FURTHER EXPERIMENTS IN FIELD TECHNIC IN PLOT TESTS [1]

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INTRODUCTION

In a former paper (*2*)[3] results of determinations of the effect of 18-inch alleys on the outside and inside border rows of oats, wheat, and barley varieties were made available. At that time no data appeared to be available regarding the possible border effect on rows farther within plots than the second 6-inch drill row. To secure data on this point, determinations of yield for the first, second, and third 6-inch drill rows from either side of each plot were made in 1918.

In the determinations of border effect with varieties, the rate of seeding as well as other factors were necessarily as nearly identical as it was possible to make them.

Cultural and rate of seeding tests on plots surrounded by alleys and roadways are being carried out yearly. To what extent does border effect influence results in such trials where all plots are sown with the same variety and where other conditions such as methods of preparation of the seed bed, rates of seeding, etc., are varied? In order to secure data on border effect in rate of seeding tests, determinations were made in 1918.

The data secured for the purpose of aiding in the interpretation of results in Minnesota may be of interest to scientific workers elsewhere and, therefore, are made available.

REVIEW OF LITERATURE

The need of using methods in conducting plot tests and in the interpretation of results from them which may be relied on to give close approximation to the actual results has been given considerable attention. The subject has been considered mainly from four standpoints, (1) selection of the location for the plots, (2) laying them out, which necessitates the consideration of how many repetitions, size and shape,

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[3] Reference is made by number (italic) to "Literature cited," p. 497-499.

number and location of controls, alleys between plots, etc., (3) the technic of harvesting and thrashing, and (4) the interpretation of the results.

Carleton (*4*), Piper and Stevenson (*17*), Thorne (*20*), and others have considered practically the entire subject in a general way and have offered suggestions looking toward the improvement of technic in plot tests. Lyon (*12*) used original data and that of others to emphasize some of the essential considerations in plot tests.

Harris (*8*) has used the original data of Montgomery (*15*) and that of Mercer and Hall (*13*) to show the need of considering variations in the soils of fields used for experiment when interpreting the results from them. In a later article (*9*) the same writer used the original data of Kiesselbach (*11*) and that of others to further demonstrate heterogeneity of soil in fields selected for their uniformity. Emphasis is laid on the necessity for greater care in the technic of plot tests and on the use of statistical methods in the analysis of the data.

Surface and Pearl (*19*) propose a method for use in correcting for soil heterogeneity in plot tests. This method is useful only when the plots are located in blocks several in extent each way.

Smith (*18*) emphasizes the value of replication and of carrying the tests over a period of years in securing dependable results. He also mentions that the plants in one plot may have an influence on those growing in adjacent plots. Montgomery (*14*) has shown that the plants of one variety may have a considerable effect on those of another variety growing near. Hayes and Arny (*10*) report on the effect that plants in rod rows spaced a foot apart may have on each other.

That the yields of plots flanked by cultivated alleys are higher because of the effect of the additional space on the outside rows has been shown by Arny and Steinmetz (*2*). The higher yields of border rows as compared with central rows in plots flanked by alleys has been shown by Arny and Hayes (*1*), and in addition, the effect of border rows on the rank of particular varieties in tests is emphasized.

Since the publication of the earlier article (*2*) several papers which relate to this subject have come to the attention of the writer. Fletcher (*7*) reports that crops growing on the border of a fallow yielded at a rate as much as 10 times as great as the rate in the center of the plot. This is accounted for largely by the absence of toxic substances on the fallow side of the outside rows. The width of the fallow area is not mentioned.

Chittenden (*5*) gives results for turnips planted in plots 33 feet long and 7 feet 6 inches wide. The rows of turnips were 18 inches apart, and the outer rows of any two plots were 4 feet 6 inches apart. This gives 36 inches of additional space to the two outside rows flanking each alley. The rows extended east and west. For the crop planted May 25 and weighed July 29, the weights of the tops of the outer rows averaged 94 as compared with the middle row's weight of 78, both on the basis of 100 for the heaviest row. On the same basis, the roots from the outside rows aver-

aged 91 and the middle row 83. In another trial, four rows of turnips each 18 inches apart were sown July 16 in plots 13 feet by 9 feet with 9 feet 6 inches as the distance between the outside rows of any two plots. These were harvested September 28. Here on the basis of 100 for the heaviest row of each plot, the roots from the outside rows yielded at the rate of 95 and the inside rows at the rate of 70. Discarding the plants in the outside rows before estimating yield is recommended.

In a later paper the same writer (*6*) reports that potatoes in 3-foot rows, with alleys several feet wide on one side and from 4 to 5 feet wide on the ends, showed marked border effect. The rows extended north and south. Inner row No. 1, next to the outer row, yielded 72, and the third row in the plot yielded 72, as compared with 100 for the outside rows. Yields of the end plants of the rows was as 100 to 82, as compared with the average of the other plants in the same rows. In other trials end plants yielded 100 to 87, 100 to 92, and 100 to 88.4, respectively, as compared with the average for the other plants in the same rows. Corner plants—those having additional space in two directions—yielded 100 to 79, as compared with the other plants in the outside rows, and 100 to 57, as compared with the inner plants. The statement is made that in yield trials at Wisley outer rows are planted which do not essentially belong to the plots. They are to protect the rows of the plants from border effect.

Wheeler (*21*) notes that in Germany at some locations provision had been made to prevent border effect, and that in some experiments at the Rhode Island Station border effect was eliminated by removing a strip 3 feet wide on the sides and 6 feet wide on the ends. This width was decided on because the area remaining was then $^1/_{10}$ acre.

Bedford and Pickering (*3*) in field tests found the weights of the entire plants in outside rows to be heavier than the weights of the produce from the inner rows. The relation in percentage was as follows: Mustard, outside 297, 201, and 200, as compared with 100 per cent for the inner rows; wheat at Ridgemont, outside 131, inside 100; wheat at Woburn, outside 204 and 161, inside 100; barley at Harpenden, outside 126, inside 100. On plots manured from 100 to 300 tons per acre the outside rows of mustard were 190, as compared with the inner 100; on land less heavily manured the outside were 228 and the inside 100. From these results the authors conclude that, under ordinary circumstances, approximately one-fourth of the border effect is due to increased food supply and three-fourths to decrease in toxic effect.

The observation is also made that with the mustard plant the border effect did not extend beyond 6 inches from the edge of the plot, no effect in the second rows being noticed when the rows were 9 inches apart. The width of the alleys or fallow spaces between plots is not mentioned.

TECHNIC OF THE EXPERIMENT

The determinations of yield to indicate the effect of alleys on first, second, and third rows on either side of each plot were made on the wheat, oat, and barley varieties at University Farm.

A rate of seeding test for oats has been conducted at University Farm for a number of years. The rates used vary from 48 to 112 pounds per acre, which gives a wide variation in the number of seedlings per acre in the spring and in the number of culms per acre at maturity. This material served for the purpose of border effect determinations, as well as for that which it was originally outlined. The various seedings, both in the variety tests and in the rate of seeding tests, are made on the same day, as far as possible, usually in early April, and the grain is harvested during the last week in July or the first week in August.

The soil at University Farm is a Hempstead silt loam, which is not representative of any large area of the State. In order to secure a variation in soil and other environment, the rate of seeding test was duplicated at the Morris Substation, which is located on a fine silt loam of Young Gray Drift formation. This is a soil more representative of a large area of the State than that on which the University Farm is located.

There were four regularly distributed plots of each variety of oats, wheat, and barley at University Farm. In the rates of seeding tests at the Morris Substation there were 3 plots of each rate except the 96-pound rate, of which there were 5 additional used as controls. At University Farm there were 2 of each rate on 5 different methods of seedbed preparations, making 10 in all for each rate.

At Morris the plots were made up of 12 six-inch drill rows, a total width of 6 feet. The length was 130 feet. At University Farm the plots were made up of 17 six-inch drill rows, a width of 8.5 feet. For the variety test the length was 129 feet, and for the rate of seeding test 132 feet. The borders on the ends of the plots next to the roads were removed accurately before harvest by trimming to a line established by a wire stretched shortly after planting.

Alleys 1½ feet wide extended between each two plots. They were cultivated to keep them reasonably free from weeds. The variety test plots extended north and south, and the rate of seeding plots at both locations extended east and west.

At Morris the series on which the test was conducted had been in meadow the year previous. Grain crops appear to be retarded, in some instances, following meadow as compared with following corn or a grain which has followed corn. The latter part of the growing season was without rainfall, which made conditions for the grain crop still less satisfactory. The University Farm tests followed corn in regular rotations, and the rainfall during the growing season was ample.

In the variety tests three rows on either side of each plot were harvested separately, bound and tagged. They are referred to as outside border, middle border, and inside border rows, respectively. In the rates of seeding tests, two border rows were removed from either side of each plot in turn, bound and tagged. They are referred to as outside and inside border rows. In both tests the rows remaining after the various border rows were removed are referred to as central rows. They were harvested with the binder. At thrashing time each row or rows, in the case of the central areas, were thrashed with a small machine, and the grain was weighed.

The sizes of the areas from which yield determinations were made are given in Table I.

TABLE I.—*Areas from which yields were determined*

Location.	Number of 6-inch drill rows.	Dimensions of areas.	Part of an acre.
Morris Substation	1	6 inches×130 feet	1/670. 15
	8	4 feet×130 feet	1/83. 77
	10	5 feet×130 feet	1/67. 015
	12	6 feet×130 feet	1/55. 84
University Farm (rate of seeding test)	1	6 inches×132 feet	1/660
	13	6.5 feet×132 feet	1/50. 77
	15	7.5 feet×132 feet	1/44
	17	8.5 feet×132 feet	1/38. 82
University Farm (variety test)	1	6 inches×129 feet	1/675. 35
	11	5.5 feet×129 feet	1/61. 40
	13	6.5 feet×129 feet	1/51. 95
	15	7.5 feet×129 feet	1/45. 02
	17	8.5 feet×129 feet	1/39. 73

In order to secure the yields of the various plots with no border row removed, one removed, two removed, and (for the variety test) three removed, the weights of all portions of each plot were added together to secure the yields with no border rows removed. Likewise for the variety test the weights of the central rows and the two middle border rows were added to secure the yields with the outside border rows only removed, and for the rate test the inside border rows were added. In the variety tests the weights of the central rows and those of the inside border rows were combined to secure the yields of the plots with two border rows removed. The yields for the variety plots with three border rows removed and the rates of seeding plots with two border rows removed were computed from the weights of the grain from the central rows. The total weight of grain from the central rows was divided by the number of rows in order to secure the average yield for these rows. All computations have been checked.

EFFECT OF CULTIVATED ALLEYS ON YIELDS OF DIFFERENT PORTIONS OF PLOTS IN VARIETY AND RATE OF SEEDING TESTS

Examinations of the yield data as given in Table II for the rate of seeding tests with oats grown at Morris on sod land and under comparatively dry conditions show that at each rate the outside border rows yielded very much higher (an average of 233.6 per cent) than the inside border rows, which in turn produced at a higher rate (an average of 139.7 per cent) than the central rows.

TABLE II.—*Average yields in bushels per acre of oats from rate of seeding trials harvested from border drill rows spaced 6 inches apart removed from either side of plots 6 by 130 feet at the Morris Substation and 8.5 by 132 feet at University Farm and from the central 8 and 13 rows, respectively, which remained after the removal of border rows*

Source.	Number of rows or plots.	Yield in bushels per acre and in percentage based on the yields of the central rows sown at the rate (in pounds per acre) of—					Average yield per acre.
		48	64	80	96	112	
Morris Substation:		*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Outside border rows	40	84.1	99.6	105.9	104.1	103.0	99.3
Inside border rows	40	56.2	59.4	68.6	58.6	53.4	59.2
Central 8 rows	20	36.8	41.2	45.8	45.4	43.4	42.5
University Farm:							
Outside border rows	100	142.9	152.4	162.9	164.1	170.7	158.6
Inside border rows	100	70.3	62.4	72.2	81.1	77.4	72.7
Central 13 rows	50	72.3	72.2	76.1	70.3	75.5	75.1
Morris Substation:		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Outside border rows	40	228.5	241.7	231.2	229.3	237.3	233.6
Inside border rows	40	152.7	144.2	149.7	129.1	123.0	139.7
Average central rows	160	100.0	100.0	100.0	100.0	100.0	100.0
University Farm:							
Outside border rows	100	197.6	211.1	214.1	206.9	226.1	211.2
Inside border rows	100	97.2	86.4	94.8	102.3	102.5	96.6
Average central rows	650	100.0	100.0	100.0	100.0	100.0	100.0

At University Farm, under more favorable growing conditions, the outside border rows yielded on an average 211.2 per cent of the yield of the central rows. The inside border rows more often yielded less rather than more than the average of the central rows. In the 64-pound rate, the abnormally low average is due to a chance combination of low-yielding rows in this particular rate of seeding.

For the work with the varieties at University Farm the data for the 1917 work are included here in order that comparisons may be more easily made. In 1918 the outside border rows yielded considerably higher than the middle, inside, or central rows for all three crops. The middle and inside border rows of the oat and wheat crops yielded practically equally, whereas for the barley crop there is a difference of approximately 5 bushels between the two yields. Both the middle and

inside border rows yielded approximately 5 bushels higher than the average for the central rows.

Considered on the percentage basis the border effect, in 1918, on the outside rows was slightly higher for the oat and wheat crops and considerably lower for the barley crop than in 1917. The most striking difference in the results for the two seasons is that in 1918 the effect of the alleys for each of the three crops is much less apparent on the second rows (the middle border rows in 1918 and the inside border rows in 1917) than it was in 1917. The average in percentage for the three crops is 115.03 in 1918 as compared with 140.93 in 1917. In 1918, the third rows from the outside yielded approximately 5 bushels more than the average for the central rows for each of the three crops. Stated in percentages, the yields of the third rows from the outside are 106.1 for the oats, 113.7 for the wheat, and 108.6 for the barley, or an average for the three crops of 109.47 as compared with the average for the central rows.

TABLE III.—*Average yields in bushels per acre of varieties of oats, wheat, and barley harvested from border drill rows, spaced 6 inches apart, removed from either side of each plot and from the central rows remaining after the removal of the border rows, and the yields of the border rows in percentages based on the yields of the central rows*

Year and source.	Oats.		Wheat.		Barley.	
	Number of rows or plots.	Average yield per acre.	Number of rows or plots.	Average yield per acre.	Number of rows or plots.	Average yield per acre.
1918:		*Bushels.*		*Bushels.*		*Bushels.*
Outside border rows	112	142.8	56	73.1	72	99.9
Middle border rows	112	82.8	56	40.8	72	60.9
Inside border rows	112	80.0	56	39.8	72	55.8
Central 11 rows	56	75.4	28	35.0	36	51.4
1917:						
Outside border rows	88	131.97	40	55.00	32	97.73
Inside border rows	88	87.95	40	40.98	32	64.56
Central 13 rows	44	71.37	20	27.25	16	42.87
1918:		*Per ct.*		*Per ct.*		*Per ct.*
Outside border rows	112	189.4	56	208.9	72	194.4
Middle border rows	112	109.8	56	116.6	72	118.5
Inside border rows	112	106.1	56	113.7	72	108.6
Central 11 rows	56	100.0	28	100.0	36	100.0
1917:						
Outside border rows	88	184.9	40	204.4	32	238.0
Inside border rows	88	123.2	40	149.3	32	150.3
Central 13 rows	44	100.0	20	100.0	16	100.0

BORDER EFFECT AND THE INTERPRETATION OF YIELDS

It has been shown that the effect of alleys increases the yields of the outside border rows very materially and, in the majority of cases, increases the yield of the second and third rows also, but to a less extent. On small plots the effect of the increased yield of these border rows

results in materially higher yields for the plots when these rows are included as compared with results when they are removed before harvest (*2*). These increases in yields are given in Tables IV and V.

TABLE IV.—*Comparisons of increases in yields in bushels per acre and in percentage of oats sown at different rates in pounds per acre, with no border rows removed and with one border row removed from either side of each plot, based on the yields as 100 with two border rows removed*

Location and rates of seeding (in pounds per acre.)	Yield per acre.			Increase in yield per acre.			
	No border rows removed.	Outside border rows removed.	Both outside and inside border rows removed.	No border rows removed.		One border row removed.	
Morris Substation:	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Per cent.*	*Bushels.*	*Per cent.*
48	48.0	40.7	36.8	11.2	30.2	3.9	10.6
64	54.0	44.7	41.2	12.8	31.1	3.5	8.5
80	59.9	50.4	45.8	14.1	30.7	4.6	10.0
96	58.7	49.8	45.4	13.3	29.3	3.5	7.7
112	55.0	45.1	43.4	11.6	26.8	1.7	3.9
Average	55.1	46.1	42.5	12.6	29.6	3.4	8.1
University Farm:							
48	80.4	72.0	72.3	8.1	11.2	−0.3	−0.4
64	80.5	70.9	72.2	8.3	11.5	−1.3	−.2
80	93.0	75.7	76.1	16.9	22.2	−.4	−.5
96	88.8	79.5	79.3	9.5	12.0	.2	.2
112	86.9	75.8	75.5	11.4	15.1	.3	.4
Average	85.9	74.8	75.1	10.8	14.5	−.3	−.1

TABLE V.—*Comparison of the increases in yield due to border effect of oats, wheat, and barley in bushels per acre and in percentage based on the yields with three, two, and one, border row removed in 1918, and on yields with two and one border row removed in 1917, at University Farm, St. Paul, Minn.*

Crop.	Number of border rows removed from either side of each plot.	1918							1917				
		Yield per acre.	Increase in yield per acre over that secured with—						Yield per acre.	Increase in yield per acre over that secured with—			
			One border row removed.		Two border rows removed.		Three border rows removed.			One border row removed.		Two border rows removed.	
		Bush.	*Bush.*	*P. ct.*	*Bush.*	*P. ct.*	*Bush.*	*P. ct.*	*Bush.*	*Bush.*	*P. ct.*	*Bush.*	*P. ct.*
Oats	None	83.4	.....	.....	.....	.....	.....	.....	80.5	.....	.....	.....	.....
	One	75.9	7.5	9.87	8.2	10.90	9.1	12.25	73.6	6.9	9.38	9.1	12.74
	Two	75.2	.....	.....	.7	.93	1.6	2.15	71.4	.....	.....	2.2	3.08
	Three	74.3	.....	.....	.....	.....	.9	1.20	.....	.....	.....	.....	.....
Wheat	None	40.8	.....	.....	.....	.....	.....	.....	32.5	.....	.....	.....	.....
	One	36.4	4.4	12.09	5.0	13.97	5.7	16.24	29.2	3.3	11.30	5.21	19.05
	Two	35.8	.....	.....	.6	1.68	1.3	3.70	27.3	.....	.....	1.90	6.96
	Three	35.1	.....	.....	.....	.....	.7	1.99	.....	.....	.....	.....	.....
Barley	None	58.3	.....	.....	.....	.....	.....	.....	51.4	.....	.....	.....	.....
	One	53.2	5.1	9.59	6.3	12.12	6.9	13.42	45.8	5.6	12.23	8.5	19.81
	Two	52.0	.....	.....	1.2	2.31	1.8	3.50	42.9	.....	.....	2.9	6.76
	Three	51.4	.....	.....	.....	.....	.6	1.17	.....	.....	.....	.....	.....

For the rates of seeding tests at Morris, there is a rather uniform increase in yield averaging 12.6 bushels higher with no border rows removed as compared with yields when two rows were removed from either side of each plot. At University Farm the average increase was 10.8 bushels. When the outside border rows only were removed, the yields at Morris were from 1.7 bushels to 4.6 bushels higher than when both outside and inside borders were removed. At University Farm the removal of the outside border row appears to have done away with any border effect.

In the variety test at University Farm, in 1918, inclusion of the outside rows increased the yields of the oat crop 7.5 bushels, the wheat crop 4.4 bushels, and the barley 5.1 bushels. Including the three border rows on either side of each plot increased the yields of the oats 9.1, the wheat 5.7, and the barley 6.9 bushels. In 1917, the increases in yield due to border effect were still more marked.

On farms where crops are produced on fields of considerable size, border effect is negligible on account of the relatively small proportion of the field in border. Yields reported from plots, the borders of which have not been removed are therefore probably somewhat misleading, in that they are higher than those which would be secured from large fields under the same conditions. However, the more important consideration is the effect of borders on the relative yields of the different treatments in cultural tests and of the several varieties in tests of that nature.

The yields with the standard deviations and the rank at each rate of seeding for the oats at Morris and University Farm are given in Table VI.

TABLE VI.—*Comparison of average yields per acre from plots having alleys on sides and ends with no border rows removed, with one border row removed, and with two border rows removed from either side of each plot, for various rates of seeding of oats*

Location and rate of seeding (in pounds per acre).	Number of plots.	No border rows removed.			One border row removed.			Two border rows removed.		
		Yield per acre.	Rank.	Standard deviation.	Yield per acre.	Rank.	Standard deviation.	Yield per acre.	Rank.	Standard deviation.
Morris Substation:		*Bush.*			*Bush.*			*Bush.*		
48	3	48.0	5	6.45±1.78	40.7	5	5.52±1.52	36.8	5	6.78±1.87
64	3	54.0	4	.46± .12	44.7	4	1.10± .30	41.2	4	1.84± .51
80	3	59.9	1	2.49± .69	50.4	1	.98± .26	45.8	1	1.44± .40
96	8	58.7	2	5.93±1.63	48.9	2	6.57±1.81	45.4	2	7.31±2.01
112	3	55.0	3	4.46±1.23	45.1	3	5.75±1.58	43.4	3	7.73±2.13
Average		55.1		3.96	45.9		3.98	42.5		5.02
University Farm:										
48	10	80.4	5	7.03±1.66	72.0	4	7.64±1.15	72.3	4	7.97±1.20
64	10	80.5	4	5.77± .87	70.9	5	4.22± .64	72.2	5	3.84± .52
80	10	93.0	1	7.74±1.17	75.7	3	6.20± .94	76.1	2	7.66±1.16
96	10	88.8	2	7.33±1.11	79.5	1	6.89±1.04	79.3	1	7.72±1.17
112	10	86.9	3	5.24± .79	75.8	2	4.70± .71	75.5	3	4.98± .75
Average		85.9		6.62	74.8		5.93	75.1		6.43

Inspection of the yields from the various rates of seeding at Morris, with no border rows removed, show that the 80-pound seeding gave the highest yield and the others ranked in the following order: 96 pounds, 112 pounds, 64 pounds, and 48 pounds. This rank is not changed by the removal of one or two border rows. The least significant difference between the yields of any two rates of seeding was found for this test by using the formula

$$\frac{\text{standard deviation} \times 0.6745}{\sqrt{n}},$$

where n denotes the number of plots for each rate (*22*). The result was multiplied by 3.2, which makes the odds 30 to 1 that the result is not due to chance (*16*). For no border rows removed, this figure is 4.93. Where one and two border rows were removed, the figures are 4.96 and 6.27, respectively. If these are used in a broad way in the interpretation of the results, it appears that where no border rows were removed the 80-pound rate of seeding gave better results than the 64-pound rate, which in turn gave better results than the 48-pound rate. The interpretation of the results where one and two border rows were removed would not be much different.

At University Farm the rank with one and two border rows removed tends to be somewhat different than with no borders removed. Employing in a broad way 4.51, 4.06, and 4.38 bushels, respectively, as the least significant differences where none, one, and two border rows were removed, an interpretation of the results may be made. Where no border rows were removed, the 80-pound rate appears to have yielded the highest, with the 96-pound and 112-pound rates equal and in turn higher than the two lower rates. For the tests with one and two border rows removed, the 96-pound rate seems to have maintained a lead over the 80- and 112-pound rate and to have yielded significantly higher than the 64- or 48-pound rate of seeding.

The results for the variety tests of oats, wheat, and barley in 1918 with none, one, two, and three border rows removed are given in Table VII.

For the oat and barley varieties there are some changes in rank brought about by the removal of border rows. It is of interest to note that the removal of borders makes no change in the rank of the last four varieties, which were also the lowest in rank in the 1917 tests. In the barley variety test the rank of the Manchuria cross and the Chevalier are not changed. The Chevalier ranked the highest in 1917.

With the same formula as was used in the rate of seeding tests to secure figures representing the least significant differences, the following were secured for the oat tests: No borders removed, 5.26 bushels; one removed, 4.54 bushels; two removed, 4.46 bushels; and three removed, 6.90 bushels. These amounts have been subtracted from the

highest yielders under each method of test, and lines have been drawn at what may be considered the discard point for the season. Removal of one and three border rows, respectively, from either side of each plot lowers the discard point in the test. Due to the removal of the border rows, there are a number of changes in rank; but in general the varieties above the discard point with no border rows removed remain there under the other methods of test, except as has been previously noted.

For the wheat variety test the least significant differences in bushels per acre for the various methods of test are as follows: No borders removed, 1.67; one removed, 1.71; two removed, 1.92; three removed, 2.14. Lines have been drawn at what may be considered the discard point for the season. When no border rows were removed, Marquis gave a lower yield than Mindum or Preston; but with one border row removed from either side of each plot, Marquis equaled the other two in yield and maintained that rank with two and three border rows removed.

In the barley variety test the least significant differences were found to be for no border rows removed, 3.94 bushels; one row removed, 3.62 bushels; two rows removed, 3.58 bushels; and three rows removed, 3.97 bushels.

The removal of one border row from either side of each plot put the yield of one variety below the discard point adopted. The removal of three border rows put Svansota below the discard point. Removal of two border rows also raised Improved Manchuria from a rank of 6 to a rank of 4 in yield.

TABLE VII.—*Comparison of average yields per acre for 1918, for four $\frac{1}{40}$-acre plots (approximate size) with no border rows removed, and with one, two, and three border rows removed from either side of each plot for 14 varieties of oats, 7 varieties of wheat, and 9 varieties of barley*

Crop and variety.	Accession number.	Descriptive note.	No border rows removed.			One border row removed.			Two border rows removed.			Three border rows removed.		
			Yield per acre.	Standard deviation.	Rank.	Yield per acre.	Standard deviation.	Rank.	Yield per acre.	Standard deviation.	Rank.	Yield per acre.	Standard deviation.	Rank.
OATS.		Time of maturity:	*Bushels.*			*Bushels.*			*Bushels.*			*Bushels.*		
Lincoln	505	Medium	91.5	4.12±0.98	1	82.2	3.43±0.81	1	81.9	3.82±0.91	1	80.3	3.38±0.81	1
Selection [a]	358	.....do	90.2	6.55±1.56	2	81.8	5.36±1.28	2	79.8	5.33±1.27	2	77.2	6.28±1.50	6
Improved Ligowa [a]	281	.....do	88.8	8.16±1.95	3	80.1	7.67±1.83	3	78.8	8.43±2.01	4	78.7	9.31±2.22	3
Victory	314	.....do	88.1	1.59± .37	4	79.8	1.70± .41	4	79.0	2.07± .49	3	78.9	2.12± .51	2
Minota [a]	512	Medium early	87.7	8.48±2.02	5	79.1	8.75±2.09	6	78.3	9.04±2.16	5	78.1	9.27±2.21	4
Silvermine	506	Medium	86.9	3.84± .96	6	78.7	3.67± .88	7	79.8	1.08± .26	2	77.0	4.08± .97	7
Do. [a]	337	.....do	86.6	2.86± .68	7	79.4	3.00± .72	5	78.1	2.59± .62	6	77.4	2.56± .61	5
O. A. C. 72	500	.....do	[b] 86.1	2.05± .49	8	77.9	2.21± .53	8	[b] 77.3	1.42± .34	7	76.2	1.85± .44	9
Banner	507	.....do	85.7	3.19± .76	9	[b] 77.5	2.55± .61	9	76.9	2.92± .70	8	76.7	3.18± .76	8
Swedish Select	502	.....do	84.1	5.23±1.25	10	76.1	4.92±1.17	10	74.9	5.36±1.28	9	[b] 73.6	5.42±1.29	10
White Tartar	339	Late	76.8	8.53±2.03	11	69.8	2.42± .58	11	69.2	3.20± .76	10	68.4	2.93± .70	11
Iowa 103	531	Early	73.2	4.64±1.11	12	68.2	4.33±1.03	12	67.5	3.95± .94	11	67.3	4.17± .99	12
Kherson	261	.....do	71.6	5.64±1.34	13	66.2	5.76±1.37	13	66.2	5.50±1.31	12	65.9	5.92±1.41	13
O. A. C. 3	491	.....do	70.9	3.32± .79	14	66.2	3.14± .75	14	65.5	3.10± .73	13	64.9	3.44± .82	14
Average			83.4	4.87		75.9	4.21		75.2	4.13		74.3	6.39	
WHEAT.		Type:												$
Mindum [a]	470	Durum	45.8	2.30±0.55	1	41.0	2.16±0.52	1	39.8	1.97±0.47	1	38.6	2.40±0.57	1
Preston [a]	924	*vulgare*	[b] 45.0	1.90± .45	2	39.6	1.94± .46	2	39.7	2.14± .51	2	38.2	2.44± .58	2
Marquis	1239	.....do	43.2	1.43± .34	3	[b] 39.2	1.93± .46	3	[b] 38.1	2.21± .53	3	[b] 37.7	2.35± .56	3
Preston×Preston [a]	188	.....do	41.5	0.16± .04	4	36.8	0.02± .00	4	35.7	0.50± .12	4	35.0	0.45± .11	4
Glyndon Fife [a]	163	.....do	38.7	1.96± .47	5	34.4	1.76± .46	5	34.2	1.81± .43	5	34.2	2.11± .50	5
Haynes Bluestem [a]	169	.....do	36.0	1.25± .30	6	32.4	1.43± .34	6	32.0	1.56± .37	6	32.0	1.68± .40	6
Acme	1967	Durum	35.2	1.84± .44	7	31.6	1.83± .44	7	30.9	2.26± .54	7	30.1	2.42± .58	7
Average			40.8	1.55		36.4	1.58		35.8	1.78		35.1	1.98	

BARLEY.		Type:													
Lion×Manchuria [a]	438	6-row smooth awn	64.3	4.35±0.10	1	60.0	4.02±0.10	1	58.9	3.76±0.90	1	58.8	4.00±0.95	1
Do	437	do	62.9	3.35± .08	2	59.3	3.25± .08	2	58.5	3.52± .83	2	[b] 57.6	3.68± .88	2
Svansota [a]	440	2-row *erectum*	61.0	6.15± .15	3	[b] 56.5	4.92± .12	3	[b] 55.3	4.93±1.18	3	53.9	4.63±1.10	3
Manchuria [a]	105	6-row common	[b] 60.7	1.66± .04	4	53.9	5.52± .13	4	50.7	1.13± .27	6	49.5	1.41± .34	7
Minsturdi [a]	439	True 6-row	59.3	5.78± .14	5	53.8	2.66± .06	5	52.1	5.20±1.24	5	51.3	7.37±1.76	6
Improved Manchuria [a]	184	6-row common	58.7	2.12± .05	6	52.9	1.70± .04	6	52.5	2.94± .70	4	52.5	3.31± .79	4
Manchuria×Manchuria [a]	390	do	57.2	2.65± .06	7	52.3	1.25± .03	7	52.1	2.08± .50	5	52.2	2.31± .55	5
Do [a]	388	do	45.0	4.38± .10	8	48.2	4.18± .10	8	46.6	4.02±1.00	7	46.1	4.19±1.00	8
Chevalier [a]	230	2-row *nutans*	46.4	2.43± .06	9	42.2	2.62± .06	9	41.5	2.30± .55	8	41.0	2.24± .55	9
Average			58.3	3.65		53.2	3.35		52.0	3.32		51.4	3.68	

[a] From the Plant Breeding Section, University Farm.

[b] Discard point for year.

SUMMARY AND DISCUSSION OF RESULTS

From the data given in Tables II and III, it appears that, subject to the influence of environment and varying somewhat with the crop, the effect of 18-inch cultivated alleys on the outside rows of plots is quite uniform and marked.

The effect on the second 6-inch drill rows within the border of the plots appears to be more variable. Thus, as shown in Table III, in the 1917 variety test, the effect ranged from 123.2 per cent in oats to 149.3 per cent in wheat and 150.3 per cent in barley, based on the average yields of the central rows. In the 1918 variety test, the second rows averaged 109.8 per cent for oats, 116.6 per cent for wheat, and 118.5 per cent for barley, based on the yields of the central rows. Considering the results for the rate of seeding tests at Morris, the second rows, inside border rows, yielded at the rate of from 152.7 per cent for the thinnest seeding to 123.0 per cent for the thickest, based on the yields of the central rows. The greatest border effect on the second rows appears to be in the thinnest-sown, and the least effect in the thickest-sown plots. In the rate of seeding test at University Farm there appears to have been no effect on the second rows.

The effect on the third rows, inside border rows of the 1918 test, was slightly less than the effect on the second rows for each crop. They yielded at the rate of 106.1 per cent for oats, 113.7 per cent for wheat, and 108.6 per cent for barley, based on the yields for the central rows as 100.

Therefore, in this test with varieties of oats, wheat, and barley, the influence of 18-inch cultivated alleys extended to the third 6-inch drill rows within the plots on either side. When sown at this distance apart, the third drill rows occur at a distance 15 inches from the outside boundaries of the plots. Possibly the differences in the crops grown and in the environment may account for the influence of the borders being exerted to a greater distance within the plots than was observed by Bedford and Pickering (*3*). In their tests it is not stated whether a crop was growing on the other side of an alley or whether the rows were bordered by a considerable fallow space. A considerable fallow area presumably would exert an influence farther within a plot than a narrow cultivated alley flanked on the other side by the same crop.

Bedford and Pickering (*3*) found it necessary to make the outside rows, since the actual outside rows were often found to be so badly injured by the cultivating implements as to be unfit for use. In the absence of any statement on this matter, it is presumed that the rows of plants were removed from the plots very early before the root systems had become moderately well established. Otherwise the border effect may have been modified considerably by the growth of the plants before removal and later by the presence of the decaying roots in the soil.

It is not within the scope of this paper to discuss in any detail the reasons for border effect; but, from the greater effect in the thickness of seeding test at Morris in 1918 under comparatively dry conditions both on the first and second rows in the plots as compared with the results at University Farm, where favorable moisture conditions prevailed, it seems reasonable to assume that increased moisture supply with accompanying results probably is one of the prominent factors.

As to the effect of border rows on the interpretation of results, it has been shown that (1) where they are not removed the yields of plots are higher than where these rows are eliminated before harvest and (2) the rank of a variety or of a rate of seeding in relation to the discard point derived for the particular test may change on account of the removal of border rows.

If the only effect of border rows lay in increasing yields beyond what would be secured in large fields under like conditions, the expense of removal of borders would probably not be warranted. However, when the interpretation of the results, as has been brought out in Tables VI and VII and in the results for the 1917 variety tests (*2*), is necessarily different in some instances when the yields with the border rows is considered than when they are removed, the matter warrants very careful consideration. It is of interest to note in this connection that the removal of the border rows did not necessarily reduce the probable error in the tests.

When border rows are removed, the question arises as to how many. From the 1917 results (*2*) it seemed desirable to remove two border rows. In the 1918 tests, the effect on the second rows at Morris is very marked and in this respect is similar to the results with the varieties at University Farm in 1917. At University Farm, the effect on the second rows in the variety tests in 1918 is less marked than in the same tests in 1917, but the effect is shown to extend definitely to the third rows. In the rate of seeding test with oats there was practically no effect on the second rows.

From the data given, unless border effect can be prevented in some other way, it appears advisable as a precaution to insure the most reliable results to remove at least two 6-inch border rows from either side of grain plots bounded by alleys or roadways.

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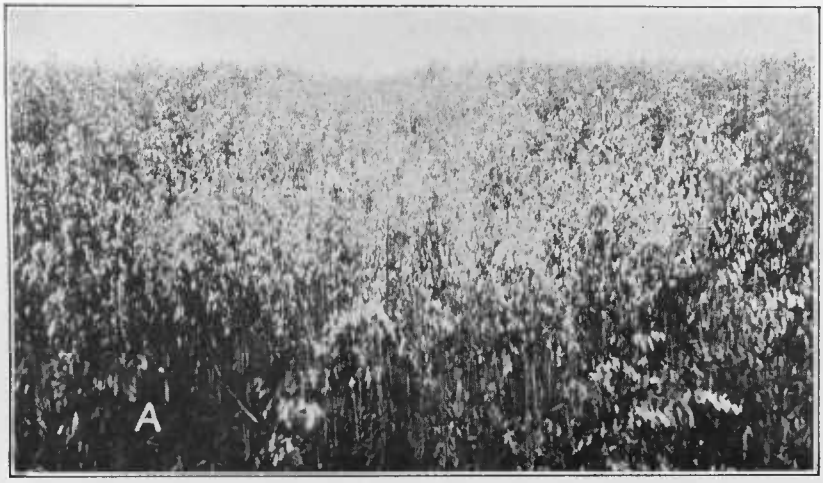
PLATE 94

Border effect shown in the experiment on rate of seeding of oats at Morris in 1918.
A.—Oats sown at rate of 48 pounds per acre.
B.—Oats sown at rate of 96 pounds per acre.
C.—Oats sown at rate of 112 pounds per acre.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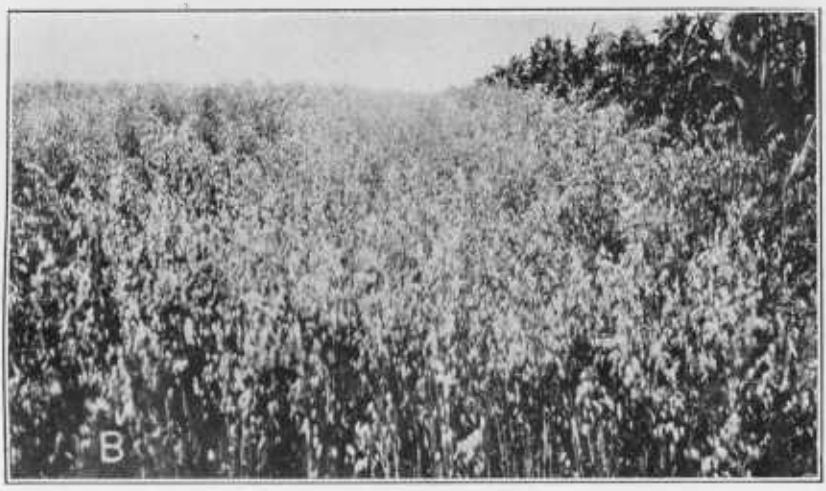
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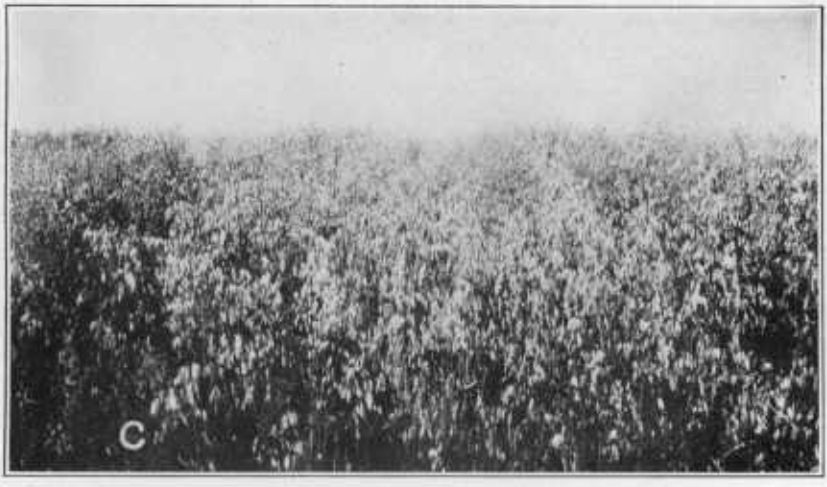
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