Use of Manures for Sugar Beets

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The use of animal manures for increasing the yields of farm crops and maintaining soil fertility is almost as old as agriculture. Much of the experimental work with farm manures has been limited to their application as a cheek on the performance of commercial fertilizers.

Salter (1) has given a resume of the use of manures in which he places the probable value of the entire production of barnyard manure in United States at 1 billion tons valued at 3 billion dollars which is more than the value of the wheat crop.[2] He suggests that the commonly used rate of application of manure is 8 tons per acre. It is also suggested in this article that phosphoric acid be applied in conjunction with manure.

One of the difficulties of manuring is that it increases foliage growth and thereby a greater amount of moisture is required for the production of a crop, but this becomes a relatively unimportant factor where ample water is available as under irrigation. Hastings (2) states that the value of a ton of farm manure in an irrigated rotation has ranged from a minimum of $1.00 to a maximum of $5.49 with a 24-year mean indicated value of $2.77. This variation in the returns from a ton of manure implies that there is a considerable increase in the returns from a ton of manure to be obtained by proper application.

Harris (3) states that the amount of manure used in the North Platte Valley is insufficient for best practices in maintaining soil fertility of the area; also, that the present method of handling the farm manures, in this area, permits a loss of from 25 to 50 percent of the value.

In work here reported, an attempt is made to remove some of the variables which are present in the experimental work which has been done to obtain information bearing upon the more efficient utilization of this valuable farm product. It is believed that these studies, in which a reasonably accurate measure of the amount of dry matter in the manure applied is given, can be used to provide information regarding the value of manures, and suggest methods for the best utilization of manures in the growing of sugar beets in the irrigated areas.

Materials and Methods

The studies were conducted with the sugar-beet crop as indicator of values obtainable from various kinds of manure and with a varied rate of application. In the field tests, plots approximately 1/30 of

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[2]Figures in parentheses refer to Literature Cited.

an acre, consisting of 14 rows, 62.5 feet long were used. In determining the results from plots, the 8 inside rows were harvested and weighed in the field; the 3 border rows on each side of the plot were discarded. The treatments were arranged as randomized blocks and the statistical reduction of data has followed the analysis of variance procedure (4). Sucrose percentage was determined by the Sachs-Le Docte method from two 20-beet samples from each plot. Apparent purity coefficients were calculated from the values for dry substance of the juice as obtained by the Bachler one-solution method.

The manures used in this test were taken from open yards, not covered sheds or stables. For each type of animal, the hay was fed from open racks. The measurement of moisture content of the manure was made immediately previous to spreading the manure since the moisture content would be quickly changed by any precipitation or prolonged dry period. A very different condition, in regard to moisture content of manure, exists where stables or sheds are used. Under such conditions, the type of animal and amount and type of bedding are the principal factors regulating the moisture content of the manure, while in these instances the frequency or the lack of precipitation is the regulating factor.

The manures used were yard manures produced over winter where straw was used for bedding in open yards, with dairy cattle, feeder lambs, and work horses, all of which were fed grain supplements. Moisture-content variation was recognized as a factor operative to interfere with the interpretation with tests of manures from various sources, places, or animals, and an attempt was made in these tests to standardize the application to a 50 percent moisture-content base. The manure was oven dried at a temperature of 85° C. to determine moisture contents. A certain amount of sand and gravel was incorporated in the manure by the tramping of the dirt in the feed yards by the animals, and this was washed out of the dried manure and redried and weighed in order to exclude this weight of sand from the weight of the dry manure. The application rates were adjusted among the different kinds of manures and for the years, so that in 6 tons comparisons, the plots received actually 3 tons of dry matter. The manure to be used on any series of plots was piled in the yard and 5 samples of moisture and sand determinations were taken from each type of manure each year, and after moisture and sand determinations were made the weighed quantity of manure was hauled to each plot and carefully spread by hand. The manure was weighed in trucks on a platform scale.

Where piled manure was used, the yard manure was placed in loose piles for 6 months or more, and applications were made upon the basis of the dry-matter content of the manure in the piles at the time of application. The fact that such piling of manures is con-

ducive to considerable losses of the weight of the manure is well known. Piling of manures is not advocated and this is only a test of the value of such materials.

Experimental Work

Tests in Field of High Fertility.—An experiment was begun in 1935 in a field near Scottsbluff, Nebraska. The treatments outlined below were repeated, using the same plots for 4 years. The growing of sugar beets without rotation provided some information on the cumulative effects of repeated manure applications. In this field, eighty 1/30-acre plots were used for treatments as shown in table 1, which gives the detailed data obtained. Since the results were, in many respects, consistent throughout these years of test, the data as summarized for the 4-year period, table 2, may be used in discussing these tests. For any individual method of treatment, a difference of 0.72 ton in acre-yields of roots is required to place it outside of chance occurrence (odds of 19 :1). For sucrose percentage, the amount of difference required for significance is 0.31; and indicated-available sugar, differences to be significant must reach 228 pounds; and for the apparent purity coefficients, the differences required are 0.30 percent.

The Interaction of Years x Blocks.—The replicates which are made up of years and blocks show significant F values for tons of beet roots, sucrose percentage of root, apparent purity coefficient of juice, and for indicated available sugar which indicates that there was considerable variation in the plot yields due to soil and seasonal variations. The effect of these variations can be calculated and eliminated in a test such as this one; however, it is of interest to note the various effects. Sucrose percentage indicates the greatest seasonal and soil variation by having the highest significance, and indicated available sugar is second in rank; purity coefficient is next in order, and tonnage of roots lowest, with all four factors being significant to much greater than the 1-percent degree (table 2).

In all these calculations on replicates, it is found that years indicate a greater significance or influence than blocks, and all are above the 1-percent point except block effect upon sucrose content of roots.

The interaction of years x blocks indicates significance beyond the 1-percent F requirement in all instances except for tons of beets where it falls between the 1 and 5-pereent points. None of the significance for this interaction is extremely high, as much of the variation is absorbed by the blocks and years.

Table 1.—The yield summary of treatment of sugar-beet plots, with manure from different types of livestock and the application of 6, 12, 18, or 24 tons per acre, over a period of 4 years at Scottsbluff, Nebraska.[1]

Manurial treatments	Tons of manure per acre	Harvested marketable beets per acre	Yield of marketable roots per acre	Sucrose content of roots	Apparent purity coefficient of juice	Gross sugar per acre	Indicated available sugar per acre
	(tons)	(beets)	(tons)	(percentage)	(percentage)	(lb.)	(lb.)
1. No manure	0	20589	16.2	17.0	89.2	5508	4913
2. Horse manure	6	20909	18.3	16.4	89.3	6002	5360
3. Cow manure	6	21224	18.0	16.3	89.6	5883	5258
4. Sheep manure	6	22077	18.5	16.4	90.2	6068	5473
5. Horse manure	6	21306	18.0	16.4	89.9	5904	5308
6. Cow manure	6	20799	18.1	16.2	88.8	5864	5207
7. Sheep manure	6	21202	18.3	16.2	89.5	5929	5306
8. Horse manure	12	20871	18.3	16.4	88.7	6002	5324
9. Cow manure	12	21037	20.5	16.9	88.7	6519	5782
10. Sheep manure	12	21556	20.4	16.1	88.5	6503	5814
11. Horse manure	18	21161	20.0	15.8	88.4	6320	5587
12. Cow manure	18	21332	19.8	15.3	88.1	6059	5328
13. Sheep manure	18	21081	20.2	15.6	87.3	6302	5502
14. Horse manure	24	20911	19.6	15.7	87.4	6154	5379
15. Cow manure	24	20308	20.3	15.4	87.2	6252	5452
16. Sheep manure	24	20123	20.3	15.5	88.4	6203	5563
Mean of all treatments		20999	19.1	16.0	88.7	6101	5410
Summation							
Piled manure	6	21403	18.3	16.4	89.7	5979	5364
Yard manure	6	21101	18.1	16.3	89.4	5899	5274
Yard manure	12	21287	19.7	16.1	88.7	6343	5640
Yard manure	18	21121	20.0	15.6	87.9	6227	5476
Yard manure	24	20147	20.1	15.5	87.7	6223	5465
Horse manure	all rates	20612	18.8	16.1	88.8	6076	5392
Cow manure	all rates	21060	19.3	15.8	88.5	6112	5407
Sheep manure	all rates	21308	19.5	16.0	88.8	6232	5532

[1]Manure used in treatments 2, 3, and 4 was piled for more than 6 months and manure for treatments 5 to 16, inclusive, was fresh from the yards. The yield figures represent the mean of 20 yields which are 5 replications of each treatment continued on the same plots over a period of 4 years.

(Table 1—continued)

Difference required for siguifieauee for the yield summary of sugar-beet plots, with manure from different types of livestock and the application of 6, 12, 18, or 24 tons per acre over a period of 4 years at Scottsbluff, Nebraska,

Manurial treatments	Yield of marketable roots per acre	Sucrose content of roots	Apparent purity coefficient of juice	Indicated available sugar per acre
Any of the 16 treatments				
odds 19 : 1	1.247	.5277	1.652	394.5
odds 99 : 1	1.621	.6860	2.148	512.9
Summation of tons per acre treatments				
odds 19 : 1	0.720	.303	0.302	227.8
odds 99 : 1	0.936	.397	0.393	296.1
Summation of kinds of manure				
odds 19 : 1	0.557	.236	0.234	177.3
odds 99 : 1	0.724	.307	0.304	230.8

The Interaction of Treatment x Years x Blocks.—The interactions of treatment x years, treatment x blocks, and treatment x years x blocks are not significantly larger than error in many instances (table 2). Treatment x blocks is greater than error for tons of roots, sucrose content of roots, and indicated available sugar but is not significant for purity. Treatment x years is greater than error for purity and indicated available sugar and less thau error for sucrose content and tons of roots. Treatment x blocks x years is greater than error for the other items of sugar-beet yield. These interactions and their significance can be interpreted as indicating that there is more difference in effect of manures upon plots than for seasons on tons of roots and sucrose content or that these treatments were inclined to have similar effects during the 4 years of treatment but some plots responded more readily to treatment than others.

With these criteria for testing results, it is found that among the kinds of manures no significant differences were found. In table 1, it is to be noted that if comparisons are made of items 2, 3, 4, or 5, 6, 7, etc. in which the amount applied was held constant, the contrasts being made between sources, the values hold at very close levels throughout any rate group. For convenience, since the treatments throughout the years were balanced, the results for each kind of manure may be summarized, and the comparisons based on the experiment as a whole.

The average acre-yield of roots over the 4 years for all plots receiving horse manure was 18.8 tons, plots receiving cow manure averaged 19.3 tons, and the plots receiving sheep manure. 19.5 tons. The greatest difference here is 0.7 ton of roots and .72 is required for significance. The sucrose percentages found for these respective kinds of manure were 16.1, 15.8, and 16.0, none of these values differing significantly from the others. The greatest difference is .30 percent and .31 is required for significance. When the products of weight of roots, sucrose percentage, and apparent purity coefficients are obtained for each plot individually to give a value designated as indicated available sugar, these values, arranged in the same order as stated above for kinds of manure, are 5.392, 5,407, and 5,532 pounds per acre. The greatest difference here is 140 pounds, and 228 pounds are required for significance. Since none of the differences between these amounts is significant, this test does not produce any evidence that the manures obtained from horses, cows, or sheep, when compared on equivalent bases of dry weight, differ in agricultural value.

The data from the 4-year experiment afford a comparison of manures stored for 6 months or more (table 1, classed as piled manure) and manures taken directly from the feeding pens. These comparisons deal with only one application rate—6 tons gross, corresponding in each case to 3 tons of dry matter. If items 2, 3, and 4

Table 2.—Analysis of variance of yield of tons of sugar-beet roots from plots variously treated with manure.

Source of variation	Degrees of freedom	Mean square	Calculated F value	Significant F values 5 percent	1 percent
Entire field 320 plots					
Between replicates	19	57.614	14.85	1.64	1.98
Between treatments	15	31.015	7.99	1.70	2.10
Replicates x treatments (error a)	285	3.880			
Years	3	330.089	121.27	2.85	3.88
Blocks	4	11.892	4.80	2.41	3.41
Years x blocks	12	4.734	1.91	1.80	2.28
Manure x none	1	175.72	70.94	3.89	6.76
Rates x kinds (piled manure)	2	0.947		3.04	4.71
Rates x kinds (yard manure)	11	19.802	7.99	1.83	2.34
Piled x yard manure	1	69.794	28.18	3.89	6.76
Treatment x years	45	2.949	1.19	1.44	1.66
Treatment x blocks	60	8.790	3.55	1.40	1.58
Treatment x blocks x years (error b)	180	2.477			
210 plots treated with yard manure and excluding piled manure and untreated check plots					
Replicates	19	42.383	11.50	1.62	1.97
Treatment	11	19.802	5.37	1.83	2.34
Replicates x treatments (error c)	200	3.685			
Years	3	23.708	11.77	2.08	3.94
Blocks	4	11.503	5.71	2.44	3.47
Blocks x years	12	4.003	1.99	1.88	2.33
Rates	3	49.973	24.81	2.68	3.94
Kinds	2	16.351	8.12	3.07	4.78
Rates x kinds	6	5.866	2.91	2.17	2.95
Treatment x years	33	1.012		1.54	1.88
Treatment x blocks	44	9.758	4.846	1.46	1.73
Treatment x blocks x years (error d)	132	2.014			

Table 2a.—Analysis of variance of sucrose content of sugar beets from plots variously treated with manures.

Sources of variation	Degrees of freedom	Mean square	Calculated F value	Significant F values	
				5 percent	1 percent
Entire field 320 plots					
Between replicates	19	28.9754	41.57	1.64	1.96
Between treatments	15	4.2154	6.05	1.70	2.10
Replicates x treatments (error a)	285	0.6970			
Years	3	171.8826	294.27	2.65	3.88
Blocks	4	1.3202	2.26	2.41	3.41
Years x blocks	12	2.4745	4.24	1.80	2.38
Manure x none	1	18.8752	32.32	3.89	6.76
Rates x kinds (piled manure)	2	0.0512		3.04	4.71
Rates x kinds (yard manure)	11	11.5052	19.70	1.83	2.34
Piled x yard manure	1	2.9771	5.10	3.89	6.76
Treatment x years	45	0.6494	1.11	1.44	1.66
Treatment x blocks	60	1.0716	1.84	1.40	1.58
Treatment x blocks x years (error b)	180	0.5840			
240 plots treated with yard manure and excluding piled manure and untreated check plots					
Replicates	19	24.8131	33.97	1.62	1.97
Treatments	11	2.9771	4.08	1.83	2.34
Replicates x treatments (error c)	209	0.7304			
Years	3	147.0111	240.10	2.68	3.94
Blocks	4	1.1879	1.93	2.41	3.47
Blocks x years	12	1.9886	3.24	1.83	2.33
Rates	3	8.5858	13.97	2.68	3.94
Kinds	2	2.9374	4.78	3.07	4.78
Rates x kinds	6	0.1860		2.17	2.95
Treatment x years	33	0.5754		1.54	1.88
Treatment x blocks	44	1.1035	1.94	1.46	1.78
Treatment x blocks x years (error d)	132	0.6148			

Table 2b.—Analysis of variance of apparent purity coefficient of sugar beets from plots variously treated with manures.

Source of variation	Degrees of freedom	Mean square	Calculated F value	Significant F values 5 percent	1 percent
Entire field 320 plots					
Between replicates	19	118.07	17.312	1.64	1.98
Between treatments	14	16.42	2.408	1.70	2.10
Replicates x treatments (error a)	285	6.82			
Years	3	462.39	63.689	2.65	3.88
Blocks	4	38.70	5.331	2.41	3.41
Years x blocks	12	58.45	8.051	1.80	2.88
Manure x none	1	4.42		3.89	6.76
Rates x kinds (piled manure)	2	4.09		3.04	4.71
Rates x kinds (yard manure)	11	78.65	10.833	1.83	2.34
Piled x yard manure	1	14.16	1.942	3.89	6.76
Treatment x years	45	7.14		1.44	1.66
Treatment x blocks	60	5.28		1.40	1.58
Treatment x blocks x years (error b)	180	7.26			
240 plots treated with yard manure and excluding piled manure and untreated check plots					
Replicates	19	87.32	11.737	1.62	1.97
Treatments	11	14.10	1.895	1.83	2.34
Replicates x treatments (error c)	209	7.44			
Years	3	363.13	45.278	2.68	3.94
Blocks	4	25.32	3.157	2.44	3.47
Years x blocks	12	39.04	4.868	1.83	2.33
Rates	3	27.61	4.077	2.68	3.94
Kinds	2	3.45		3.07	4.78
Rates x kinds	6	5.95		2.17	2.95
Treatment x years	33	7.01		1.54	1.88
Treatment x blocks	44	6.03		1.46	1.73
Treatment x blocks x years (error d)	132	8.02			

Table 2c—Analysis of variance of indicated available sugar per acre of sugar beets from plots variously treated with manures.

Sources of variation	Degrees of freedom	Mean square	Calculated F value	Significant F values 5 percent	1 percent
Entire field 720 plots					
Between replicates	19	8,492,748	21.82	1.64	1.98
Between treatments	15	839,245	2.16	1.70	2.10
Replicates x treatments (error a)	285	388,855			
Years	3	45,753,118	126.58	2.65	3.88
Blocks	4	2,227,328	6.16	2.41	3.41
Years x blocks	12	1,233,621	3.41	1.80	2.88
Manure x none (piled manure)	1	5,383,711	15.31	3.89	6.76
Rates x kinds (piled manure)	2	86,744		3.04	4.71
Rates x kinds (yard manure)	11	211,418		1.85	2.34
Piled x yard manure	1	606,369	1.68	3.89	6.76
Treatment x years	45	359,051		1.44	1.66
Treatment x blocks	60	491,305	1.36	1.40	1.58
Treatment x blocks x years (error b)	180	361,469			
240 plots treated with yard manure and excluding piled manure and untreated check plots					
Replicates	19	6,102,482	15.72	1.62	1.97
Treatments	11	606,369	1.56	1.85	2.34
Replicates x treatments (error c)	209	388,219			
Years	3	32,409,069	85.73	2.68	3.94
Blocks	4	1,988,870	5.26	2.44	3.47
Blocks x years	12	889,056	2.35	1.83	2.32
Rates	3	1,130,081	3.01	2.68	3.94
Kinds	2	108,072	1.29	3.07	4.78
Rates x kinds	6	486,111		2.17	2.95
Treatment x years	33	425,825	1.15	1.54	1.98
Treatment x blocks	44	519,661	1.38	1.46	1.73
Treatment x blocks x years	132	377,958			

of table 1 are used in the appropriate comparisons with items 5, 6, and and 7. it is to be noted that the values obtained show about the same performance level for crop and sugar production. When these data are summarized, the stored versus fresh manure (horse, cow, and sheep), when compared on the same dry-matter level, gave results from applications to sugar beets which did not differ significantly.

The data, also, may be used to determine the relative gains coming from the successive 6-ton increments in comparison with that obtained by a 6-ton application over the contrasted series. With this high-yielding field, as has been mentioned, the mean yield from untreated plots was at the rate of 16.2 tons of roots per acre. The application of 6 tons of manure gave an increase in yield of 2 tons of roots per acre, or a 12.4 percent increase in yield. Increasing the applications to 12 tons per acre resulted in an average increase over the untreated of approximately 21.6 percent, hence the gain from the second 6-ton application over the first was slightly less than 9.2 percent. The addition of 6 more tons in the application rate so that 18 tons of manure were applied only increased the yield 0.3 of a ton per acre above the average yield obtained from the 12-ton applications, and increasing the application to the rate of 24 tons per acre resulted in an increase in yield of only 0.1 of a ton above the acre-yield of roots from the 18-ton application. There was a definite decrease in sucrose percentages as the rates of manure applications increased, as shown in table 1, the sucrose percentages for plots receiving 18 and 24-ton manure applications being 15.6 and 15.5 respectively.

It is probably more informative to base consideration on acre-yields of indicated available sugar with the respective 6, 12, 18, and 24-ton rates of application. On this basis, there is about 8.3 percent increase over the unfertilized plots in the plots receiving 6 tons of manure. The gain of the plots receiving 12 tons of manure over the unfertilized plots is 14.8 percent. With still heavier application, the gains in yield are no larger than from the 12-ton application. There are direct implications from these diminishing returns as manure applications increase above a certain point which will be further considered after the results from the other test are presented.

Tests in Field of Low Fertility.—In 1936, a second experiment was begun in a field of low fertility. Fifty 1/30-aere plots were used for 10 treatments to be replicated 5 times. The treatments, as shown in table 3, were as follows: Fresh cattle manure was used in 4 plots at rates of 6, 12, 18, and 24 tons (.50 percent moisture basis) per acre. In 4 plots these same rates of manure were used but a supplementary treatment of 150 pounds of treble superphosphate (43 to 45 percent P_2O_5) was given. One plot received only 150 pounds of treble superphosphate, and one plot was not fertilized. The 4-year average for

acre-yield of roots in this field from the untreated plots was only 8.0 tons.

The detailed results for 1936, 1937, 1938, and 1939 are given in table 3. Since there is a fair concordance among the tests, the 4-year averages, as shown in table 4, may be used as a basis of discussing the experiments in this field.

Table 3.—The yield summary of treatment of sugar-beet plots, with barnyard manure applied at the rates of 6, 12, 18, and 24 tons and ISO pounds of acid phosphate per acre, over a period of 4 years at Torrington, Wyoming.

No.	Treatments: Phosphate per acre	Treatments: Manure per acre	Percentage stand	Yield of marketable roots per acre	Sucrose content of roots	Gross sugar per acre
	(lb.)	(tons)	(percentage)	(tons)	(percentage)	(lb.)
1.	0	0	60	8.0	17.0	2788
2.	0	6	73	12.9	17.3	4462
3.	0	12	72	13.9	17.4	4805
4.	0	18	75	14.5	16.8	4841
5.	0	24	72	15.1	16.3	4895
6.	150	0	70	10.8	17.8	3808
7.	150	6	74	13.9	17.2	4724
8.	150	12	74	13.7	17.5	4752
9.	150	18	73	14.6	16.3	4718
10.	150	24	77	15.3	16.1	4914
Mean of all treatments			72	13.3	17.0	4471

Difference required for significance for the yield summary of sugar-beet plots, with application of 0, 12, 18, 24 tons of manure and 150 pounds of acid phosphate per acre, over a period of 4 years at Torrington, Wyoming.

Any of the 10 treatments				
odds 19: 1	5.22	0.96	1.802	398
odds 99: 1	6.77	1.25	2.343	517

Table 4.—Analysis of variance of yield of tons of sugar-beet roots front plots variously treated with manure,

Sources of variation	Degrees of freedom	Mean square	Calculated F value	Significant F values: 5 percent	Significant F values: 1 percent
Between replicates	19	55.89	24.19	1.65	2.03
Between treatments	9	101.77	44.06	1.94	2.53
Replicates x treatments (error a)	171	2.31			
Years	3	238.39	102.27	2.70	3.98
Blocks	4	39.11	16.79	2.46	3.51
Years x blocks	12	15.87	6.81	1.85	2.36
Manure and phosphate vs. none	9	101.77	44.06	1.94	2.53
Treatment x years	27	2.29		1.57	1.80
Treatment x blocks	36	2.91	1.25	1.55	1.87
Treatment x blocks x years (error b)	98	2.33			

Table 4a.—Analysis of variance of sucrose content of sugar beets from plots variously treated with manure.

Between replicates	19	8.54	11.90	1.62	2.03
Between treatments	9	7.13	9.90	1.94	2.53
Replicates x treatments (error a)	171	.72			
Years	3	24.78	29.56	2.70	3.98
Blocks	4	11.19	13.48	2.46	3.51
Years x blocks	12	3.60	4.34	1.85	2.36
Manure and phosphate vs. none	9	7.13	9.90	1.94	2.53
Treatment x years	27	.47		1.57	1.89
Treatment x blocks	36	.82		1.55	1.87
Treatment x blocks x years (error b)	98	.83			

Table 4b.—Analysis of variance of gross sugar per aero of sugar beets from plots variously treated with manure.

Sources of variation	Degrees of freedom	Mean square	Calculated F value	Significant F values 5 percent	1 percent
Between replicates	19	4404425	11.716	1.62	2.03
Between treatments	9	9175872	23.005	1.94	2.53
Replicates x treatments (error a)	171	398234			
Years	3	19180085	30.237	2.70	3.98
Blocks	4	2650119	4.206	2.46	3.51
Years x blocks	12	1493008	3.055	1.85	2.36
Manure and phosphate vs. none	9	9175872	23.005	1.94	2.53
Treatment x years	27	318250		1.57	1.89
Treatment x blocks	36	312730		1.55	1.87
Treatment x blocks x years (error b)	98	488827			

Table 4c.—Analysis of variance of percentage stand of sugar beets from plots variously treated with manure.

Between replicates	10	628	9.24	1.62	2.03
Between treatments	9	445	6.54	1.94	2.53
Replicates x treatments (error a)	11	68			
Years	3	2775	40.79	2.70	3.98
Blocks	4	141	2.07	2.46	3.51
Years x blocks	12	253	3.72	1.85	2.36
Manure and phosphate vs. none	9	445	6.54	1.94	2.53
Treatment x years	27	112	1.65	1.57	1.89
Treatment x blocks	36	54		1.55	1.87
Treatment x blocks x years (error b)	98	68			

The tests in the field of low fertility have given interesting results which also have bearing on the rates of fertilizer application. In this 4-year test, only manure from cattle-feeding pens was used, the rates being 6, 12, 18, and 24 tons of 50 percent dry-matter manure per acre. The test also affords an opportunity to evaluate effects derived from the supplementary phosphate application which occurred on one-half of each of the manured plots. The plots without treatment had an average lower stand of harvested beets than any treated plots in the series, and the acre-yield of roots over the period was 8.0 tons. Sucrose percentage was high (17.6 percent) and the pounds of gross sugar per acre as calculated was only 2,788 pounds. By the application of 6 tons of manure per acre the acre-yield of roots was increased 4.9 tons, and the sugar-per-acre production increased 60.0 percent. Further increase of 1 ton of roots was shown by an application of 12 tons of manure and sugar-per-acre gain over untreated plots was 72.4 percent. With higher rates of manure application, slight gains were shown.

The Effect of Different Rates of Application of Manure

The amount of manure applied per acre is of much more importance than the kind of manure. Tons of beets per acre, sucrose (tontent of roots, and apparent purity coefficient are significantly influenced to the 1-percent F degree while indicated available sugar is significant to above the 5-percent F and not to the 1-percent F This is due to the lighter application of manure producing the lower yield of roots which had higher sucrose content and higher apparent purity than the beets from the plots which received more than 6 tons of manure per acre per year. The highest yield of gross sugar and indicated-available sugar per acre was produced by the use of 12 tons of manure per application (table 2). The most efficient use of manure is indicated by the use of 6 tons of manure per acre and the least efficient use of manure is where 24 tons were applied per acre. This is true for both fields tested.

The Relative Value of Sheep, Cow, and Horse Manure

The effect of kinds of manure as calculated for yard manures indicates a significant difference in the tons of roots and sucrose content but no significant difference for apparent purity or indicated-available sugar (table 2). Sheep and cow manures produced higher tonnage of roots and lower sucrose content of beets than horse manure, while all had practically the same purity coefficient and the indicated-available sugar and gross sugar per acre were slightly highest for sheep manure and lowest for horse manure. Since indicated-available sugar per acre is the most efficient comparison of the value of manure used in sugar-beet production, it is upon this measure of yield that the conclusions from these tests are made. The indications

from these tests are that equal amounts of cattle, horse, or sheep manure (based upon dry weight) are of equal value in the production of sugar beets.

The item, rates x kinds, of piled manures includes only one rate -6 tons of manure per acre per year—and therefore the differences are entirely due to kinds of manure. No significant variation in effect of treatment is found which indicates no difference in the value of kinds of piled manures.

The calculation of piled manures versus yard manures shows significance for tons of roots, sucrose content, and apparent purity but no significance for. indicated available sugar because the purity and sucrose content are lower and the tonnage higher for yard manures than for the piled manures. This item is of little value because the yard manures were used at different rates while the piled manure was applied only at the rate of 6 tons per acre.

A record of the differences in dry matter in manures from different kinds of animals and differences in the manure from the same kinds of animals during different years is included in table 5.

The item of sand is made up of particles which were obtained by washing and "panning" the manure to float out manure and retain the heavy particles. In this manner, all fine soil is washed out and included in the weight of the manure.

The Use of Phosphate with Manure

Where 150 pounds of superphosphate (43 to 45 percent P_2O_5) were applied per acre, the increase in gross sugar per acre was 1,020 pounds, the increase in sucrose percentage was 0.2, which is not significant, and the increase in roots per acre was 2.8 tons, which is significant. The addition of 6 tons of manure per acre along with 150 pounds of phosphate gave a greater increase than the use of either 150 pounds of phosphate or 6 tons of manure. However, in one instance, in which the use of phosphate along with a given amount of manure was compared with the use of the manure alone, there was significant increase in favor of the first.

The use of 150 pounds of phosphate and 6 tons of manure per acre did give an increase in yield which more closely approaches that produced by 12 tons of manure than that produced by 6 tons of manure. With 12, 18, or 24 tons of manure, the yield was not increased by the addition of phosphate. The addition of phosphate to repeated heavy applications of manure is apparently not beneficial. However, with light applications of manure, phosphate should be added to this type of soil. Infrequent applications of manure should respond in a manner similar to the light applications of manure.

Table 5.—Dry matter, sand, and water content of the manures used in these tests, in percentages.

Kind of manure	1935			1936			1937			1938		
	Dry matter	Sand	Water	Dry matter	Sand	Water	Dry matter	Sand	Water	Dry matter	Sand	Water
(Scottsbluff, Nebraska, test)												
Cattle manure, yard	52.0	4.5	43.5	34.1	6.9	59.0	27.1	1.1	71.8	29.0	1.8	69.2
Cattle manure, piled	62.1	10.6	27.3	65.0	9.1	25.9	90.5	0.5	9.0	71.0	7.9	21.1
Horse manure, yard	52.4	7.8	40.3	47.2	5.8	46.0	43.0	7.1	49.9	45.0	6.7	48.3
Horse manure, piled	33.1	16.9	50.0	42.1	8.5	57.4	30.1	3.2	66.7	40.0	6.9	53.1
Sheep manure, yard	43.5	4.6	47.4	43.2	2.8	54.0	32.0	1.0	67.0	36.0	5.2	58.8
Sheep manure, piled	60.9	15.0	24.1	70.0	3.5	26.5	68.0	2.8	29.2	69.0	4.4	26.6
(Torrington, Wyoming, test)		1935			1937			1938			1939	
Cattle manure from the feed yard	58.5	10.1	31.4	40.0	9.2	50.8	49.9	8.1	42.0	48.0	10.0	32.0

Summary

1. Horse, cattle, and sheep manures are of equal value for use on sugar beets if value is based upon the dry-matter content of the manures.

2. Six tons of manure per acre produced the greater increase in yields for each ton of manure.

3. The maximum production per acre was obtained by the use of 12 tons of manure per acre.

4. The use of 18 or 24 tons of manure does not increase the yield sufficiently to recommend the use of more than 12 tons per acre per yea r.

5. Greater returns were obtained by the use of manure on low-yielding; fields than on the fields of higher production.

6. Phosphate was beneficial where used with a light application of manure.

Literature Cited

1. Salter, Robert M., and Schollenberger, C. J. 1938. Farm Manure, U. S. D. A. Yearbook, pp. 445 to 461.
2. Hastings, Stephen H. 1936. Irrigated Crops in Western Nebraska, 1912-1934, U. S, D. A, Tech. Bul. 512, 36 pp., illus.
3. Harris, Lionel. 1938. The Value of a Ton of Farm Manure in the North Platte Valley. Univ. of Nebr., Col. of Agri., Lincoln, Nebr. Bul. 318, 20 pp., illus.
4. Fisher, R. A. 1932. Statistical Methods for Research Workers., Ed. 4 Rev. and enl. 307 pp. illus., Edinburgh & London.