots would be sufficient to eliminate most end-border effects in Arizona barley yield trials.

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APPENDIX

In the Appendix Tables the barley varieties are listed by number as follows:

Variety Number	Variety
1	Arivat
2	Harlan
3	California Mariout
4	Vaughn
5	Atlas 57
6	Atlas 54
7	California 1096
8	Rojo
9	Winter Tennessee
10	Glacier
11	Naked Barley Bulk
12	White Barley from Composite Cross II

Table I. Average yield in grams for 12 1-foot sections for the 12 barley varieties in a barley variety yield test grown at Mesa, Arizona in 1960.

Section No.	Varieties											
	1	2	3	4	5	6	7	8	9	10	11	12
1	164	156	160	161	142	141	180	175	155	106	96	144
2	71	80	73	66	77	70	90	80	71	91	38	99
3	70	68	82	66	66	75	74	82	78	80	35	63
4	77	82	94	71	75	66	57	107	67	82	31	78
5	77	74	80	78	80	72	78	102	75	83	45	87
6	69	84	81	75	71	70	93	89	82	70	41	63
7	70	69	72	55	67	75	79	68	68	75	47	73
8	79	80	76	94	71	64	83	69	63	73	35	76
9	84	61	78	71	75	80	76	77	69	83	49	68
10	87	69	80	73	86	62	79	75	63	88	56	66
11	87	74	76	85	94	75	82	98	61	91	39	72
12	215	182	197	202	202	208	210	194	194	210	118	218

Table II. Average number of tillers per unit area for the 12 barley varieties in a barley variety yield test grown at Mesa, Arizona in 1960.

Section No.	Varieties											
	1	2	3	4	5	6	7	8	9	10	11	12
1	142	137	115	129	122	123	118	121	120	123	87	101
2	82	89	84	83	87	91	89	81	72	80	57	69
3	86	82	81	79	79	80	85	74	76	74	51	55
4	90	89	78	82	75	72	73	82	65	74	42	63
5	85	86	90	86	88	81	84	77	68	77	59	69
6	89	87	84	80	73	82	91	74	75	69	59	55
7	87	82	86	77	88	79	89	70	71	77	61	65
8	92	101	82	108	86	86	91	88	75	80	56	70
9	95	88	99	84	84	86	93	78	85	84	65	77
10	92	100	85	86	91	85	89	82	74	93	67	62
11	87	98	75	95	88	79	85	82	82	88	57	63
12	141	155	134	148	146	139	136	119	134	148	112	131

Table III. Average number of seeds per head per section for the 12 barley varieties in a barley variety yield test grown at Mesa, Arizona in 1960.

Section No.	Varieties 1	2	3	4	5	6	7	8	9	10	11	12
1	30	26	33	29	31	28	35	33	36	30	33	35
2	24	23	22	22	27	21	27	25	28	27	21	37
3	24	20	26	22	25	25	24	30	29	24	23	30
4	25	24	27	21	29	24	22	32	29	26	22	33
5	27	22	27	23	27	25	27	32	30	24	23	32
6	24	25	28	24	29	23	29	32	30	24	21	28
7	24	23	24	20	24	28	26	27	29	25	26	30
8	28	22	28	25	26	23	28	30	30	23	22	32
9	27	19	23	22	28	29	25	31	31	27	25	24
10	28	19	27	22	29	22	26	24	30	25	29	28
11	28	20	25	19	30	26	27	30	27	26	22	32
12	38	28	33	36	34	32	35	36	40	31	31	38

Table IV. Average weight of 400 seeds per section for the 12 barley varieties in a barley variety yield test grown at Mesa, Arizona in 1960.

Section No.	Varieties 1	2	3	4	5	6	7	8	9	10	11	12
1	15.7	16.3	17.2	17.5	15.4	16.5	18.0	17.5	14.6	17.0	13.2	16.6
2	14.4	15.8	15.6	14.3	13.6	15.0	15.2	16.1	14.0	16.7	12.6	16.4
3	14.0	16.6	15.7	15.4	13.8	15.0	14.4	16.6	14.3	18.3	12.7	15.6
4	13.8	16.2	15.8	15.5	14.1	15.2	14.4	16.4	14.4	17.2	12.9	15.4
5	13.7	15.8	15.4	15.3	14.1	14.8	13.9	16.0	14.5	17.1	13.0	15.9
6	13.7	15.6	15.4	15.3	14.4	14.8	14.3	16.4	14.5	17.1	12.8	16.2
7	12.6	14.7	14.2	14.8	13.0	13.5	13.9	19.7	13.1	15.7	12.2	15.2
8	12.8	14.6	13.2	14.2	12.5	12.7	12.8	13.1	11.3	14.9	11.8	14.5
9	13.4	14.8	13.7	14.8	13.0	12.8	13.0	13.2	10.6	14.7	12.3	14.9
10	13.7	14.6	15.3	15.8	13.5	13.1	14.0	14.4	11.4	15.5	12.0	14.8
11	14.6	15.3	16.7	16.4	14.4	15.2	14.6	16.1	11.3	16.1	12.6	15.2
12	16.5	17.9	18.2	17.8	16.5	17.8	17.9	18.1	14.7	18.5	13.5	17.7

Table V. Average yield in grams for 12 1-foot sections for the 12 barley varieties in a barley variety yield test grown at Yuma, Arizona in 1960.

Section No.	Varieties 1	2	3	4	5	6	7	8	9	10	11	12
1	102	108	120	115	89	94	143	118	108	121	70	101
2	94	59	102	74	54	66	113	80	66	74	38	81
3	106	61	84	61	51	63	111	70	57	62	31	62
4	68	43	76	66	55	64	102	61	58	49	24	71
5	62	51	79	57	40	56	104	73	64	58	28	63
6	64	52	76	62	65	55	103	72	56	55	23	67
7	78	50	72	57	47	34	89	72	52	58	41	77
8	71	61	72	56	59	53	90	63	54	65	39	64
9	80	65	81	70	57	71	96	52	55	58	39	65
10	100	61	89	61	51	57	82	72	50	55	46	61
11	104	59	99	76	67	71	70	74	52	70	38	63
12	149	98	195	110	111	117	159	128	102	124	61	113

Table VI. Average number of tillers per unit area for the 12 barley varieties in a barley variety yield test grown at Yuma, Arizona in 1960.

Section No.	Varieties											
	1	2	3	4	5	6	7	8	9	10	11	12
1	82	68	85	88	87	86	88	83	78	90	64	69
2	75	55	74	72	73	62	77	71	57	70	49	58
3	74	72	69	60	55	61	74	63	56	63	42	55
4	70	66	61	69	63	57	72	64	62	63	37	58
5	68	71	69	62	60	58	73	66	70	69	32	61
6	67	73	65	62	63	54	70	64	61	70	35	61
7	77	66	67	61	54	39	73	59	66	66	44	63
8	69	73	62	59	67	48	77	56	66	70	43	54
9	71	73	72	65	69	54	76	63	67	69	46	56
10	70	74	70	76	64	59	72	62	64	75	52	58
11	74	89	80	75	81	72	76	61	67	88	53	65
12	83	109	100	99	105	93	101	87	92	109	67	90

Table VII. Average number of seeds per head per section for the 12 barley varieties, in a barley variety yield test grown at Yuma, Arizona in 1960.

Section No.	Varieties 1	2	3	4	5	6	7	8	9	10	11	12
1	42	43	44	40	39	38	42	37	47	41	47	42
2	40	37	42	37	36	35	38	34	42	37	44	40
3	38	35	44	39	34	34	42	35	40	33	40	41
4	39	35	42	36	35	36	41	36	37	35	42	37
5	38	34	41	35	35	34	40	33	37	34	41	41
6	42	34	41	35	34	35	37	32	36	34	39	38
7	41	36	42	36	37	36	39	34	38	35	45	41
8	39	34	38	36	33	36	38	31	41	33	47	39
9	38	37	42	37	36	36	40	35	40	37	46	43
10	40	36	42	35	35	34	39	35	40	35	50	39
11	40	37	41	37	41	35	44	38	41	34	49	40
12	47	37	48	42	44	39	45	39	49	38	51	45

Table VIII. Average weight of 400 seeds per section for the 12 barley varieties in a barley variety yield test grown at Yuma, Arizona in 1960.

Section No.	Varieties											
	1	2	3	4	5	6	7	8	9	10	11	12
1	11.9	10.8	12.8	13.1	10.6	11.4	15.2	15.3	11.8	13.3	9.4	13.8
2	12.3	8.4	13.3	11.0	9.8	12.4	15.2	13.1	11.1	11.6	7.2	14.0
3	19.5	9.0	11.6	10.6	12.9	12.6	14.4	12.7	10.1	11.5	6.7	10.6
4	16.8	8.8	11.4	11.4	10.7	12.6	13.8	10.6	9.5	9.4	5.7	12.8
5	9.6	8.1	11.3	10.6	7.4	10.9	14.1	12.8	9.9	9.9	8.7	10.0
6	9.7	8.7	10.8	11.5	11.1	11.3	14.7	14.0	10.4	8.9	6.0	11.4
7	9.6	8.8	10.4	10.3	8.6	9.6	11.9	15.4	10.7	10.2	8.0	12.5
8	8.6	9.2	11.8	10.5	9.8	13.1	12.9	13.8	8.0	11.8	7.4	11.7
9	10.8	9.6	10.6	12.3	9.3	12.4	12.3	9.5	8.4	9.1	6.9	10.8
10	16.0	9.4	12.3	9.7	10.6	11.4	11.7	13.0	7.5	9.6	6.4	11.1
11	16.4	7.0	11.3	10.1	7.3	10.9	11.0	12.8	7.5	9.5	5.6	9.7
12	15.2	8.7	16.4	10.6	9.2	12.5	14.2	15.0	9.2	12.5	10.0	11.1