BULLETIN 493 NOVEMBER, 1931

Celery Fertilizer Experiments in Ohio

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CELERY FERTILIZER EXPERIMENTS IN OHIO

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The state of Ohio contains many acres of bog and marsh land. Much of this land is still in the process of forming—and some has already formed—soils of agricultural value. The estimate for the acreage of peat and muck soils is 150,000, some of which are not suitable for cultivation at the present time. Just what proportion of this area may be considered muck soil of value for vegetable production is not accurately known. The most reliable estimate places the acreage of muck soil under cultivation as 75 per cent (67,000 acres) of that suitable for vegetable production.[1]

The actual experimental data on the nutrient requirements of vegetable crops grown on muck soils are meagre. It has already become the accepted practice among growers to govern their application of fertilizers in accordance with the crop to be grown rather than the soil type. For this reason experimental work with fertilizers is usually reported with reference to the requirements of a specific crop rather than a soil type although the latter is always taken into consideration.

Since the work on celery herein reported is the first attempt made by the Ohio Station to determine, experimentally, the nutrient requirements of vegetable crops on muck soils, the lack of finality in the work is partially explained. It is hoped that still more definite results will be obtained in the future.

The majority of celery growers in Ohio are convinced that adequate fertilization is necessary for the production of a satisfactory yield of a high quality celery, but observation is not always sufficient to prove the superior value of certain fertilizer treatments.

Popular fertilizer practices based on the experience of celery growers in this State include formulas with nitrogen, phosphoric acid, potassium ratios of 1-2-3, 1-3-6, 1-4-8, and occasionally 1-4-12. The majority of growers use either a 2-8-16 or a 3-9-18 fertilizer and are pretty general in their use of at least ½ ton per acre of these mixtures.

To determine more definitely by experiments the requirements of celery, the Department of Horticulture has had in progress a series of fertilizer plots on muck located 5 miles northwest of the city of Ravenna in Portage County.[2] [3]

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[1]Dachnowski, Geological Survey of Ohio, 4th Series, Bull. 16. 1912.

[2]The experiment was located on the farm of J. S. DeYoung, whose cordial aid and willingness to meet the requirements of controlled experimental work contributed greatly to the reliability of the results. He was in complete charge of the growing of the crop and undertook a great deal of responsibility during this period.

[3]During the first year the work was under the direction of Dr. Roy Magruder formerly of this Station; and subsequently under that of the author.

OUTLINE AND METHODS OF EXPERIMENTS

The soil on which the experiments were conducted is a typical muck and characteristic of those used for the production of celery in Ohio. It was cleared of virgin growth in 1924 and was in good physical condition at the time the experiments were started. The land selected for the plots was drained by tile lines and adjoining ditches. The muck layer had a minimum depth of 3 feet. The area used was divided into 15 plots, 64 feet by 18 feet 9 inches. They were arranged in one row in a continuous series. The north half of each plot received 2 tons of ground limestone per acre every other year, the initial application being made in 1925.

All plots of the limed and unlimed series were of the same size, containing eight rows of approximately 45 plants each and comprising approximately one-seventieth acre. There were guard rows between the two series and on the outside, and buffer spaces between treatments. These were not included in the harvest records.

Seed of the variety Columbia was sown about May first of each year, and the seedlings set the first week in July, 5 inches apart in rows 3½ feet apart.

The general plan of the experiment, including plot treatments, is given in Table 1. A basic treatment of 1000 pounds per acre of a 2-8-16 fertilizer, considered an average application for the district, was applied to all plots, including the checks, with the single exception of Plot 8 which received common table salt alone.

TABLE 1.—Fertilizer Treatments and Yields on Celery Experimental Plots at Ravenna, Portage County, Ohio

Average annual yield and increase due to supplement in pounds per acre, 5 years, 1925-1929

Plot	Total application 1000 pounds per acre	Actual yield	Supplemental treatments				
			Supplement to 1000 pounds of 2-8-16 fertilizer	Applied after or before setting plants	Increase above check		
			Pounds		*Pounds*	*Per cent*	*Odds*
1 Ck..	2- 8-16	37914					
2.....	2- 8-32	41645	320 Mur. Potash	Before	3326	8.6	20 : 1
3.....	2-16-16	41600	400 Superphosphate	Before	2876	7.4	14 : 1
4.....	2- 8-16	43946	8 T. Manure	Before	4817	12.3	18 : 1
5.....	10-12-24	46355	1000 8-4-8	Before	6821	17.2	9 : 1
6 Ck..	2- 8-16	39940					
7.....	2- 8-16*	33755			— 5950	—14.9	72 : 1
8.....	400 Salt†	29438			—10032	—25.4	134 : 1
9.....	8- 8-16	42112	400 Nit. Soda	3 wks. after	3209	8.1	8 : 1
10.....	8- 8-16	41836	200 Nit. Soda	3 and 6 wks. after	2836	7.2	14 : 1
11 Ck..	2- 8-16	38764					
12.....	8- 8-16	42109	160 Amm. Sulphate	3 and 6 wks. after	3419	8.8	65 : 1
13.....	4-16-32	46879	500 2-8-16	3 and 6 wks. after	8263	21.3	40 : 1
14.....	3-12-24	45053	250 2-8-16	3 and 6 wks. after	6511	16.8	65 : 1
15 Ck..	2- 8-16	38469					

*The mixture used on this plot was purchased in the open market.
†The salt applied on this plot was the only application made.

The initial fertilizer treatments were applied by hand, prior to setting the plants, and the delayed top-dressing at definite periods thereafter.

Previous to 1927, the main drainage ditch nearest the experimental plots was in need of dredging and the water table under two or three plots on the unlimed half of the treated area was too high during periods of excessive rainfall. It was impossible to correct satisfactorily for the stunting effect of this high water table; consequently, less reliability is placed on the yield records from this half of the plots. The interpretations in this bulletin are based, with one exception, chiefly on the limed half of the series. Good cultural practices were followed throughout.

EXPERIMENTAL RESULTS

The results of the experiments are given in terms of the weight of the stalks, roots, and adhering soil as they were removed from the ground for trenching. Approximately 40 per cent of the crop was trimmed away in preparation for market. Yields of all plots are given for reference in Table 2. Interpretations are based upon the progress or graded use of checks as used by Thorne.[4] The significance of the differences in yield between the treated checks and the remaining plots and between the increased yields of several plots has been determined by Student's method,[5] using Meyers' modification of Student's tables.[6]

TABLE 2.—Actual Yield of Celery on Treated Check Plots
Annual yield in pounds per acre, 5 years, 1925-1929

Plot	1925	1926	1927	1928	1929	Average
Limed half						
1	34280	23481	37636	60765	33408	37914
6	40279	29566	32911	65325	31618	39940
11	40193	25538	29429	68392	30266	38764
15	35308	14740	30921	73532	37843	38469
Unlimed half						
1	30852	20053	34486	54216	25864	33094
6	34794	21339	36144	63169	27066	36502
11	42250	25195	41201	62257	25085	39197
15	42250	24853	43439	78506	36451	45100

[4]Ohio Agr. Exp. Sta. Bull. 381. 1924.

[5]Love, H. H. A modification of Student's table for use in interpreting experimental results. Amer. Soc. Agron. Jour. 16: 68-73. 1924.

[6]Unpublished tables of M. T. Meyers, formerly of the Ohio State University.

Where the odds are 30 to 1 or greater, the differences are considered significant and may be expected to be due to treatment rather than chance.

Response to basic fertilizer.—One thousand pounds of a 2-8-16 fertilizer applied on four check plots for 5 years produced an average yield of 38,772 pounds per acre of untrimmed celery, Table 2.

Although the yields of the check plots varied some during any single year, this variation was considerably reduced when the 5-year averages were computed. This increases the confidence to be placed on the 5-year average increased yields as recorded in the included tables.

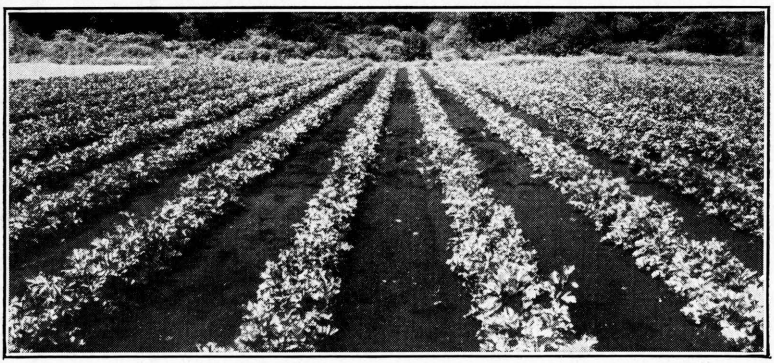

Fig. 1.—Celery 6 weeks after setting. Note the dark spotting between rows which extends across the photograph and marks the top-dressed plots

With no untreated plot available for comparison, the best estimate of the yield from unfertilized muck is based upon the salt treatment on Plot 8. If it is assumed that the salt applied to this plot has only a slight detrimental effect on celery yields, which is cumulative, the yield the first year of the experiment is probably close to what an untreated plot would have yielded. During the first year of the experiment the four check plots averaged 39,765 pounds per acre of celery, or 8,913 pounds more than were produced on Plot 8 for the same period. From this it should be safe to conclude that the increase produced by the basic treatment was approximately 8,000 pounds per acre.

Response to lime.—The north half of each plot in the experiment received 2 tons per acre of ground limestone every other year. With the initial application in 1925, this half of the series has received a total lime application of 6 tons. There exists a peculiar lack of effect from lime in this experiment. It is generally

recognized that muck soils are highly buffered, and this may explain the close agreement in the pH[7] values reported in Table 3.

TABLE 3.—Comparison of Celery Yields on Limed and Unlimed Check Plots
Soil pH—1929—and average annual yield in pounds per acre, 5 years, 1925-1929

Plot	pH	Unlimed yield	pH	Limed yield
		Pounds		*Pounds*
1	5.84	33094	5.92	37914
6	5.84	36502	5.84	39940
11	6.01	39197	5.67	38764
15	5.58	45100	5.69	38469
Average	5.81	38473	5.78	38771

In determining the value of lime for celery, the actual yields of adjacent halves of the four check plots were chosen, since they seemed to show no ill effects from occasional wet periods, Table 3. These figures present evidence that the crop grows equally well with or without lime, providing the pH of the soil is not too far below the neutral point. The yields of all check treatments included in this experiment were about equal, the average for the 5 years being 298 pounds per acre, or 0.7 per cent more celery from the limed half. The results would not justify the use of lime on muck of this type.

The lime applied to Plot 12 apparently increased the efficiency of the sulphate of ammonia top-dressing, for the lack of lime reduced the average yield 25 per cent. The yield from sulphate of ammonia on the unlimed section was depressed during 1925 and 1927 nearly as much as it was increased during 1926 and 1928; whereas in 1929 the increase over the check yield was small, accounting for the low 5-year average increase, Table 7.

Celery has been reported in the literature to be sensitive to acid soil conditions.[8] Although the pH taken November 25, 1929 was approximately the same on each half of Plot 12, the effect of the physiologically acid sulphate of ammonia may have been temporarily detrimental or only during certain seasons as the yield figures point out.

Response to nitrogen.—Nitrogen used as a supplement to the basic treatment of 2-8-16 fertilizer produced moderate increases in celery yields. The average increase of Plots 9, 10, and 12, each receiving 64 pounds per acre of nitrogen annually, in addition to

[7]pH is a logarithmic index to soil acidity, pH 7 representing neutrality and less than 7 indicating an acid soil.

[8]Hartwell, B. L. and Damon, S. C. The comparative effect on different kinds of plants of liming an acid soil. Rhode Island Agr. Exp. Sta. Bulletin 160. 1914.

the 20 pounds applied in the basic treatment, was 3,154 pounds, Table 4. This increase of approximately 1½ tons of celery represents 8 per cent of the check plot yield.

TABLE 4.—Increase in Yield of Celery From Nitrogen Fertilizers
Average annual increase over checks in pounds per acre and per cent, 5 years, 1925-1929

Plot	Supplemental applications	Time of application after plants are set	Increase due to nitrogen	
	Pounds		*Pounds*	*Per cent*
10	200 Nitrate of soda	3 and 6 weeks	2836	7.2
9	400 Nitrate of soda	3 weeks	3209	8.1
12*	160 Ammonium sulphate	3 and 6 weeks	3419	8.8
Average			3154	8.0

*Ammonium sulphate application carries the same amount of nitrogen as the nitrate of soda treatments on Plots 9 and 10.

The fluctuation in increased yields from this nitrogen supplement ranges from a decrease below the check plot yield of 10 per cent to an increase of 22 per cent. There were fourteen increased yields recorded for nitrogen supplements in this experiment over the 5-year period, in contrast to one decreased yield. The odds are 20 to 1 that the average increased yield from nitrogen applied to the above three plots is not due to chance.

Another nitrogen comparison, although less accurate than those just mentioned, is afforded by comparing Plots 5 and 14. The former received a 10-12-24 fertilizer, the latter a 3-12-24.

One-third of the total application on Plot 14 is applied in two top-dressings. The increase in yield from the increased nitrogen application was 310 pounds per acre as a 5-year average. The fluctuation in increased yields from the additional nitrogen ranged from a negative 3.8 to a positive 31.6 per cent.

Sulphate of ammonia versus nitrate of soda.—Sulphate of ammonia applied to Plot 12 at the rate of 320 pounds per acre produced an average increase in yield above the fertilized check of 3,419 pounds or 8.8 per cent, Table 4. The annual fluctuation in increased yields from this supplement was low, and thus significant odds of 65 to 1 were obtained. Expressed as a percentage increase, this nitrogen carrier did somewhat better than the nitrate of soda on Plot 10, producing 20.5 per cent more celery, and the resulting increases were more consistent. The odds, however, in favor of sulphate of ammonia over nitrate of soda for the 5-year period are negligible.

Split application of nitrogen.—The supplemental nitrogen, as applied to Plot 9, was split when applied to Plot 10, one-half being applied 3 weeks after setting the plants as on Plot 9, and the remaining half 3 weeks later. Delaying part of the application reduced the 5-year average increase 11.6 per cent, Table 4. The delayed application produced a more consistent increase over the 5-year period, however, than was produced by the single application. The odds were 14 to 1 and 8 to 1, respectively.

It would appear from the results that some environmental factors are responsible for the wide fluctuation in the yields produced on the nitrogen plots. Over the 5-year period there was no advantage in delaying the nitrogen top-dressing beyond 3 weeks after the plants were set.

Response to phosphoric acid.—Doubling the phosphorus applied in a 2-8-16 fertilizer produced an average increased yield of 7.4 per cent, Plot 3 Table 5. This increase from an additional 400 pounds of superphosphate amounted to 2,876 pounds per acre. The efficiency of this phosphorus increase varied considerably during the 5-year period. Some increase was produced every year with a maximum of 156 per cent during 1928 and a low of 0.2 per cent during 1926. Such a seasonal variation reduced the reliability of the treatment average to odds of 14 to 1.

TABLE 5.—Celery Yields Obtained on Selected Plots of Fertilizer Experiment at Ravenna, Portage County, Ohio.

Average annual yield and increase due to supplement in pounds per acre, 5 years, 1925-1929

Plot	Total application, 1000 pounds per acre	Supplemental treatments				
		Supplement to 1000 pounds of 2-8-16 fertilizer	Applied after or before setting the plants	Increase due to supplement		
		Pounds		*Pounds*	*Per cent*	*Odds*
14.....	3-12-24	250 2-8-16	3 and 6 wks. after	6511	16.8	65 : 1
13.....	4-16-32	500 2-8-16	3 and 6 wks. after	8263	21.3	40 : 1
5.....	10-12-24	1000 8-4- 8	Before	6821	17.2	9 : 1
4.....	2- 8-16	8 T. Manure	Before	4817	12.3	18 : 1
10.....	8- 8-16	200 Nit. Soda	3 and 6 wks. after	2836	7.2	14 : 1
9.....	8- 8-16	400 Nit. Soda	3 wks. after	3209	8.1	8 : 1
12.....	8- 8-16	160 Amm. Sulphate	3 and 6 wks. after	3419	8.8	65 : 1
3.....	2-16-16	400 Superphosphate	Before	2876	7.4	14 : 1
2.....	2- 8-32	320 Mur. Potash	Before	3326	8.6	20 : 1

Response to potassium.—Doubling the potash in the basic treatment produced an average increase of 8.6 per cent, Plot 2 Table 5. Four years out of 5, the additional 160 pounds of potassium as muriate of potash increased the yields considerably with a slight depression during 1927 and an average of 3,326 pounds per

acre for the period. This increase is of the same magnitude as that produced by the ammonium sulphate on Plot 12 or the nitrate of soda treatments on Plots 9 and 10 or the superphosphate on Plot 3.

The calculated odds of 20 to 1 for this treatment indicate that more potash may be used than the 160 pounds applied in the basic treatment.

Response to common salt.—Many growers of celery believe that common salt (sodium chloride) is beneficial to this crop. This conviction may possibly have grown out of the knowledge that the native habitats of this plant are low marshy lands whose total soluble salt content usually runs relatively high.

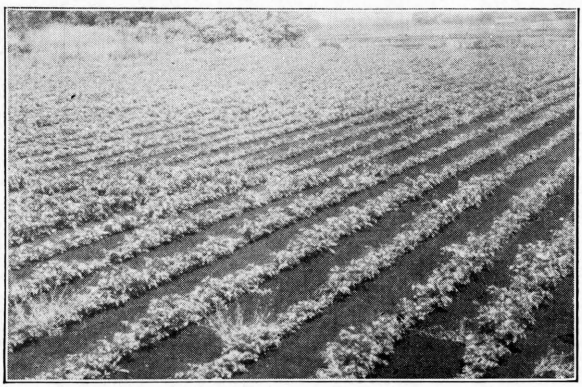

Fig. 2.—Plot 8—center—shows depressing effect of salt on celery during fifth year. Application 400 pounds per acre, annually

One of the common sources of salt for fertilizing purposes is the waste material from meat packing establishments. This product carries some meat scraps and dried blood which may be responsible for some of the beneficial results reported.

In this experiment, Plot 8 has received salt at the rate of 400 pounds per acre for the last 5 years. The salt was purchased as common barrel salt. No treatment other than the salt was applied to this plot, which precludes a comparison with the supplements in this experiment. Compared with the fertilizer on the check plots the salt depressed the yield 25.4 per cent, or 10,032 pounds per acre, Plot 8 Table 1. The low yield was consistent with odds of 134 to 1.

Judging from these results, there seems to be no merit in using commercial salt to increase celery yields.

Response to manure.—Manure as a supplement to the basic treatment produced larger increases than any single element in the experiment. The 8 tons per acre, applied after plowing and worked into the soil by discing, increased the yield above the treated check 12.3 per cent, Plot 4 Table 5. This increase represents 4,817 pounds of untrimmed celery, which more than offsets the cost of the manure.

Even more beneficial results might have been obtained had better manure been available. The applications in this experiment were made with manure obtained from a local barnyard where the material was constantly exposed and undoubtedly varied considerably with the season and age of the material.

The fluctuations in yields were not great on the manured plot. An increase was obtained every year, with 4 per cent the first year followed by a steady rise to 19.8 per cent during 1928. Due to unfavorable conditions in 1929 the increase from manure dropped to 11.9 per cent. The odds were 18 to 1 that the 5-year average increase was not due to chance.

Response to the chemicals in manure.—The chemical content in manure has been calculated to be approximately 10 pounds of nitrogen, 5 pounds of phosphorus, and 10 pounds of potash per ton.[9] These three elements, on the above basis, were applied to Plot 5 as 1000 pounds per acre of an 8-4-8 fertilizer equivalent to 8 tons of manure. This fertilizer as a supplement to the basic treatment produced approximately 40 per cent more celery than the manure supplement, Table 5. That this increase in celery yield from the chemicals in manure over the manure is highly significant is evident from the high odds of 584 to 1.

Response to supplements of a 2-8-16 fertilizer.—Five hundred pounds of a 2-8-16 fertilizer, applied in two equal portions at 3 and 6 weeks after setting the plants, in addition to the initial treatment of 1000 pounds of the same formula, produced an average increase in yield of 6,511 pounds per acre, or 16.8 per cent. Doubling this supplement (Plot 13) gave the highest yield obtained, 21.3 per cent more celery than the basic treatment, Table 6.

Assuming 8,000 pounds to be the increase in yield above the unfertilized muck obtained from the initial 1000-pound treatment, an additional 500 pounds raised this increase to 14,500, and a still further addition of 500 pounds brought the total increase to more than 16,200 pounds per acre of untrimmed celery.

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[9]Ames, J. W. and Gaither, E. W. Ohio Agr. Exp. Sta. Bull. 246. 1912.

TABLE 6.—Increase in Yield of Celery From 2-8-16 Fertilizer
First year (1925) and 5-year average (1925-1929) annual increase in pounds per acre and per cent

Plot	Amount of 2-8-16 fertilizer in pounds per acre	Increase due to 2-8-16 fertilizer			
		1925		Average, 1925-1929	
Initial treatment*					
		Pounds	*Per cent*	*Pounds*	*Per cent*
8†	1000	9393	30.4	10032	34.9
14	1500	11483	37.2	15615	53.0
13	2000	16625	53.8	17441	59.2
Supplemental treatment‡					
14	500	5806	15.9	6511	16.8
13	1000	9726	25.7	8263	21.3

*Increases obtained from initial treatments calculated on the basis of Plot 8 as being unfertilized.
†Plot 8 received annually 400 pounds per acre of salt. See discussion page 10.
‡Treatments supplemented 1000 pounds per acre annually of a 2-8-16 fertilizer.

A larger increase being produced by 2000 than by 1500 pounds of the 2-8-16 fertilizer would indicate that celery is a gross feeder and can be fertilized relatively heavily with profit. The maximum profitable supplemental application has not been determined by this test, but still larger applications will be made in the future to decide this point.

Odds of 65 to 1 and 40 to 1, respectively, indicate the reliability of the 500- and 1000-pound supplemental applications.

Response to factory and home-mixed fertilizer.—The two lots of a 2-8-16 fertilizer used in this experiment to compare the commercial product with that mixed on the farm are not strictly comparable. The commercial brand employed was guaranteed to contain 2 per cent nitrogen in "animal, vegetable, and mineral form", 8 per cent available P_2O_5 (phosphoric acid), and 16 per cent available K_2O (potash). An official analysis was made by the Division of Feed and Fertilizer, State Department of Agriculture, and the results show the fertilizer to contain 1.82 per cent total nitrogen, 8.48 per cent available phosphoric acid, and 15.28 per cent potash. Too much emphasis should not be placed on this comparison since nitrate of soda was used as the source of nitrogen in the home-mixed fertilizer whereas nothing is known of the proportions of the various nitrogen carriers in the commercial product.

The home-mixed fertilizer out-yielded the factory-mixed by 5,950 pounds per acre, or nearly 15 per cent, Table 1. The fluctuation in yields during this period was slight, resulting in odds of 72 to 1 that the above difference was not due to chance.

That the difference between these two fertilizers was not entirely due to the greater proportion of quickly available nitrogen carried in the home-mixed fertilizer is evident when the increases obtained from the nitrogen top-dressing on Plots 9, 10, and 12 are considered. In case the difference between these two lots of fertilizer was the nitrogen only, the difference should not be more than 7 per cent.

Under the conditions of this experiment the evidence favors the home-mixing of fertilizers. The cost of home- versus factory-mixed fertilizers was not considered in this test.

DISCUSSION OF VARIOUS TREATMENTS

In Table 5 is presented clearly the comparative response of celery to the various treatments. Incidentally, the plot treatments fall into groups based on the similar magnitude of their yield increases. Thus, 400 pounds per acre of nitrate of soda or superphosphate were approximately equal in their effects on celery yields. Likewise, 320 pounds of muriate of potash can be considered nearly equivalent to the same quantity of ammonium sulphate.

The following statements indicate what can be expected on similar soils with celery under normal weather conditions. The heaviest fertilizer treatments produced the largest increases in this experiment, indicating the need for abundant fertilization of this crop. Manure was replaced more economically and beneficially by commercial fertilizers. All of the single elements—nitrogen, phosphorus, and potassium—were limiting factors in this soil. The odds of significance show ammonium sulphate to have been the single fertilizer most consistent in increasing celery yields, as well as producing the largest increased yields. Potash did about as well and may be considered of most value on muck soils. Lime had but little effect on this muck having a pH of about 5.5.

GENERAL DISCUSSION

The striking thing brought out in Table 1 is the relatively small increases produced by most of the supplements employed in this experiment. However, these small increases are more important than would be thought at first sight, for celery is a very high money-value crop, and consequently small crop increases return profits on large fertilizer investments. For example, doubling the phosphoric acid applied in 1,000 pounds of a 2-8-16 fertilizer applied

to Plot 3 produced an average increased yield of 7.4 per cent. This increase from an additional 400 pounds of 20 per cent superphosphate amounted to 2,876 pounds per acre. Assuming a loss of 40 per cent in trimming and a market price of $2 per hundred weight for the marketable celery produced, the grower would net approximately 40 per cent on his investment in the additional phosphate supplement.

In connection with the interpretation of comparative yields recorded in Table 1, it should be kept in mind that the calculated increased yields from the supplemental treatments are more accurate than the actual yields in that the former figures are based on an attempt to correct for soil variability which often is so large as to mask treatment differences.

The table of odds, being based on the seasonal variation in increased yields, is a fairly accurate index to the effect of environment on celery or the efficiency of celery under various environments. In this experiment the variation in effect of any fertilizer treatment has been fairly large in almost all cases. The reasons for this are not yet fully known; the shallow rooting habit of celery is one explanation. There is further need for knowledge of the correlations existing between celery yields, fertilizers, rainfall, temperature, and many other factors before the experimenter can predict the effect of a treatment under various conditions.

The grower should consider the magnitude of difference between yields obtained by various treatments in an economic light, since he may discover that apparently small percentage increases are actually quite profitable. The effect of season should be taken into consideration too, for the likelihood that a definite fertilizer program can be repeated year after year with success is dependent upon the season.

For purposes of standardizing the opinions of many workers, odds of 30 to 1 or greater have been accepted as indicating that differences obtained in any comparison are considered significant and may be expected to be due to treatment rather than to chance. However, since the element of chance is present, many growers will readily take these chances of less than 30 to 1 that their proposed treatments will net them a profit. For this reason several of the lesser odds reported for treatments in this experiment may be sufficiently significant to warrant their use. Until more is known about the definite requirements of the celery plant, the wide fluctuations in yields as a result of various treatments applied during several seasons will need to be considered and a chance taken on relatively small odds.

TABLE 7.—Summary of Celery Yields Obtained on Fertility Plots, Ravenna, Portage County, Ohio

Actual yields from total treatments, increased yields from supplemental treatments, and 5-year averages for both. 1925-1929, inclusive

Plot	Actual yield						Increase due to supplement					
	1925	1926	1927	1928	1929	Average	1925	1926	1927	1928	1929	Average
Limed series												
1 Ck	34280	23481	37636	60765	33408	37914						
2	41735	29395	35978	66568	34552	41645	6256	4697	— 713	4891	1502	3327
3	39679	25967	39543	69967	32844	41600	3001	52	3797	7378	152	2876
4	39422	28966	39045	76102	36194	43946	1545	1834	4244	12601	3860	4817
5	45421	28623	42196	84806	30731	46355	6341	274	8340	20393	—1245	6821
6 Ck	40279	29566	32911	65325	31618	39940						
7	33080	24253	28683	56040	26710	33755	— 7182	— 4507	—3532	— 9898	—4638	— 5951
8	30852	17482	24952	52724	21180	29438	— 9393	—10472	—6567	—13827	—9898	—10031
9	45249	28195	36641	74444	27688	42443	5022	1047	5818	7280	—3120	3209
10	41564	28452	33077	75521	30565	41836	1354	2110	2950	7744	27	2837
11 Ck	40193	25538	29429	68392	30266	38764						
12	43192	27081	32331	74692	33251	42109	4220	4242	2529	5015	1091	3419
13	47477	23738	38134	86879	38167	46879	9726	3598	7959	15917	4113	8263
14	42335	22539	38216	83231	38946	45053	5806	5098	7668	10984	2998	6511
15 Ck	35308	14740	30921	73532	37843	38469						
Unlimed series												
1 Ck	30852	20053	34486	54216	25864	33094						
2	39764	17739	37719	65159	26909	37458	8124	— 2571	2902	9152	805	3682
3	31623	19968	42444	68392	26320	37749	— 806	— 599	7296	10594	— 24	3292
4	35651	23053	41947	74527	27373	40510	2434	2229	6468	14938	789	5371
5	33680	18768	42859	72786	25052	38629	— 326	— 2313	7049	11406	—1772	2809
6 Ck	34794	21339	36144	63169	27066	36502						
7	29823	18511	30673	58527	26188	32744	— 6462	— 3599	—6300	— 4460	— 481	— 4260
8	23996	14140	29678	52144	18412	27674	—13780	— 8741	—8124	—10661	—7861	— 9833
9	40707	25452	40538	70879	25607	40637	1440	1800	1907	8256	— 270	2627
10	46192	35222	44766	78506	25068	45951	5433	10799	5306	16065	— 413	7438
11 Ck	42250	25195	41201	62257	25085	39197						
12	38222	29909	38714	70547	29429	41364	— 4028	4799	—3046	4228	1503	691
13	47049	29737	48247	86547	34229	49162	4799	4712	5928	16166	3462	7013
14	45935	30680	51729	84309	33806	49292	3685	5740	8851	9866	198	5668
15 Ck	42250	24853	43439	78506	36451	45100						

SUMMARY AND RECOMMENDATIONS

The following recommendations are made in view of the facts discovered in these experiments, which include the results from 15 fertilized plots of celery on muck over a period of 5 years from 1925 to 1929, inclusive. These recommendations are not final and should be altered when the evidence warrants.

1. The unfertilized muck produced close to 30,000 pounds of untrimmed celery the second year after clearing the land from the virgin condition. The basic treatment of 1,000 pounds per acre of a 2-8-16 fertilizer increased the yield approximately 8,000 pounds.

2. The results from lime would not justify its use on muck of the type used in this experiment. These results were obtained under a soil acidity indicated as pH 5.5 to 6.0. No lime applications are recommended where the soil may be termed a "high-lime muck" or where the pH value is above 5.5.

3. All nitrogen supplemental treatments in this test produced average increased yields of celery with only one decrease in yield in 5 years. The average increases were in the neighborhood of 8 per cent.

In the presence of phosphorus and potassium, as added in the basic treatment, the lack of ample nitrogen is considered to be limiting celery yields on this soil. It is recommended that not less than 65 pounds per acre of nitrogen in some quickly available form be used as a top-dressing on this crop where not less than 20 pounds are used in the basic treatment.

Seasonal fluctuations in yield indicate that nitrogen applications should be altered when conditions of moisture and sunshine, as well as the color of celery foliage, indicate the need for more of this element or when that which has already been applied is unused, due to low moisture content of the soil.

4. Sulphate of ammonia, when used in conjunction with lime, gave somewhat better and more consistent results than nitrate of soda on this soil. It is recommended that where liming is practiced, sulphate of ammonia be used in preference to nitrate of soda, especially when a price differential exists in its favor.

5. No consistent advantage was secured by delaying the nitrogen top-dressing beyond 3 weeks after the plants were set. Since in some seasons a later application at 6 weeks proved advantageous, it is recommended that the (nitrogen) top-dressing be light and be applied at intervals through the growing period during seasons when rainfall is plentiful and heavy leaching of nitrates is apt to occur.

6. Doubling the phosphorus in the basic treatment increased the yields every year. A maximum increase of 165 per cent was obtained in 1928 and the 5-year average increase returned approximately 40 per cent on the investment.

7. Doubling the potassium applied in the 1000-pound basic treatment increased the celery yields by 8.6 per cent. Attention should be paid to the potash fertilization since muck soils are more often low in their content of this element in relation to the phosphorus and nitrogen present.

8. Common salt (sodium chloride) has proven detrimental to celery. Its use in the pure form is not recommended.

9. Manure has produced substantial yield increases when used to supplement the basic treatment in this test. Since the chemicals in manure have produced 40 per cent more celery when applied in the commercial form, the use of manure is not recommended when green manure crops are grown and manure costs over $2 per ton applied to the land.

10. Two thousand pounds per acre of a 2-8-16 fertilizer were the largest application in this experiment. This treatment produced the most celery and resulted in a substantial increase over the 1500-pound application.

11. The present fertilizer recommendation for celery grown on muck includes an application of not less than 1 ton of a 2-8-16 fertilizer, or its equivalent in some other form, with additional topdressing of nitrogen as advised in 3, 4, and 5 above.

This recommendation is based upon the dual evidence obtained in connection with the increased applications of the single elements and the complete mixtures. When the quantity of each of the elements nitrogen, phosphorus, and potassium in the basic treatment was increased, one at a time, substantial increases in celery yields were obtained. When the three elements were increased together in a larger complete mixture and applied to celery, increases in yield were again obtained.

12. In conclusion, the grower is cautioned against applying too little fertilizer, neglecting the use of any of the three elements nitrogen, phosphorus, or potassium, and failure to fertilize according to the crop's need as manifest by its appearance.

An effort towards experimentation with fertilizers on the part of the grower is encouraged.

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