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SOIL MANAGEMENT

FOR INTENSIVE VEGETABLE PRODUCTION ON SANDY CONNECTICUT VALLEY LAND

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CONCLUSIONS

The experiments described in this bulletin justify the following conclusions concerning soil management for intensive vegetable production in Connecticut, particularly on the sandy soils of the Connecticut Valley:

1. A combination of moderate manuring and medium rates of complete fertilizer application is most effective in producing high yields of miscellaneous vegetable crops without depletion of the soil.

2. A combination of green manuring, winter cover crops and liberal rates of application of well-balanced complete fertilizer is successful in maintaining favorable yields of most vegetable crops. However, the organic content of the soil suffers some depletion under intensive vegetable cropping unless manure or other organic soil amendment is applied to the soil at frequent intervals. As a rule in seasons of abundant rainfall, early planted, cool season crops produce better yields from high rates of fertilizer treatment without manure, than from moderate fertilization with manure.

3. Liming acid soils in sufficient amount to keep the reaction at from 6.2 to 6.6 pH is necessary to produce favorable yields of such crops as spinach, lettuce, radishes, beets, carrots, peppers and lima beans. Moderate acidity, between 5.2 and 5.6 pH, with low amounts of active aluminum present, is not unfavorable to sweet corn, sweet potatoes and tomatoes.

4. Concentrated grades of well-balanced complete fertilizers may be used successfully for vegetable crops. However, fertilizers of medium-analysis grade give slightly better results in seasons of excessive rainfall.

5. Fertilizers supplying from 90 to 135 pounds of nitrogen, from 90 to 135 pounds of phosphoric acid and from 120 to 180 pounds of potash, per acre, are desirable for most vegetable crops on unmanured land under intensive vegetable culture. Smaller amounts of nitrogen are preferable in the growing of peppers and sweet potatoes in rotation with other vegetables.

6. Light sandy soils that have been planted to tobacco for many years require little phosphorus for the growing of potatoes. Accumulated potash from past tobacco fertilization is rapidly depleted by the potato crop. Results of the potato fertilizer experiment on old tobacco land indicate the need of a fertilizer supplying 80 to 100 pounds of nitrogen, 40 to 80 pounds of phosphoric acid and 120 to 160 pounds of potash, per acre.

7. Magnesium is an important factor in fertilizing for potatoes. However, since the acidity of fertilizer constituents should be counteracted for this crop on the acid soils that are generally most magnesium-deficient in this State, dolomitic (high-magnesian) lime, either formulated with the fertilizer or as a separate application, is the most economical protection against magnesium deficiency.

8. For sweet potatoes in continuous culture on very sandy soils, a suitable fertilizer supplies from 30 to 40 pounds of nitrogen, 80 to 120 pounds of phosphoric acid and 120 to 160 pounds of potash, per acre. The fertilizer is best applied as a side-dressing.

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The production of vegetable crops has greatly increased in Connecticut during recent years, and has come to be one of the important uses of Connecticut soils. Approximately one-tenth of the plowable land is now devoted to various vegetable crops, including potatoes and sweet corn. It is a well known fact that the greater portion of the desired yield must be obtained as a result of soil treatment, and that land receiving no fertilizer, lime or manure cannot be expected to produce satisfactory yields of any of the common vegetable crops. There is an abundance of soil of light loam or sandy loam texture, well drained, and not too stony or hilly for convenient culture. With reasonable attention to soil improvement by fertilizers, manures, lime and crop rotation, excellent yields of high quality vegetable crops are readily obtainable.

The Soils Department of this Station has devoted much attention to the soil management problems of vegetable growers. Since 1930, various groups of plots have been in operation at the Windsor Substation, designed to measure the responses of several of the more important vegetable crops to various soil treatments. The results of these trials, during the ten years ending with the 1939 season, are presented in this bulletin. They are especially applicable to the light, sandy soils of the Connecticut Valley tobacco area. However, many of the principles revealed in these studies apply elsewhere.

FERTILIZER, MANURE AND LIME EXPERIMENTS WITH MISCELLANEOUS VEGETABLE CROPS

In the spring of 1930, the leasing of the Pomeroy lot at Windsor provided the Station with a tract including two one-acre blocks of level and exceptionally uniform land, of the Merrimac sandy loam (deep phase) type frequently used for vegetables in the Connecticut Valley. At the urgent request of the Connecticut Vegetable Growers' Association, it was decided to utilize this land, and federal funds made available for such a project, for the conduct of plots involving comparisons of soil management practices of special significance to Connecticut vegetable growers. Since the trials were to be conducted on land where the duration of tenure was uncertain, the plot layout was made as simple as possible. Important principles of field plot design from the standpoint of modern statistical analysis have been violated, since a compromise had to be made between such considerations and the simplicity and cultural practicability of trials involving numerous practices with as many vegetable crops as could be conveniently included in the cropping plan.

Pertinent data relative to the characteristics of the soil occurring on these plots are shown in Table 1.

TABLE 1. PHYSICAL AND CHEMICAL MEASUREMENTS OF THE SURFACE SOIL OF VEGETABLE FERTILIZER BLOCKS A AND B.

		Range	
	Average	High	Low
Mechanical Analysis			
Total sands	72%	74%	70%
Silt	20%	23%	18%
Clay (< .002 mm).	8%	7%	9%
Moisture Equivalent	11%	9%	13%
Base exchange capacity	4.7*	6.5*	4.2*

Organic matter (original soil) — 2.17%
Nitrogen " " — .088%
Soil Reaction " " — 5.36

Indications of soil tests on original soil:

Phosphorus	— very high
Potassium	— high
Calcium	— low
Magnesium	— low
Aluminum	— low
Manganese	— medium

Mgm. equiv. per 100 gms. of soil.

The original series of treatments as conducted during the first three years included comparisons of concentrated fertilizer materials that had been formulated to include special additions of magnesium and manganese. However, the lime that it was necessary to use on these plots to meet the needs of the more acid-sensitive vegetable crops provided considerable magnesium, and the field was shown by supplemental chemical studies to contain more than the usual amount of active manganese; consequently, these plots were discontinued and replaced by trials involving varying rates and times of application of fertilizer nitrogen.

The plot and cropping plan for 1939, shown as Figure 1, indicates the typical arrangement of crops with respect to plots.

During the first three years, early crops were followed by fall vegetables. However, it proved to be very difficult to obtain good stands of crops seeded or transplanted in midsummer on this light sandy soil, especially when the season was dry. Artificial irrigation was not practised, as it was believed that the water could not be applied sufficiently uniformly to prevent irregularities from plot to plot. During the last seven years, the late crops were replaced by a summer green manure, except on plots receiving stable manure. Buckwheat, millet and sudan grass were used from year to year. The fall vegetables or green manures were followed by a rye winter cover crop (no rye on manured plots). This was plowed under about May 10, for planting to the vegetable crops, as shown on Block B in Figure 1. After their harvest was completed, winter rye was seeded as early as possible (except on manured plots). The following spring the ground was plowed up about April 1, in order to permit planting the early vegetables as shown on Block A. Thus crops alternated between Block A and Block B. There was also a re-arrangement of the crops each year, so that no area would be planted to the same crop more often than every fourth or sixth year.

The schedule of treatments on the various plots is shown in Table 2.

TABLE 2. PLAN OF FERTILIZER TREATMENT, WINDSOR VEGETABLE PLOTS, BLOCKS A AND B.

Plots	Treatments, per acre, per year				Concentration of materials
	Manure	Fertilizer			
		Nitrogen	Phosphoric acid	Potash	
1–11	40 T.	—	—	—	—
2–12	20 T.	45 lbs.	45 lbs.	60 lbs.	medium
3–13	—	135 "	90 "	120 "	
4–14	—	90 "	90 "	180 "	
5–15	—	90 "	90 "	120 "	
6–16	—	45 "	90 "	120 "	high
7–17	—	90 "	90 "	120 "	
8–18	—	45 " to preceding rye cover crop			
		45 "	90 lbs.	120 lbs.	
9–19	—	45 "	90 "	120 "	medium
10–(no *lime*)		90 "	90 "	120 "	
20–		45 "	45 "	60 "	

The following exceptions to the above schedule should be noted:

In 1930, plots 2 and 12 were given full-rate fertilizer treatments, instead of half-rate as in other years.

Standard rates of N, P_2O_5 and K_2O were 100, 160 and 120 pounds, respectively. Plots 5-15 were given 100 pounds of P_2O_5.

From 1930 to 1933 the following comparisons were made, involving plot pairs 6-16, 7-17 and 8-18:

6-16—concentrated fertilizer materials, with addition of magnesium salts supplying 50 pounds MgO per acre.

7-17—same as plots 6-16, plus manganese sulfate at 50 pounds per acre.

8-18—concentrated fertilizer materials only.

No measurable benefits from magnesia or manganese were obtained during the four years of these comparisons. Since 1934 the treatments were revised to conform with the above schedule, except that the application of half of the fertilizer nitrogen to the preceding rye crop was not possible in that year, due to extreme weather conditions.

In 1939 fertilizer grades in the simple ratios adopted for Connecticut[1] were used on the various plots, as follows:

[1] Fertilizer grades for Connecticut. Univ. of Conn. Ext. Bul. 285. 1939.

1–11: Manure, 40 tons per acre; no fertilizer
2–12: " , 20 " " " ; 1000 lbs. 5-10-5 per acre
3–13: 1500 lbs. 8-8-8 per acre
4–14: 2000 " 4-8-10 " "
5–15: 2000 " 5-8-7 " "
6–16: 1000 " 8-16-16 per acre
7–17: 1000 " 10-16-14 " "
8–18: 1000 " 8-16-16 " " , plus extra nitrogen (40 lbs. per acre, on preceding rye crop)
9–19: 1600 lbs. 5-10-10 per acre
10– : (No lime) 2000 lbs. 5-8-7 per acre
20– : 1000 lbs. 4-16-20 per acre

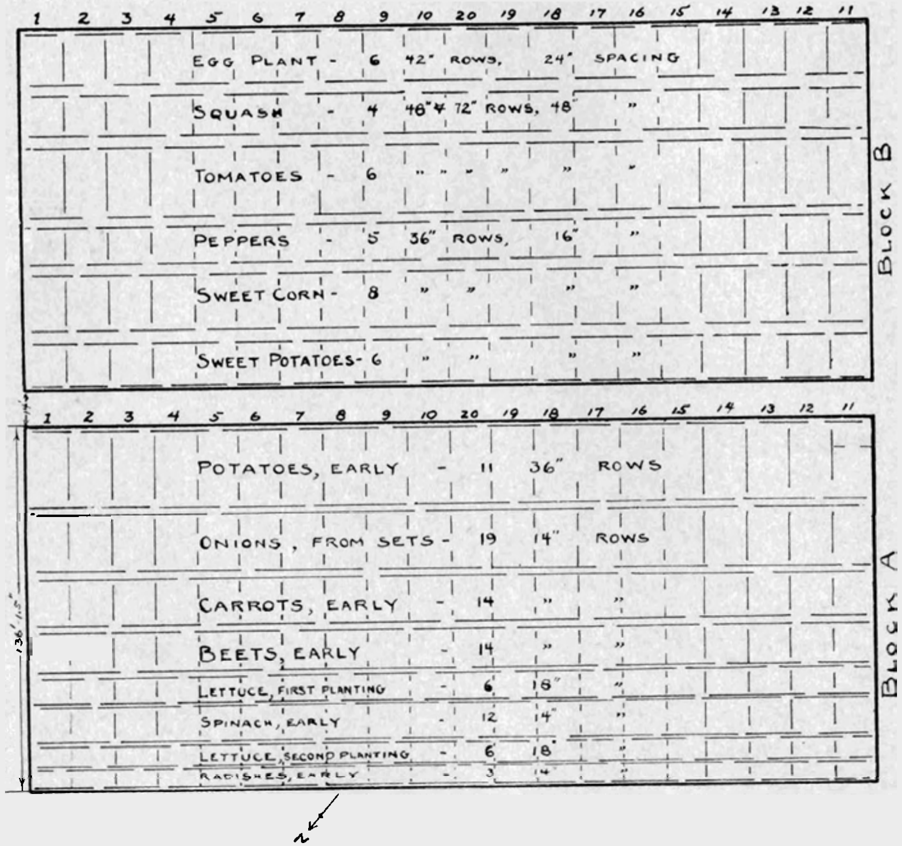

FIGURE 1. Plot and cropping plan, Windsor vegetable fertility plots, 1939, Blocks A and B.

The preceding changes afforded interesting opportunities to study the adaptations of simple ratio grades to the needs of various vegetable crops, as will be noted later. However, several of the treatments are not strictly comparable to those of the earlier years.

Seasonal Differences, as Related to Yield and Fertilizer Performance: Details of individual plot yields by separate years for all of the various vegetable crops grown in these trials are quite voluminous, and it is considered impracticable to present them in full. However, pertinent observations concerning seasonal differences with respect to the effects of treatment are given in the following paragraphs.

1930—The cool spring weather apparently delayed nitrogen liberation from manure treatments, since in this season early planted crops were much retarded and showed marked yellowing of the foliage on manure treatments. Because there was no leaching during the growing season of the early crops, the heavier rate of nitrogen treatment (Plots 3-13) was of relatively little benefit. Only slightly diminished yields were produced on the half-rate fertilizer. A storm period in June caused some leaching affecting results on the midseason block. The rest of the season was rather dry.

1931—Unusually wet weather in May and early June caused much leaching of nitrates from the soil, especially on the earlier fertilized early-crop block where the nitrogenous constituents of the fertilizer had been considerably nitrified before heavy rains occurred. Even on the extra nitrogen treatment there was serious yellowing of the foliage of most crops on the early block. Later planted crops did well under conditions of high temperatures and frequent light showers during much of their growing season. Manure was less effective than usual for the midsummer crops.

1932—Dry and moderately cool weather in April and early May provided very favorable conditions for early planted crops, as shown in Figure 2. The midsummer period was practically normal in temperature and rainfall, resulting in good yields in all cases. The higher levels of both nitrogen and potash were unusually effective. Manure benefits were very slight.

1933—Warm, wet weather in April gave early planted crops a good start, but leached a considerable portion of the nitrates from the soil. Unusually warm and dry weather prevailed during May and June. This was very unfavorable to lettuce. Yields on this crop were poor and quite variable from plot to plot, irrespective of treatment. However, there was a definite trend toward better than average results from "concentrated grade" fertilizer as compared to normal strength treatments. Manure was quite favorable to all crops except spinach and radishes. Midseason crops suffered considerably from this early summer dry period. During the latter part of the summer (July, August and early September) the rainfall was adequate and well distributed, resulting in reasonably good yields. Response to manure was especially noted, probably due to improved moisture conditions during the early season dry period.

1934—A warm, wet spring followed by a summer of normal temperature and abundant, well distributed rainfall provided exceptionally good growing conditions. Manure, without fertilizer, gave especially poor results on all early crops, since the nitrogen liberated from manure was seriously leached by the heavy April rains, and nitrification of the remaining less available organic nitrogen was too slow to replenish the losses. Conversely, extra nitrogen was especially beneficial. As noted in other years of good yields, greater responses to the higher rates of both nitrogen and potash were observed. Similar trends were in evidence for midseason crops. "High analysis" fertilizer applied in early April was less effective than fertilizer of normal strength, probably in consequence of greater leaching losses during the early period. On the other hand, the more concentrated fertilizer applied in May was especially effective for all midseason crops.

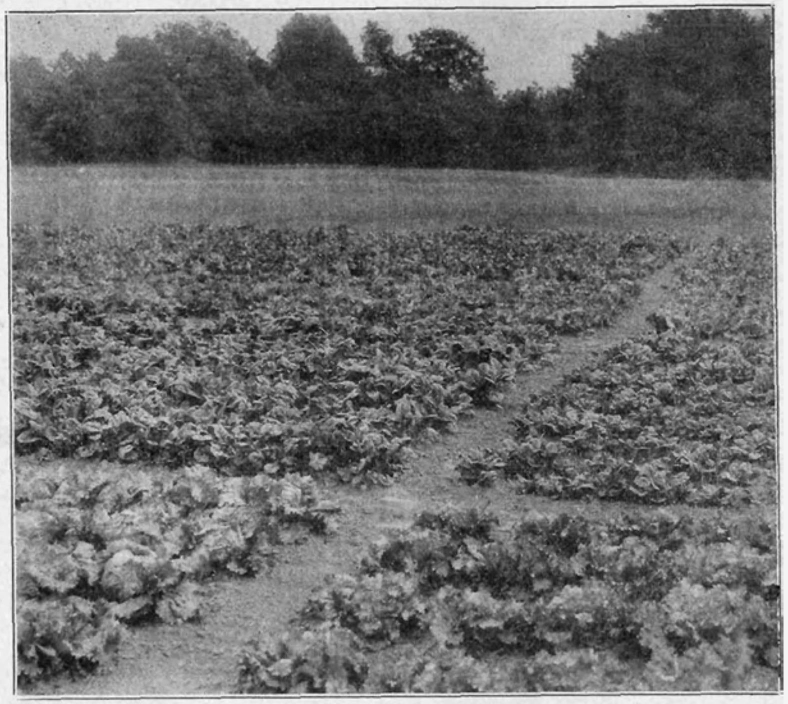

FIGURE 2. Early vegetable crops on Block A, 1932. Lettuce and spinach in the foreground. Left of alleyway—manure, 20 tons per acre, plus 750 lbs. 6-6-8 fertilizer; right of alleyway—manure, 40 tons per acre, without fertilizer.

1935—Dry weather prevailed in April and May, with rather cool weather in the latter month. June and July provided abundant rainfall and favorable temperatures. August was moderately dry and warm. Early September brought cooler weather and heavy rains. Yields of most crops were notably high. Unusual increases for manure were obtained on early planted crops, in consequence of the dry weather and absence of early leaching. Responses to nitrogen were less than usual, and the half-rate nitrogen treatment was only slightly poorer than the full-rate (90 pounds per acre). This was to be expected under favorable conditions for nitrification in the early season, in the absence of any spring leaching.

1936—Dry and unusually warm weather in May was adverse to early planted crops. Moderately dry weather continued through most of the summer, but the rainfall distribution was fairly favorable. Yields of most crops were reasonably good, but considerably below the 1935 level. Differences due to treatment were insignificant except for unusually good benefits from manure on the medium early crops (especially on onions), the usual decreased yields of acid-sensitive crops on the no lime plots, and diminished yields on the half-rate fertilizer treatment.

1937—The entire growing season was rather wet and above normal in temperature. Considerable leaching was caused by heavy rains occurring practically every month. This placed the lower rates of nitrogen and the more soluble fertilizers under an unusual handicap. Response to extra nitrogen was notable, ranging up to 49 percent in case of spinach. The "high analysis" treatments were especially poor. Manure without fertilizer was especially unfavorable to the early crops. The usual beneficial effects of manure as a supplement to fertilizer were less noticeable on early crops. Midseason crops were adversely affected by the period of dry hot weather in mid-July, followed by frequent heavy storm periods from July 27 to August 23. Plant diseases were especially troublesome due to high temperature and humidity conditions. However, some crops, notably sweet corn, peppers and sweet potatoes, were unusually good. Heavy manuring, without fertilizer, was especially beneficial to these crops. It appeared that most of the nitrate nitrogen from the fertilizers was leached during May and June. On the other hand, the manure was still able to liberate much available nitrogen in July and August.

1938—Rainfall during April and May was plentiful, but not excessive. Spring weather came unusually early, and the early planted short-season crops did exceptionally well, with excellent results from the heavier nitrogen and potash treatments and satisfactory performance of the more concentrated fertilizer grades. Beginning on June 11, a frequent recurrence of heavy rains persisted for the next six weeks, culminating in seven days of almost continuous downpour during the week ending July 25. All crops growing during this period suffered seriously from nitrogen depletion by leaching, even at the heaviest rates of treatment. Manured plots were unusually superior to those receiving fertilizer only. A drier period during August and early September brought only partial recovery, except on the manure plots, since little available nitrogen remained in the soil. Depletion of potash and other nutrient constituents in the soil solution had doubtless been effected. Since all crops had been harvested by the time of the hurricane, the trials were not disturbed by this disaster.

Responses to lime were less than usual. In fact, the less acid-sensitive midsummer crops gave better yields on the unlimed plots. This had been noted in other wet seasons. It appeared likely that the more acid conditions tended to retard nitrification during the early part of the summer, so that more nitrogen remained to be liberated after the rains had ceased.

Results with sweet corn were especially striking. A planting made about May 20 was badly damaged by crows, and was replanted about June 10. Consequently, the plants had made but little growth before soil leaching became severe. Plants on all plots showed conspicuous yellowing due to nitrogen starvation. However, the manured plots produced a fair crop of ears. The only other plots that produced any marketable ears were those receiving extra nitrogen treatment, but these were decidedly inferior to the manure plots. The appearance of the crop is shown by Figure 3. Sweet potatoes and peppers, requiring less fertilizer nitrogen than other vegetable crops, did reasonably well. However, contrary to the usual results, they gave best yields at the highest rate of nitrogen treatment.

1939—Rainfall was favorable in April, but cold weather delayed planting later than usual. May was unusually warm and dry, adverse to early planted crops. Precipitation was nearly normal during the summer months, with frequent showers and no heavy storms to produce leaching. Excellent yields of all the later planted crops were obtained. Responses to nitrogen were less than usual. Only slight gains were obtained from manure treatments. High analysis fertilizers gave very satisfactory performance.

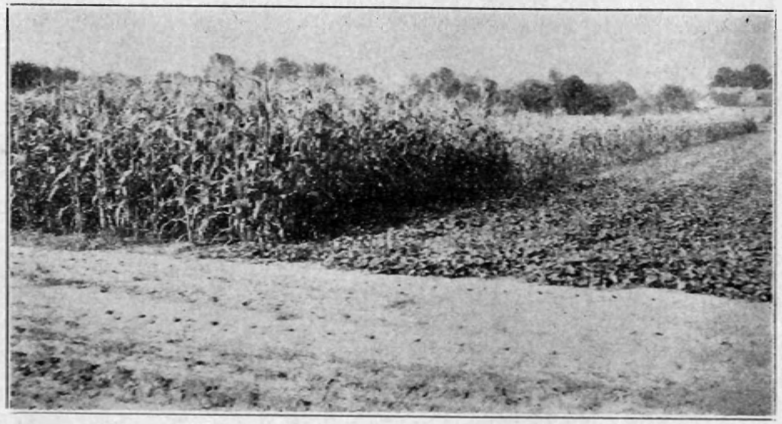

FIGURE 3. Sweet corn on vegetable plots, 1938. Manured plots in foreground to the left; without manure, beyond, to the right.

The data for crops grown in each of the ten years have been grouped on the basis of the five wetter seasons and the five drier seasons. This difference was rather clear-cut in case of the growing seasons of crops on the early block, since the following years were distinctly wet during April or May, sufficient to cause some leaching from the topsoil: 1931, 1933, 1934, 1937 and 1938. The other years were definitely lower in spring and early summer rainfall. For the midseason block, not planted until the latter half of May, periods of heavy rainfall occurring in June, July, or August were more prevalent in 1930, 1931, 1935, 1937 and 1938. However, only the last three of these seasons were definitely wet, while no serious summer drought occurred in any year

The above comparisons are shown in Table 3, for those treatments that showed consistent differences in performance in relation to the season throughout the ten-year period.

In the wetter seasons, the following points should be especially noted:

1. The half-rate fertilizer treatment is generally insufficient for good yields.

2. Additional fertilizer is relatively more effective than manure for radishes, spinach, the later planting of lettuce, and beets.

3. Manure alone, even at this very heavy rate, gives poor results except on the crops that extend their growing season into the warm months.

4. Fertilizer of concentrated grade is less effective than the normal strength grade.

5. The high nitrogen treatment (135 pounds N per acre) is decidedly superior to the standard rate treatment (90 pounds N per acre) except for the later planting of lettuce, for carrots and for peppers.

In drier seasons, when little or no fertilizer is lost by leaching, the following observations appear justified:

1. The half-rate fertilizer treatments, while less effective than the full-rate, give proportionately larger yields than in the wetter seasons.

TABLE 3. COMPARATIVE RESULTS IN FIVE WETTER (W) AND FIVE DRIER (D) SEASONS, FOR CROPS GROWN DURING EACH OF THE 10 YEARS.

(Yields of Marketable Crop, in Hundreds of Pounds per Acre)

		Half-Rate Fertilizer Standard Grade	Half-Rate Fertilizer + 20 T. Manure	Full-Rate Fertilizer Standard Grade	Full-Rate Fertilizer Concentrated Grade	High Nitrogen Fertilizer	Manure *only*, 40 T.
Early Block							
Radishes	W	45.8	53.5	68.8	63.6	72.9	23.6
	D	46.9	60.6	56.4	62.5	50.2	42.6
Spinach	W	84.9	130.8	133.5	107.5	166.1	87.3
	D	104.4	181.4	142.7	138.2	154.7	141.8
Lettuce, 1st planting	W	151.1	428.0	319.3	295.5	435.6	223.9
	D	283.6	502.6	366.0	381.1	376.7	413.2
Lettuce, 2nd planting	W	284.8	362.2	393.0	366.3	371.8	248.5
	D	301.3	503.7	356.1	381.1	372.6	420.8
Beets	W	118.8	169.4	193.6	150.2	243.9	117.4
	D	162.3	245.6	230.4	206.5	256.6	220.4
Carrots	W	116.4	171.4	157.1	149.2	158.7	167.6
	D	148.5	216.0	160.0	173.6	172.8	218.8
Onions	W	192.5	257.1	220.5	219.9	241.9	223.9
	D	189.2	272.9	194.8	214.0	211.8	275.1
Midseason Block							
Sweet Corn	W	76.8	97.2	82.9	80.5	95.4	102.9
	D	97.3	111.6	101.6	102.8	107.9	121.1
Tomatoes	W	178.4	250.2	236.0	230.2	243.0	250.2
	D	264.2	331.4	303.6	302.2	325.6	316.8
Peppers	W	101.4	117.5	102.8	104.6	100.1	124.0
	D	168.7	183.5	173.5	176.9	152.9	194.0

Wet seasons for early block: '31, '33, '34, '37, '38.
Wet seasons for midseason block: '30, '31, '35, '37, '38.

2. The addition of manure to the half-rate treatment is relatively more effective than applying the full-rate fertilizer treatment without manure, in all cases, and to a greater degree than in the wetter years.

3. Manure alone at the heavy rate gives relatively better results than in the wetter years.

4. The fertilizer of concentrated grade gives equally good or better results than the normal strength grade, except in case of beets, when it was noted that the stand was frequently poorer, causing some decrease in yield.

5. The high nitrogen treatment was proportionally less effective than in the wetter years, in most comparisons.

The effect of season upon the performance of the concentrated type of fertilizer is possibly explained on the basis of the greater solubility and more rapid nitrification of the materials from which it is formulated, causing it to suffer greater losses from leaching in the wet years. Typical comparative formulae of the two grades, on an acre basis, were substantially as follows, except for minor differences during the first two and last years of the series:

Medium analysis grade		High analysis grade	
Lbs. per acre		Lbs. per acre	
160	Nitrate of soda	200	Nitrate of potash
220	Sulfate of ammonia	102	Urea (42%)
250	Castor pomace	55	Peat
70	Ammophos "A"	190	Ammophos "A"
260	Superphosphate	70	Muriate of potash
240	Muriate of potash	133	Limestone, dolomitic
300	Limestone, dolomitic		
1500		750	

Effects of lime: The field was tested at the time of laying out the plots. The reactions at eight points distributed over both blocks ranged from 5.20 to 5.61 pH, with an average of 5.36 pH. The lime requirement to bring the soil to approximately 6.2 pH was estimated at two and a half tons of limestone per acre. This amount was applied to all plots on each block, except on plots 10A and 10B. Tests made in 1931 showed a need for further liming. An additional two tons of limestone was used in the spring of 1932. This brought the pH to approximately 6.5 by the spring of 1933. Fertilizer treatments were formulated to contain a sufficient amount of limestone to prevent residual acid effects. This was apparently successful, since in the spring of 1940, eight years after the 1932 lime application, the average reaction of all limed plots was 6.25 pH. The unlimed plots were very slightly less acid than in 1930—5.48 pH. However, the difference as compared with the original test is within the normal errors of measurement.

The acidity of the unlimed plots could not be considered as severe, since most unlimed soils in Connecticut are more acid. The soil of this field had been used for tobacco for many years prior to 1930. (In 1928 and 1929 cabbage had been grown on portions of the area.) In common with most old tobacco land in the Connecticut Valley, the residual effects

of long continued liberal fertilizer treatment had built up a considerable reserve of readily available phosphorus, sufficient to prevent the development of active aluminum to the degree usually associated with strongly acid soils. Hence the adverse effects of acidity on plots 10A and 10B could not be expected to be as pronounced as on most Connecticut soils testing from 5.2 to 5.6 pH.

The relative yields on these unlimed plots, as compared with the same limed plots with the same fertilizer treatment (5A, 5B, 15A, 15B) are shown in Table 4.

Table 4. Relative Yields on Unlimed Plots
(Based on average yields for crops grown successfully for three or more years, in percentage of yields on limed plots receiving the same fertilizer treatment)

	Percent		Percent
Spinach, fall	55.3	Lima Beans	89.9
Lettuce, first planting	59.0	Cucumbers	92.1
Spinach, early	61.7	Squash, summer	92.9
Radishes	72.9	Onions, sets	93.3
Beets, fall	74.1	Potatoes, Cobbler	94.1
Carrots, early	78.4	String Beans	99.3
Beets, early	84.2	Tomatoes	102.4
Lettuce, second planting	86.7	Sweet Potatoes	107.9
Peppers	88.5	Sweet Corn	117.2

The greater yields of sweet corn and tomatoes on the unlimed plots were possibly associated with the delay of the peak period of nitrification to coincide more closely to the time of greatest demand by the crop, as was pointed out in discussing results during the very wet seasons of 1937 and 1938 when effective leaching took place in June. Sweet potatoes suffered less injury from soil-borne diseases, such as black rot and scurf, on the unlimed plots.

Manure in Relation to Vegetable Crop Yields and Soil Organic Matter Conservation: The relationship of seasonal conditions to the effects of manure upon vegetable crop yields has been cited in a previous section.

Manure applied at the rate of 40 tons per acre per year is at a very heavy rate, but not greater than employed by many market gardeners in this State. The cost of this treatment is difficult to assess, since some growers also have dairy herds, or have cheap local sources available to them, while others are obliged to pay up to from $2.00 to $3.00 per ton. However, use of the more moderate rate (20 tons per acre) together with fertilizer at half the rate used without manure, has been more effective in most comparisons, at a much lower cost.

The heavy rate of manuring has caused a considerable increase in the organic matter content of the soil. The original soil in 1930 contained 2.17 percent organic matter. This, distributed through an eight-inch depth of plowed soil with a volume weight of 330,000 pounds per acre inch, represents 57,290 pounds of organic matter per acre. The soil of the heavily manured plots, at the end of ten years, contained 2.80 percent organic matter, representing 73,920 pounds per acre, or a net gain of 16,630 pounds. However, the soil of the unmanured plots with standard fertilizer treatment had suffered losses of organic matter during the ten-year period of intensive vegetable cropping, in spite of the turning under of ten over-winter rye cover crops and three summer green manure crops (buckwheat, millet and sudan grass). These unmanured plots contained 1.76 percent organic matter in the spring of 1940, representing 46,380 pounds per acre, or a net loss of 10,910 pounds, approximately 1000 pounds per acre. It may be conservatively estimated that the cover and green manure crops plowed under on the unmanured plots had prevented a further loss of organic matter of approximately 4000 pounds per acre. The residual organic matter contributed by the heavy manuring is thus approximately 31,540 pounds. Manure of average quality, such as used in these trials, may be expected to contain about 400 pounds of organic matter per ton of moist manure, as applied. The heavy manuring thus placed approximately 160,000 pounds of organic matter in the soil during the ten years. Approximately 80 percent of it has been decomposed, leaving only 20 percent to contribute toward maintaining and enriching the humus supply of the soil. This is in line with similar studies elsewhere[1,2,3] concerning the more or less permanent contribution of manure to soil organic matter.

Manure at the more moderate rate (20 tons per acre), supplemented with fertilizer, has been quite effective in maintaining a high level of production for vegetable crops. Except for radishes and early beets, the combination of manure and half-rate fertilizer has been more effective than full-rate fertilizer alone. However, it must be realized that the expense of 20 tons of manure greatly exceeds that of 750 pounds of fertilizer costing not more than $15.00 per acre. The average superiority of 20 tons of manure over 750 pounds of fertilizer in this comparison, on the basis of all crops, has been nearly 15 percent. If manure costs $2.00 per ton, on the land, the vegetable crops would have to be worth approximately $200.00 per acre to make the manure and fertilizer combination as profitable as fertilizer alone. This is not unreasonable, since the market value of many vegetable crops greatly exceeds this figure.

The 20-ton rate of manuring has also tended to increase the organic matter content of the soil. Four samples of surface soil from the manured plots, taken in 1940, contained 2.41 percent organic matter, representing 63,020 pounds per acre to plow depth (8 inches). Using the same basis of comparison as for the heavily manured plots, there has been a net gain of 5,710 pounds per acre, and an overall residue, allowing for losses that would have been suffered on unmanured land without green manure or cover crop, of 20,600 pounds per acre. This represents a somewhat greater residual effect than in case of the heavier manure application. However, crop yields have averaged about 10 percent greater than under

[1] Blair, A. W. and Prince, A. L. Some effects of long-continued manure, fertilizer and lime treatments on the composition of cropped soils. N. J. Agr. Expt. Sta. Bul. 604. 1936.
[2] Metzger, W. H. Nitrogen and organic carbon of soils as influenced by cropping systems and soil treatments. Kans. Agr. Expt. Sta. Tech. Bul. 45. 1939.
[3] Salter, R. M. and Schollenberger, C. J. Farm manure. Ohio Agr. Expt. Sta. Bul. 605. 1939.

heavy manuring, without fertilizer, thus contributing somewhat larger unharvested residues (roots, stems, etc.).

Since the 20-ton manure treatment more than maintained the original organic content of the soil, it is reasonable to suppose that a lighter application would have prevented any decline. The data are not sufficient to reveal the minimum rate of manuring needed for exact soil organic matter stabilization. However, under the program of intensive cropping without green manure or cover crop used in these trials, it seems likely that 16 tons of manure per acre per year would prevent any decline in soil organic matter. It should be understood that this is based on results on a light sandy soil containing approximately 2.0 percent of organic matter.

A summary of relative yields in manure and fertilizer comparisons for all crops grown for more than four seasons of these trials is shown in Table 5.

Table 5. Relative Yields in Manure and Fertilizer Comparisons, in Percentage of Yields with Full Rate Fertilizer Treatment, without Manure.

	Half-Rate Fertilizer Treatment		40 Tons of Manure, No Fertilizer.
	Without Manure	With 20 Tons of Manure	
Radishes	73.6	89.2	53.3
Spinach	65.8	113.2	82.9
Lettuce, 1st planting	52.4	138.0	93.0
Lettuce, 2nd planting	78.7	107.2	88.9
Beets, early	64.5	97.4	80.8
Carrots, early	80.2	121.9	124.0
Onions, sets	91.0	127.7	122.6
Potatoes, Cobbler	82.5	118.3	120.4
Sweet Corn	93.6	113.0	121.4
Tomatoes	80.7	104.2	102.5
Squash	82.7	122.7	116.8
Peppers	93.9	109.7	115.1
Sweet Potatoes	86.1	139.1	144.6
Average of 12 crops	80.0	114.9	106.3

The results of these comparisons between fertilizer supplemented with green manure crops, and fertilizer and stable manure in combination are in substantial agreement with those reported by Hartwell and Crandall[1], and later by Crandall and Odland[2] based on similar studies at Kingston, Rhode Island, on a somewhat heavier soil type (Bridgehampton silt loam).

[1] Hartwell, B. L. and Crandall, F. K. On the amount of stable manure necessary for vegetable growing. R. I. Agr. Expt. Sta. Bul. 195. 1923.
[2] Crandall, F. K. and Odland, T. E. Substituting fertilizers, green manure and peat for stable manure in the growing of vegetables. R. I. Agr. Expt. Sta. Bul. 234. 1932.

However, in their studies certain crops, notably tomatoes, showed much greater benefits from manure, even when applied at a much smaller rate (8 tons per acre).

It should be noted that in the Windsor trials manured plots remained fallow while green manure crops were grown. In practical vegetable cropping management a cash crop could have been produced during the time required for the growth of a summer green manure crop on unmanured land. On this basis Crandall and Odland concluded that vegetable fertility maintenance could be more profitably accomplished by light to moderate applications of stable manure and commercial fertilizer treatment than by resorting to summer-grown green manures, even under the most favorable fertilizer combinations. These data tend to confirm this view.

Effects of Increased Potash Treatment: Plots 4A, 4B, 14A and 14B provided potash treatment increased by 50 percent, compared with the standard rate (120 pounds per acre) used in plots 5A, 5B, 15A and 15B. Increases due to the extra potash have been relatively small, and have attained significance (a gain of 5 percent or more) only for the following crops: spinach, lettuce, squash and sweet potatoes. There is no indication that the root crops as a class need more potash than other crops, as is the popular opinion. It must be remembered that this soil was relatively well supplied with available potash at the beginning of these trials, due to past liberal fertilization for tobacco.

Relative yields at the 180-pound potash level, as compared with the 120-pound rate, for all crops grown for more than four seasons, are shown in Table 6.

TABLE 6. YIELDS WITH POTASH AT 180 POUNDS PER ACRE, IN PERCENTAGE OF YIELD AT THE NORMAL RATE OF 120 POUNDS PER ACRE.

	Percent		Percent
Lettuce, 1st planting	112.2	Onions, sets	102.0
Squash	109.4	Beets, early	101.6
Spinach	108.5	Potatoes, Cobbler	100.0
Lettuce, 2nd planting	107.6	Carrots	98.3
Sweet Potatoes	107.1	Peppers	94.7
Tomatoes	104.9	Radishes	91.8
Sweet Corn	104.1		

Rates of Application of Nitrogen: Beginning in 1934, nitrogen treatments were compared at three rates, as follows: 45 pounds (half-rate), 90 pounds (full-rate) and 135 pounds (1½ rate) per acre. The half-rate and full-rate treatments were also compared in both the normal strength and concentrated grades, from 1934 to 1938 inclusive.

The soil on these plots is rather poor in its ability to liberate available nitrogen from the natural organic matter of the soil. Studies conducted on

soil from an adjacent field in lysimeter experiments have shown an average yearly production of less than 50 pounds of nitrate nitrogen per acre without treatment. Of this amount, only about 20 pounds per acre was available to tobacco, growing from June 1 to August 15. The remainder was leached from the soil.

Since successful yields of most vegetable crops are capable of withdrawing from 100 to 150 pounds of nitrogen per acre during their growth cycle, it is evident that the treatment must supply a large proportion of these demands.

Yields of various crops at the three levels of nitrogen treatment, based on average yields during the six-year period 1934-1939, are shown in Table 7.

TABLE 7. YIELDS OF VARIOUS VEGETABLE CROPS AT THREE LEVELS OF NITROGEN FERTILIZATION, 1934-1939.

AVERAGE YEARLY MARKETABLE CROP—IN HUNDREDS OF POUNDS PER ACRE

	Half-Rate 45 lbs. N per A.	Full Rate 90 lbs. N per A.	1½Rate 135 lbs. N per A.
Radishes	58.1	76.1	75.4
Spinach	102.7	144.1	178.5
Lettuce, first planting	323.6	418.2	512.4
Lettuce, second planting	377.6	456.2	447.2
Beets, early	199.8	271.6	315.2
Carrots, early	164.6	184.3	201.7
Onions, sets	239.7	246.7	276.1
Potatoes, Cobbler	146.6	170.3	191.5
Sweet Corn	75.1	84.5	96.4
Tomatoes	168.2	194.3	204.3
Squash, summer	283.3	303.7	353.3
Peppers	137.5	138.4	126.1
Sweet Potatoes	291.0	286.7	298.0

Peppers and sweet potatoes were the only crops that failed to show a consistent decrease in yield at the half-rate treatment. An interesting difference is shown between the earlier and the later setting of New York head lettuce (Imp. 847). The extra nitrogen, in excess of 90 pounds, has been very effective for the first planting, while the second planting failed to respond—in fact, showed some decrease. The extra nitrogen tended to cause too great a stimulation of leafiness, producing large open heads of non-marketable quality, when the growing season of the crop was extended into the warmer weather as in case of the second planting. On the other hand, the high rate of nitrogen seemed to promote heading when the planting was made earlier.

Similar yield differences between the 45-pound and 90-pound nitrogen treatments were observed when these were compared in concentrated, or "high-analysis" formulae, during the 1934-1938 period. However, in general, the yields at the 45-pound rate were slightly higher in relation to the 90-pound rate. This is shown in Table 8.

TABLE 8. RELATIVE EFFECTIVENESS OF NITROGEN AT 45 POUNDS PER ACRE AS COMPARED WITH THE 90-POUND RATE, IN STANDARD STRENGTH AND CONCENTRATED FORMULAE (Average Data 1934-'38)

	Yield at 45-pound rate, in percentage of yield at 90-pound rate	
	Standard Strength	Concentrated
Radishes	75.9	87.1
Spinach	71.4	93.0
Lettuce, 1st planting	77.7	85.0
Lettuce, 2nd planting	83.0	97.3
Beets, early	73.3	86.0
Carrots, early	89.5	92.0
Onions, sets	96.2	94.8
Potatoes, Cobbler	87.1	94.7
Sweet Corn	89.2	88.4
Tomatoes	86.4	100.1
Squash, summer	97.5	88.9
Peppers	96.6	96.1
Sweet Potatoes	96.8	95.2
Average of 12 crops	86.7	92.3

Normal Fertilizer Treatment in Concentrated and Medium Analysis Formulae: The diminished effectiveness of concentrated, soluble and quickly nitrified fertilizer materials in wet years, when soil leaching occurred, has already been discussed.

The average results during the entire ten-year period are shown in Table 9, for all crops grown for four or more years. These are based on results from plots 7A, 7B, 17A and 17B, with 90 pounds of nitrogen, 90 pounds of phosphoric acid and 120 pounds of potash supplied from 750 pounds of fertilizer of the concentrated type, as compared with those from plots 5A, 5B, 15A and 15B supplying the same amounts of "plant food" from 1500 pounds of fertilizer of the medium-analysis type.

Effectiveness of Nitrogen Applied to the Preceding Rye Cover Crop: During the last five-year period (1935-39) the rye winter cover crops on plots 8A, 8B, 18A and 18B were treated with nitrogen, at approximately 45 pounds per acre, applied as cyanamid during the first three and as urea (42 percent) during the last two years. The application was made

in early March, the exact date varying with the season. The rye responded to this treatment, although some temporary injury was caused by cyanamid in 1935. After the rye was turned under, the same treatment used on plots 6A, 6B, 16A and 16B was made before planting. Thus the total yearly treatment was 90 pounds of nitrogen, 90 pounds of phosphoric acid and 120 pounds of potash per acre, one-half of the nitrogen applied to the preceding rye crop and one-half just before planting.

TABLE 9. YIELDS OF VEGETABLE CROPS WITH STANDARD FERTILIZATION IN THE CONCENTRATED GRADE, IN PERCENTAGE OF YIELDS FROM THE MEDIUM-ANALYSIS GRADE.

	Percent		Percent
Radishes	101.6	Potatoes, Cobbler	93.8
Spinach	78.5	Sweet Corn	99.3
Lettuce, 1st planting	98.7	Tomatoes	95.0
Lettuce, 2nd planting	99.9	Squash	99.6
Beets, early	83.7	Peppers	101.9
Carrots, early	100.1	Sweet Potatoes	97.6
Onions, sets	104.5	Average of 12 crops	96.2

TABLE 10. EFFECT OF NITROGEN TOP-DRESSING ON RYE COVER CROP

	Plot 7 No Nitrogen Top-dressing on Rye	Plot 8 Nitrogen Top-dressing on Rye
Dry Weight		
Stems and leaves, per A.	866 lbs.	1885 lbs.
Roots, " "	328 "	356 "
Total, " "	1194 lbs.	2241 lbs.
Organic Matter		
Stems and leaves, per A.	780 lbs.	1676 lbs.
Roots, " "	276 "	310 "
Total, " "	1056 lbs.	1986 lbs.
Nitrogen		
Stems and leaves, composition	1.28%	1.98%
" " " , per acre	11.1 lbs.	37.3 lbs.
Roots, composition	0.73%	0.98%
" , per acre	2.4 lbs.	3.5 lbs.
Total, per acre	13.5 lbs.	40.8 lbs.

When the treatment was applied to rye preceding the early planted block, the cover crop had to be plowed under soon after the first of April; hence time did not permit more than a slight increase from the nitrogen treatment. However, on the later planted block, for midseason crops, the rye made greatly increased growth on the treated plots. In 1936 and in 1938 small "meter-square" plots of the rye were harvested on plot 8, in comparison with plot 9. Comparative data, based on averages for the two years, are shown in Table 10.

The rye, when harvested for the above data, was just beginning to show a few heads, the average condition when plowed during the first week of May. It is apparent that if the plowing under of the rye is deferred until this stage, most of the nitrogen top-dressing is utilized by the crop, and that the total growth is approximately doubled. The much higher percentage composition of the crop with respect to nitrogen should tend to facilitate its decay without any significant demand upon the soil for available nitrogen.

Table 11. Comparative Yields with Half of the Nitrogen Applied to Previous Rye Crop, in Comparison with Half-Rate and Full-Rate Nitrogen Treatments (of Concentrated Grade) at Planting Time.
Average Data, 1935-39.

	45 lbs. of nitrogen at planting time	45 lbs. of nitrogen applied to rye plus 45 lbs. at planting time	90 lbs. of nitrogen at planting time
Radishes	76.3	95.1	100
Spinach	71.3	116.7	100
Lettuce, 1st planting	77.4	102.2	100
Lettuce, 2nd planting	82.5	108.2	100
Beets, early	73.6	110.2	100
Carrots, early	89.3	99.4	100
Onions, from sets	97.2	103.9	100
Potatoes, Cobbler	86.1	100.6	100
Sweet Corn	88.9	100.6	100
Tomatoes	86.6	97.1	100
Squash	93.3	107.3	100
Peppers	99.3	96.3	100
Sweet Potatoes	101.5	103.9	100
Ave. of 12 crops	86.9	103.0	100

Evidence of the later recovery of nitrogen applied to the preceding rye crop is afforded by measurements of the sudan grass green manure crop, following early vegetables in 1939. This was a season with relatively little leaching, and early crops grew almost equally well at the 45-pound rate of nitrogen (plots 6-16) and when this was supplemented by nitrogen applied to the preceding rye crop (plots 8-18). However, the sudan grass grew much more luxuriously and with better color on the rye top-dressed plots. Meter-square plots were harvested just before the green manure crop was turned under, and both dry weight and nitrogen content were determined, with the following average results:

	Nitrogen at 45 pounds per acre, applied before early vegetables: No nitrogen on rye	45 lbs. of nitrogen on rye
Sudan grass green manure after early vegetables		
Dry wt. (exclusive of roots and stubble)	4262 lbs. per A.	5759 lbs. per A.
Nitrogen content	0.86% 36.7 lbs. per A.	1.31% 75.4 lbs. per A.

The yields of various vegetable crops, as affected by this program of nitrogen treatment, are shown in Table 11, in comparison with those obtained when all of the nitrogen is applied just before planting.

It is apparent that nitrogen applied to the preceding rye crop has been quite effective, and there is some indication that this plan tends to give a better distribution of nitrogen availability through the season.

Effect of Treatment on Early Yield of Tomatoes: Tomatoes were the only crop harvested on several dates during the season for which there were sufficient reasonably consistent data to permit evaluation of treatments with respect to early production. Yields of tomatoes picked prior to August 10 were separately tabulated, with average results for those comparisons that were continued throughout the ten-year period shown in Table 12.

Table 12. Effect of Various Treatments upon Earliness of Unstaked Tomatoes

	Early Yield	Total Yield	Percent of Total Yield
Manure, 40 T., no fertilizer	1863	23,290	8.00
Manure, 20 T., plus half-rate fertilizer	2361	24,600	9.60
High nitrogen fertilizer	2240	24,120	9.29
High potash fertilizer	2089	23,950	8.72
Standard fertilizer (medium-analysis)	2168	22,840	9.49
Concentrated fertilizer	2057	21,680	9.49
Half-rate fertilizer	1738	18,740	9.27
Standard fertilizer, no lime	2012	23,390	8.60

In general, the early yields showed a somewhat greater relative spread between treatments than the total yield. The manure treatment, without fertilizer, apparently tended to delay the production of ripened fruit to a slight extent.

FERTILIZING POTATOES ON OLD TOBACCO LAND

(Coöperative experiment with Agronomy Dept., Storrs Agr. Expt. Sta.)

During recent years the chief expansion of potato production in Connecticut has been on land formerly used for tobacco for many years. Since that crop is unusually well fertilized, in excess of the removal of fertilizer constituents by the harvested tobacco, a considerable accumulation of readily available "plant food", particularly phosphorus and potassium, is the rule on such fields. Most previous trials with fertilizer for potatoes have been conducted on soils of more normal degrees of chemical fertility; hence, fertilizer practices based on such results may not be applicable to much of the potato area in Hartford and Tolland counties.

In 1933 a tract of land adjacent to the Tobacco and Vegetable Field Station at Windsor (Solkowski field) was selected for a study of the fertilizer needs of potatoes on old tobacco land. This field has been in practically continuous tobacco for more than 25 years, with liberal fertilizer treatment at approximately 3000 pounds per acre of fertilizer, supplying from 150 to 200 pounds of nitrogen, from 60 to 120 pounds of phosphoric acid and from 150 to 200 pounds of potash. The soil is a rather coarse phase of the Merrimac sandy loam type, containing approximately 78 percent sand (chiefly of the coarse and medium sand grades), 17 percent silt and 5 percent clay (.002 mm. or finer). Its organic matter content was found to be relatively low for Connecticut conditions, a representative sample containing 2.07 percent organic matter. The total phosphorus content, at .137 percent, reflected the accumulation of this constituent from previous tobacco fertilization. The available phosphorus was estimated at 98 parts per million by the laboratory method of Truog. While similar to that found in most old tobacco soils, this was quite high as compared with other soils not subjected to such intensive fertilization. The soil of the Storrs field used for potato fertilizer trials showed only eight pounds of available phosphorus by the same method.[1] The readily available (exchangeable) potassium, at 293 parts per million, was typical of old tobacco soils, and much higher than most soils that are known to give significant response to potash treatment. The readily available (replaceable) magnesium, at 39 parts per million, was definitely low for Connecticut soils, and was so estimated by quick test methods by the Universal soil testing technique. The soil was found to be moderately acid, the original composite sample from the field testing 5.21 pH. Except for a degree of sandiness that is somewhat excessive as compared with most of the potato areas of the Connecticut Valley, the soil appeared to be well suited to a study of this sort.

The field was laid out in a rectangular arrangement of 70 plots, each including 4 rows 85 feet, 10 inches long, spaced 38 inches between rows. The two center rows of each plot were used for yield records, with five feet at each end of the plot omitted, thus giving an area of 1/91 acre per plot. Four replicates of each of 17 treatments were provided, with one extra plot of the arbitrarily selected standard treatment, and one unfertilized check plot. The arrangement of the plots is shown in Figure 4. Careful study of soil variability and yield differences on different plots with the same treatment during the course of the experiment have influenced the

[1] Brown B. A. Fertilizing for potatoes (second Report). Storrs Agr. Expt. Sta. Bul. 203. 1935.

pattern of the replicate blocks shown in this diagram. The soil of Blocks A and D is somewhat ligher than that of the other two, with Block C most favorable for good yields, as follows:

	Average yield on all plots of block, for 5 years
Block A —	235.6 bu. per acre
Block B —	257.9 " " "
Block C —	264.5 " " "
Block D —	238.0 " " "
All Blocks—	249.1 " " "

An analysis of variance indicates that 23 bushels per acre is a significant difference in the average yields of the four replicates of a treatment for the five-year period.

The treatments shown in Table 13 correspond to the numbers shown in Figure 4.

TABLE 13. PLAN OF TREATMENT, POTATO FERTILIZER PLOTS, SOLKOWSKI FIELD 1933-1938.

(Pounds per acre per year)

	Nitrogen	Phosphoric acid P_2O_5	Potash K_2O	Magnesia MgO	Lime Oxide CaO
1–	100	120	120	100[1]	150[1]
2–	"	0	"	"	"
3–		40	"	"	"
4–		80	"	"	"
5–		160	"	"	"
6–		120	0	"	"
7–	"	"	40	"	"
8–	"	"	80	"	"
9–			160	"	"
10–			200	"	"
11–			120	0	125[2]
12–	"	"		33[2]	"
13–				67[2]	"
14–	"	"		100[2]	"
15–				0	0
16–	100 (½ organic N)			70[1]	100[1]
17–	60	"		60[1]	90[1]
18–	No fertilizer or lime.				

[1] Supplied as dolomitic limestone. In 1933, the rates were 40 pounds of CaO and 60 pounds of MgO.
[2] Calcium supplied as high-calcic limestone. Magnesium supplied as magnesium sulfate (Kieserite). (In 1933, the rate was 60 pounds of magnesia).

The standard fertilizer treatment was formulated as follows: Cottonseed meal—100 pounds, sulfate of ammonia—330 pounds, Ammophos "A"—250 pounds, sulfate of potash—250 pounds, dolomitic limestone—500 pounds. In order to provide varying rates of phosphoric acid or

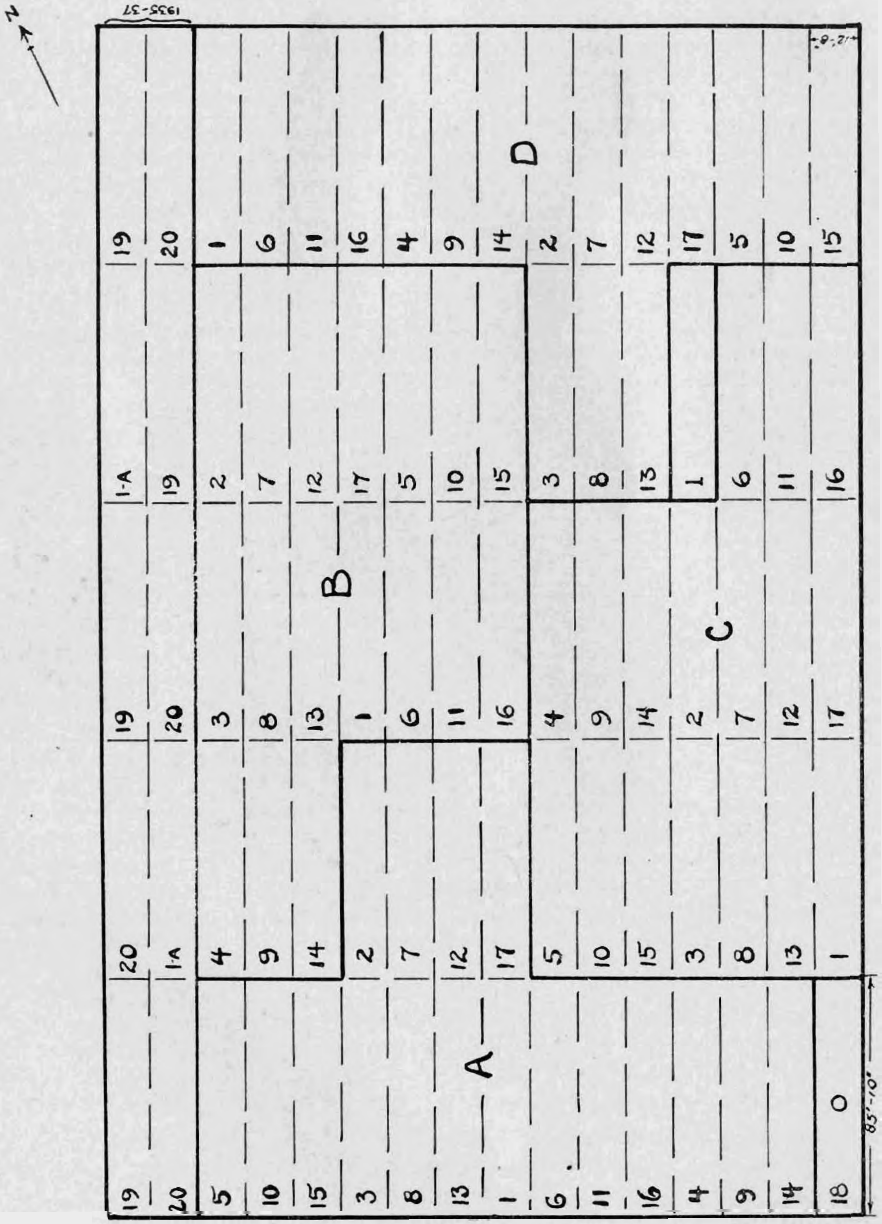

FIGURE 4. Windsor potato fertilizer plot plan, 1933-37.

nitrogen, the sulfate of ammonia and Ammophos "A" were used in varying amounts and superphosphate was introduced into the formula at the higher rates of treatment. Similarly, the amounts of sulfate of potash were varied in the potash series. The 60 percent organic nitrogen in treatment

16 was supplied as cottonseed meal. Due to the less acid effect of the materials, a small amount of limestone was used in treatments 16 and 17. As noted, somewhat smaller lime treatments were used in the first year. Except for treatments 11 to 15, inclusive, the fertilizers during the remaining years were substantially neutral in their net effects upon the soil reaction. Treatments 11 to 14 were acid to the extent of approximately 250 pounds $CaCO_3$ equivalent per acre per year, while treatment 15 was acid to the extent of 500 pounds $CaCO_3$ equivalent per acre per year.

Liming in Relation to Fertilizer Treatment: Careful studies of soil acidity on the various plots showed that a considerable variability persisted, irrespective of treatment, during the first two years. Hence, in the spring of 1936, high calcic hydrated lime was used in amounts calculated to bring the reaction to approximately 5.4 pH, except on treatment 15. Plots 11 to 14 showed the effects of the increased acidity during the first three years, since average liming was equivalent to 670 pounds of $CaCO_3$ on treatments 1 to 10, while for plots 11 to 14 the lime needed to adjust the reaction was equivalent to 1050 pounds of $CaCO_3$, a difference of 380 pounds. Since treatments 1-10 received 1200 pounds of dolomitic limestone, and treatments 11-14 received only 620 pounds of calcic limestone per acre in the combined treatment of the three previous years, or a difference of 580 pounds, treatments 11-14 have been only slightly less acid than one should expect from their fertilizer formulae. At the conclusion of five years of cropping, the 40 plots of treatments 1-10 averaged 5.07 pH, indicating that the soil had become slightly more acid during the five years, in spite of the application of 2870 pounds of limestone equivalent per acre in the fertilizer treatments and special lime application of 1936. (The original composite sample from the field in April, 1933, tested 5.21 pH). However, the final sampling was done in the fall, when pH results are usually somewhat low. In comparison, the 16 plots of treatments 11-14 averaged 4.83 pH. These had received 2170 pounds of limestone equivalent in the treatment during the five years. The four plots of treatment 15 averaged 4.32 pH, showing the marked degree of soil acidification effected by a fertilizer that supplied practically all of its nitrogen as sulfate of ammonia and ammo-phos, theoretically acid to the extent of causing a cumulative lime deficiency equivalent to 2500 pounds per acre over a five-year period.

TABLE 14. RATES AND SOURCES OF NITROGEN

Treatment		Bushels per acre, U. S. No. 1. Potatoes					
		1st Yr. 1933	2nd Yr. 1934	3rd Yr. 1935	4th Yr. 1936	5th Yr. 1937-38	Ave.
16	60 pounds N, inorganic	358	255	245	205	164	245
1	100 pounds N, inorganic	367	259	274	190	171	252
16	100 pounds N, 60% organic	366	274	262	200	171	255

Nitrogen: The plan involved a comparison of two rates of nitrogen: 60 pounds (treatment 17) and 100 pounds (treatment 11) per acre. A fertilizer containing 60 percent of its nitrogen from an organic source (treatment 16) was also studied. Data from these trials are shown in Table 14.

The results indicate that under the conditions of this experiment, only insignificant differences can be noted in either of the above comparisons. It is somewhat surprising that 60 pounds of nitrogen, usually considered a rather low rate of treatment under Connecticut conditions, has not produced a greater decrease as compared with 100 pounds. However, the yields are lower, even under the best treatments, than can be readily attained on the more loamy soils that are most favorable for this crop.

During the last three years of the experiment, an additional set of plots was added along the west side of the same field (see Figure 4), in order to study two other rates of nitrogen treatment: 80 pounds and 120 pounds per acre, as compared with the standard rate of 100 pounds per acre. Yields in these trials are shown in Table 15.

TABLE 15. RATES OF NITROGEN—THREE-YEAR TRIALS.

Treatment	Bushels per acre U. S. No. 1. Potatoes 1st Year 1935	2nd Year 1936	3rd Year 1937	Ave
19— 80 lbs. N	365	211	130	235
1A—100 " "	345	191	142	226
20—120 " "	321	187	114	207

These differences are not statistically significant. However, the indications point to the conclusion that approximately 80 pounds of nitrogen per acre is a suitable rate of treatment for potatoes on light sandy soil with an average yield capacity of around 250 bushels per acre.

As shown in Table 14, there is no consistent advantage from using large amounts of an expensive organic nitrogen source in potato fertilizers. This is in agreement with more detailed experiments conducted in Aroostook County, Maine.[1]

Even though 60 pounds of nitrogen per acre appeared to give practically as good yields as higher rates, it must be pointed out that the unfertilized check plot, receiving no nitrogen and not significantly limited in yield by the absence of phosphorus or potash during the first year, yielded 279 bushels per acre in 1933 as compared with 358 bushels per acre for the 60-pound nitrogen treatment, indicating clearly that nitrogen fertilization at that rate has produced a very significant contribution toward improved yields, even in the first year of potatoes on old tobacco land. In subsequent years, the diminishing yield on the unfertilized plot was in part due to progressively greater potash deficiency; hence, they cannot be directly compared with the nitrogen-treated plots. However, it is of interest to note that the yield of the check plot had fallen to only 18 bushels per acre in the fifth year. The year-to-year yields, without any fertilizer, as compared with fertilizer plots, were as follows:

[1] Brown, B. E., Owen, F. V. and Tobey, E. R. Sources of nitrogen for potato fertilizers in Aroostook County. Me. Agr. Expt. Sta. Bul. 354. 1930.

	Yield on check plot	Ave. yield on all fertilized plots
1st year —	279 bu. per A.	377 bu. per A.
2nd year —	160 " " "	266 " " "
3rd year —	48 " " "	264 " " "
4th year —	81 " " "	180 " " "
5th year —	18 " " "	160 " " "

Phosphorus: Since past treatment and soil tests indicated that little or no response to phosphorus would be obtained during the first year or so at least, although common potato fertilizer practice supplies 160 pounds of phosphoric acid per acre, the following rates were compared, in order to ascertain as closely as possible the amount that would be needed from year to year: none, 40 pounds, 80 pounds, 120 pounds, 160 pounds. The results of this series are given in Table 16.

TABLE 16. POTATO YIELDS AT VARYING RATES OF PHOSPHORUS

Treatment No.—Lbs.	P_2O_5 per A.	Bushels per acre—U. S. No. 1 Potatoes 1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr.	Ave.
2	0	386	271	253	194	171	257
3	40	410	279	285	206	158	267
4	80	402	274	277	177	152	254
1	120	367	259	274	190	171	252
5	160	395	260	232	171	167	241

The above data show clearly that on old tobacco land, such as in this case, the accumulated available phosphorus from many years of liberal fertilizer treatment is capable of preventing a need for phosphorus fertilization for several years of potato cropping. There is a slight indication that 40 pounds of phosphoric acid has increased the yield by a few bushels. However, plot variability on the field is sufficient to account for this. In some years the heaviest rate of treatment (160 pounds) has been considerably adverse to yield, and on the average for the five years, the 40-pound rate has been significantly better than 160 pounds. It should be emphasized that such results are entirely different from those secured in most other fertilizer experiments in the Northeast, on soils of more normal fertility.

It is of interest to note that the phosphorus treatments have shown little or no effect upon the amounts of phosphorus determined by the available phosphorus method of Truog[1], or by the phosphorus test used in the Universal soil testing procedure[2]. The results of these measurements are summarized in Table 17.

[1] Truog, E. The determination of the readily available phosphorus in soils. Jour. Amer. Soc. Agron. 22: 874-882. 1930.

[2] Morgan, M. F. The Universal soil testing system. Conn. Agr. Expt. Sta Bul. 372. 1935.

TABLE 17. AVAILABLE PHOSPHORUS AS MEASURED BY LABORATORY AND QUICK TEST PROCEDURES, ON SOIL SAMPLES FROM THE PHOSPHORUS SERIES.

Yearly Treatment	Averages of samples from all plots at the end of the fifth season: Truog method parts per million	Universal soil tests pounds per acre
2 - No P_2O_5	138	150
3 - 40 lbs. P_2O_5	153	162
4 - 80 " "	132	138
1 - 120 " "	178	187
5 - 160 " "	148	185

Soil of the "no phosphorus" treatment is still definitely well supplied with available phosphorus as estimated by both methods. However, the phosphorus added in the treatment, in considerable excess of crop removal, has not remained in the soil in a form that can be measured by either of these methods, to any significant degree.

Potash: Potassium in readily available form was present in favorable quantities in this soil at the beginning of the experiment, However, since the crop removes larger amounts of this constituent (approximately 150 pounds in an average crop for this field), the response to liberal potash fertilization might be expected to increase after the first two or three years. Amounts up to 200 pounds of potash per acre are frequently used by potato growers in this section. Hence, the following rates were compared: no potash, 40 pounds, 80 pounds, 120 pounds, 160 pounds, 200 pounds. The results of these trials are shown in Table 18.

TABLE 18. POTATO YIELDS AT VARYING RATES OF POTASH

Treatment		Bushels per acre—U. S. No. 1 Potatoes					
No.-Lbs.	K_2O per A.	1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr	Ave.
6	0	369	255	248	113	98	217
7	40	372	264	276	155	128	238
8	80	384	271	282	168	165	253
1	120	367	259	274	190	171	252
9	160	380	261	258	181	182	252
10	200	368	251	272	176	184	250

During the first two years the responses to potash were insignificant, although there was some indication that 80 pounds per acre was better than lower or higher rates. By the third year the yields from the "no potash" treatment had dropped significantly as compared with other plots. In the fourth year the 40-pound rate became quite inadequate, and by the fifth year there was an indication of some response even up to the 160-

pound rate. It is thus apparent that most of the residual potash from past treatment has become exhausted during the first three years. If conditions had been favorable for higher yields during the last two years, the response to the larger amounts would probably have been greater, since a larger crop would make greater demands upon the soil.

After the second year, the no potash plots could be distinguished from others by the appearance of the vine growth, especially after the vines had begun to die as a result of hot, dry periods in July. Without potash, the vines died much sooner.

The results of these trials are in agreement with soil studies with respect to readily available potash determinations by the base exchange method of Schollenberger[1], as well as quick tests by the Universal soil testing system. These data are shown in Table 19.

TABLE 19. EXCHANGEABLE AND QUICK TEST POTASH, IN SOILS FROM POTATO PLOTS IN THE POTASH SERIES

Lbs. K_2O applied per Yr.	Pounds Exchangeable K_2O per A. to 7 in. Depth* (Average of 4 Plots): After 4th Yr. Crop	After 5th Yr. Crop	Universal Tests after 5th Yr.
0	103	57	110
40	117	70	130
80	166	114	150
120	188	133	190
160	267	212	275
200	340	223	330

* Based on estimated per acre weight of 2,300,000 lbs. of soil.

In comparison, a composite sample from the entire field in 1933 showed 674 pounds of exchangeable potash per acre. This amount is surprisingly higher than the later tests on any of the plots. However, there is an indication of some exhaustion of residual available potash even at the higher rates, and at the lower rates the soil has been depleted to a very low level. The 200-pound rate should have supplied much more than crop removal. However, lysimeter experiments on similar soil indicate a yearly loss of approximately 100 pounds of potash per acre by leaching, under tobacco crop fertilized at the 200-pound rate. Some of this is liberated by slow disintegration of the difficultly soluble potash from mineral particles in the soil. Unpublished lysimeter data for one year show that about 60 pounds of potash are leached from an uncropped soil receiving no potash fertilizer.

Chemical analyses with respect to the potash content were made on the potato crop of 1936 on composite samples from the replicates to Treatment 6 (no potash) and Treatment 1 (120 pounds K_2O). The data are shown in Table 20.

[1] Schollenberger, C. J. and Dreibelbis, F. R. Analytical methods in base exchange investigations on soils. Soil Sci. 30: 161-173. 1930.

TABLE 20. CHEMICAL COMPOSITION OF POTATO TUBERS AS AFFECTED BY POTASH TREATMENT

	Dry matter percent	Percent of dry weight K_2O	CaO	MgO	P_2O_5	N
No K_2O	18.87	2.21	.10	.21	.68	2.40
120 lbs. K_2O	17.04	2.72	.08	.17	.68	2.63

On the basis of the above analyses, the amounts of various constituents in the crops on the two treatments for 1936 are given in Table 21.

TABLE 21. AMOUNTS OF VARIOUS CONSTITUENTS REMOVED BY THE POTATO CROP OF 1936.
(In Pounds per Acre)

	Total yield*	Dry wt.	K_2O	CaO	MgO	P_2O_5	N
No. K_2O	8,580	1619	35.8	1.6	3.4	11.0	38.9
120 lbs. K_2O	12,420	2116	57.6	1.7	3.6	14.4	55.7

* Including unmarketable "seconds".

The yields of U. S. No. 1 grade, 113 bushels and 190 bushels, respectively, for the two treatments were low in comparison with those attained on most commercial potato areas in this section.

Magnesia: Soil tests of the original composite sample from this field indicated a relatively low magnesium level. Since magnesium deficiency of potatoes had been encountered in Maine and Rhode Island prior to 1933, a series of plots was established in order to study response to varying amounts of magnesium. The following rates were provided: no magnesia, 33 pounds, 67 pounds, 100 pounds. The magnesium was added in the form of anhydrous magnesium sulfate (Kieserite—similar to the commercial product known as "Emjo"). Approximately the same amount of calcium as used in the standard treatment (1) was applied as high calcic limestone containing less than 1 percent of magnesia. This amount was only one-half that used in the dolomite limestone component of the formula of Treatment 1; hence the fertilizers on Treatments 11-14 were somewhat acid in their residual effects, as discussed earlier in this paper. The results from the magnesia series are presented in Table 22.

TABLE 22. YIELDS WITH VARYING QUANTITIES OF MAGNESIA

Treatment	Bushels of U. S. No. 1 Potatoes per Acre 1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr.	Total
11—No MgO	351.2	269.5	271.2	169.9	169.2	246.2
12— 33 lbs. MgO	388.0	277.9	260.5	189.9	190.3	261.3
13— 67 " "	397.4	289.8	291.9	196.3	186.9	272.5
14—100 " "	362.4	256.9	268.0	181.1	178.6	249.4

The above data show a significant yield increase of 26.3 bushels for the 67-pound rate, as compared with the no magnesia treatment. The increase at the 33-pound rate, 15.1 bushels, is probably significant. A significant decrease from using the 100-pound rate as compared with the 67-pound rate may be due to a great concentration of soluble salts resulting from the treatment. Slight injury to the stand was frequently noted when the potato vines first appeared.

Soil samples from the various plots were sampled from year to year and tested by the Universal soil testing system. Magnesium in the exchangeable form was determined after the fourth and fifth crops. Results of these determinations are indicated in Table 23.

TABLE 23. MAGNESIA AS DETERMINED BY QUICK TEST METHODS AND AS EXCHANGEABLE MAGNESIUM.

	Quick Tests average of 5 sets of tests on each plot		Exchangeable MgO in pounds per acre to 7-inch depth	
	Rating	Index No.*	After 4th crop	After 5th crop
15—No MgO (unlimed)	Extra low	0.6	126	62
11—No MgO	Very low	1.0	157	103
12—33 lbs. MgO	Low	1.9	176	116
13— 67 " "	Medium low	3.3	235	138
14—100 " "	Medium	4.0	218	142
1—100 " " (as dolomite)	Medium	4.5	285	158

*Based on a scale ranging up to 10 for soils giving very high magnesium tests.

These results appear to indicate that definite response to magnesium is to be expected on a soil giving "very low" tests by the quick test methods and a probable response on a soil giving "low" readings. The quick test results give better correlations with treatment than do the exchangeable magnesia data, by a laboratory method.

Adjustment of Acid Effects of the Fertilizer and Supplying Magnesia by Dolomitic Limestone: Comparisons between the results from Treatment 15, supplying no lime or magnesia, and Treatment 1, supplying 100 pounds of magnesia in a sufficient amount of dolomitic limestone to neutralize the acid effects of the fertilizer materials permit an evaluation of the success of accomplishing both these purposes on an acid, magnesium-deficient soil. Data are given in Table 24.

TABLE 24. YIELDS WITH AND WITHOUT LIME AND MAGNESIA ADJUSTMENT

Treatment	Bushels U. S. No. 1. Potatoes per Acre 1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr.	Ave.
15—No lime or magnesia	358	254	248	176	105	228
1—Dolomitic limestone	367	259	274	190	171	252

The results during the first two years were insignificant, but during the last three years they were definitely much better from the use of the dolomitic limestone. The progressive increase in acidity under Treatment 15 was probably the predominant factor involved. Similar beneficial effects of small amounts of lime used in connection with potato fertilizers on strongly acid fields have been found by Brown[1] in field trials on several Connecticut farms.

SWEET POTATO FERTILIZER EXPERIMENT

A series of trials with varying amounts of nitrogen, phosphoric acid and potash was conducted for the five-year period 1935-39. This also included a comparison between broadcast and side-dressing methods of fertilizer application.

The plots were placed on a field of the Tobacco Substation that had been in tobacco trials for several years, but which had been given up from that crop because the soil was found to be too sandy for good yields, except in the northwest corner where the soil was somewhat affected by an adjacent poorly drained spot. There were four replicate blocks of plots, the treatments randomized within the blocks. Each plot consisted of 4 rows spaced 36 inches apart, 72 feet, 7.2 inches long, or an area of 1/50 acre. The plot plan is shown in Figure 5.

The two inside rows, with ends trimmed to 70 feet, were harvested for yield records. Slips of the yellow jersey variety (little stem strain for the first three years; big stem strain for the last two years), obtained from Virginia or New Jersey, were set about June 1. The average harvest date was October 10.

The soil is a rather sandy phase of the Merrimac sandy loam, averaging approximately 79 percent sand, 15 percent silt and 6 percent clay (.002 mm. or less), and containing approximately 1.9 percent organic matter. However, there is a considerable degree of variation with respect to texture and organic matter content. This is reflected in the moisture equivalent as determined by the Briggs-McLane method[2]. The average moisture equivalents for the four replicate blocks were found as follows, on the basis of final soil sampling in 1939:

I—Northwest	Section	7.76
II—Southeast	"	6.93
III—Northwest	"	10.10
IV—Southeast	"	7.24

The extreme variation between plots is represented by that between plot 12 near the southeast corner, and plot 15 in the northwest corner. Comparative data for these plots are as follows:

	Plot 12	Plot 15
Sand	79.6%	76.4%
Silt	15.8%	17.0%
Clay	4.6%	6.6%
Organic Matter	1.25%	2.5%
Moisture Equivalent	6.6%	11.9%

[1] Brown, B. A. Fertilizers for potatoes (Second Report). Storrs Agr. Expt. Sta. Bul. 203. 1935

[2] Briggs, L. J. and McLane, J. W. Moisture equivalent determinations and their application. Jour Amer. Soc. Agron. 2: 138-147. 1910.

The northwest corner of Block III is inclined to be somewhat wet during the early part of the season; on the other hand, the southeast portion of the field, in Block II, is excessively dry in periods of deficient rainfall and rather "leachy" in wet seasons.

In other respects the soils of the various plots are quite similar. All plots are nearly uniformly acid, tests of samples in the fall of 1939 ranging from 4.8 to 5.6 pH, and averaging 5.1 pH. In common with most old tobacco soils, the tests for available phosphorus and potassium are relatively high.

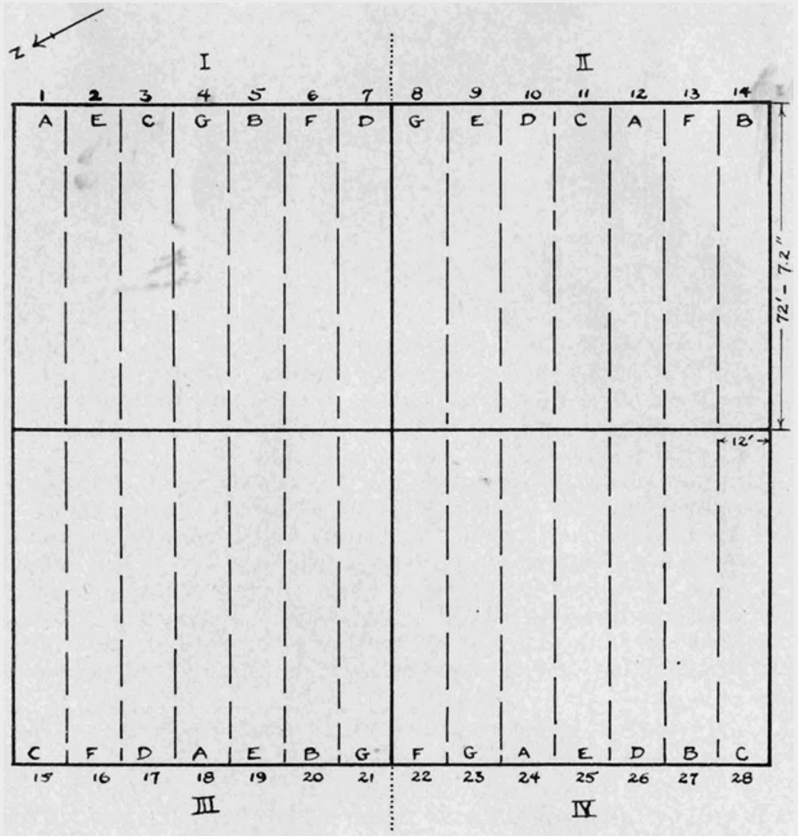

FIGURE 5. Plot plan of sweet potato fertilizer experiment, 1935-1939.

The treatments provide the following comparisons: nitrogen at the rates of 24, 48, and 96 pounds per acre; phosphoric acid at the rates of 72 and 144 pounds per acre; potash at the rates of 72, 120 and 168 pounds per acre; 1200 pounds of a 4-6-10 grade, broadcast before setting, and side-dressed along the rows two weeks after setting. Except for the latter treatment, all fertilizer was broadcast just before setting.

A summary of the results of these trials for the various treatments is presented as Table 25.

TABLE 25. SUMMARY OF RESULTS OF SWEET POTATO FERTILIZER EXPERIMENT 1935-1939

Treatment		Av. Yield of Marketable Crop—Bushels per A. 1935	1936	1937	1938	1939	Ave.
B — 24 lbs. N	72 lbs. P_2O_5	201.2	303.4	193.0	157.0	296.2	230.2
A — 48 " "	120 " K_2O	178.9	278.9	164.6	182.4	276.0	216.2
C — 96 " "		156.4	247.2	160.3	197.8	235.7	199.5
A — 72 lbs. P_2O_5	48 lbs. N	178.9	278.9	164.6	182.4	276.0	216.2
F —144 " "	120 " K_2O	184.3	271.7	178.6	177.1	319.7	226.3
D — 72 lbs. K_2O	48 lbs. N	182.2	276.5	175.7	181.0	252.0	213.5
A —120 " "	72 " P_2O_5	178.9	278.9	164.6	182.4	276.0	216.3
E —168 " "		185.0	287.0	152.6	190.6	296.6	222.4
A —Broadcast. 1200 lbs. 4-6-10		178.9	278.9	164.6	182.4	276.0	216.2
B —Side-dressed, 1200 lbs. 4-6-10		182.7	305.8	160.8	211.7	284.2	229.0

On the basis of the above data, the variations between treatments are small, and in most cases insignificant by statistical analysis. Since the variation between replicates has been considerable, due to soil differences previously described, an average yield difference of 25.6 bushels per acre must be found in order to show significance. This requirement is met only in case of Treatment B, with 24 pounds of nitrogen, as compared with Treatment C, with 96 pounds of nitrogen, when the former was definitely better. The differences in rate of nitrogen treatment would have been greater, except for the data for 1938 when, contrary to other years, nitrogen was beneficial in both of the two higher rates because of the unusually heavy rainfall and consequent severe leaching during that growing season.

TABLE 26. FACTORS FOR CORRECTING YIELDS TO THE BASIS OF MOISTURE EQUIVALENT 8.0.

Moisture Equivalent	Factor	Moisture Equivalent	Factor
6.5	1.18	9.5	.91
7.0	1.11	10.0	.89
7.5	1.05	10.5	.885
8.0	1.00	11.0	.88
8.5	.96	11.5	.88
9.0	.93	12.0	.88

Detailed study of yield variations on various plots, irrespective of treatment, has shown a definite correlation of yield with moisture equivalent. Yields increase progressively with moisture equivalent, especially from 6.5 to 10.0. This is shown graphically in Figure 6. Assuming such a relationship, the yields have been recalculated to the basis of a moisture equivalent of 8.0, for all plots, by multiplying the actual yield by the factors for the various moisture equivalents, as shown in Table 26.

A summary of the data on the basis of these adjusted yields is shown in Table 27.

TABLE 27. SUMMARY OF RESULTS OF SWEET POTATO FERTILIZER EXPERIMENTS 1935-1939, ON BASIS OF ADJUSTMENT TO YIELDS AT A MOISTURE EQUIVALENT OF 8.0 PERCENT

Treatment		Av. Yields of Marketable Crop—Bu. per A. 1935	1936	1937	1938	1939	Ave.
B 24 lbs. N	72 lbs. P_2O_5	213	322	203	164	313	243
A 48 " "	120 " K_2O	184	283	169	182	281	220
C 96 " "		136	244	161	193	236	198
A 72 lbs. P_2O_5	48 lbs. N	184	283	169	182	281	220
F 144 " "	120 " K_2O	190	281	184	178	326	232
D 72 lbs. K_2O	48 lbs. N	183	276	176	180	255	214
A 120 " "	72 " P_2O_5	184	283	169	182	281	220
E 168 " "		192	295	158	192	304	228
A Broadcast, 1200 lbs. 4-6-10		184	283	169	182	281	220
B Side-dressed, 1200 lbs. 4-6-10		192	322	170	223	299	241

The above table shows a considerably greater difference between treatments than that in Table 26. From an analysis of variance, a difference of 24 bushels is definitely significant. On this basis, the 24-pound nitrogen rate is now shown to be better than the 48-pound rate. The side-dressing method of application is apparently superior to the broadcast application. There are indications of increased yield up to 144 pounds of phosphoric acid and up to 168 pounds of potash, but the increases over the lower rates are insignificant.

The results of these trials appear to justify the use of from 600 to 800 pounds of a 4-16-20 grade of fertilizer for sweet potatoes, preferably applied as a side-dressing along the rows after the plants have become well rooted. This conforms with fertilizer practice found to be most advantageous in the sweet potato sections of the Middle Atlantic States, on coarse sandy soils.

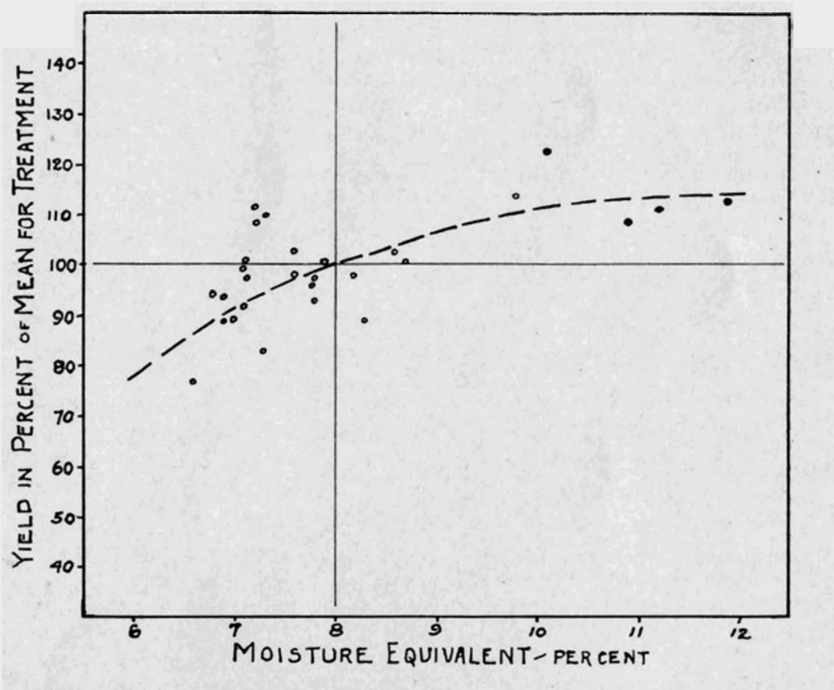

Figure 6. Relationship between sweet potato yields and the moisture equivalents of the surface soil samples from various plots of the sweet potato fertilizer series.

SUMMARY

Fertilizer, manure and lime trials with several important vegetable crops of Connecticut were conducted during the ten-year period 1930-39. The field used for this experiment, located at Windsor, is of the Merrimac sandy loam (deep phase) type, and was formerly used for tobacco for many years.

Yearly variations in seasonal conditions revealed important differences in crop growth with respect to season. Larger amounts of nitrogen were especially beneficial in seasons with frequent heavy rainfall. Manure was less effective for early crops after cold, wet springs. Concentrated fertilizers gave somewhat poorer results than normal-strength fertilizers in wet seasons. Supplementing fertilizer with manure gave greater responses in dry years.

Most crops showed significant responses to lime. Spinach, lettuce, radishes, beets and carrots were especially poor on the unlimed plots. Peppers, lima beans, cucumbers, squash, onions and potatoes also gave increased yields with lime. String beans, tomatoes, sweet potatoes, and sweet corn produced as well or better without lime. The unlimed soil on this field is only moderately acid (5.2 to 5.6 pH) and contains little active aluminum in consequence of its high content of readily available phosphorus.

Manure was most effective when used at the moderately heavy rate of 20 tons per acre, in combination with fertilizer treatment equivalent to 750 pounds of a 6-6-8 grade, per acre. Some crops produced somewhat larger yields at the very heavy rate of manuring, without fertilizer, but the cost of the extra manure was much greater than that of the fertilizer treatment supplementing the lighter rate of manuring.

Heavy manuring for ten years has caused a material increase in the organic matter content of this light sandy soil. At the 20 ton per acre rate, manure has also caused some improvement in this respect. Fertilizers and a modest program of green manuring failed to provide full organic matter maintenance on this field, although producing very good yields of all crops except in unfavorable seasons.

In the fertilizer comparisons, increasing the potash treatment from 120 to 180 pounds per acre produced larger yields of lettuce, squash, spinach, sweet potatoes, tomatoes and sweet corn. The root crops were apparently less responsive to extra potash than other types of vegetables.

Responses to fertilizer nitrogen in amounts greater than 45 pounds per acre were considerable for all crops except peppers and sweet potatoes. Most crops showed considerable benefits from increasing the nitrogen dosage from 90 to 135 pounds per acre. Lettuce set in the field in early April gave best yields at the highest rate of nitrogen treatment, while the same crop planted two weeks later was adversely affected by the additional nitrogen, apparently in consequence of excessive leafiness at the expense of heading when the heads were formed during a later and warmer period. Fertilizer formulated from the more concentrated fertilizer materials gave relatively better yields at the lower rate of nitrogen.

On the whole, fertilizer treatments in the medium-analysis grade have been slightly more consistent in effectiveness than treatments in the concentrated or "high-analysis" grade. However, as previously mentioned, seasonal factors are involved in this difference in performance, chiefly due to earlier soil leaching losses from the more rapidly available concentrated sources of nitrogen. The average difference in favor of the medium-analysis treatment is very slight and possibly not significant.

The application of one-half of the yearly nitrogen treatment to the preceding rye crop, in early spring, has been equally or slightly more effective than when all is applied just before planting. This practice has increased both the total growth and the nitrogen content of the crop that is turned under for soil improvement.

The proportion of unstaked tomatoes available for early picking during the period of maximum prices was least in case of manure, without fertilizer, and was diminished to some extent by extra potash and by the omission of lime. However, in general, treatments that have given largest total yields have given the largest yield of the early pickings.

Various rates of fertilizer components were used in a potato (Green Mountain) experiment conducted for five years on old tobacco land. Phosphorus gave no consistent benefits in amounts exceeding 40 pounds of phosphoric acid (P_2O_5) per acre per year, and there was no indication of increased need for phosphorus in the course of the trials. Potash gave only slight increases during the first two years, but the responses to the larger amounts became greater from year to year. By the fifth year, there was some indication of increased benefit up to the 160 pound per acre rate. Nitrogen at the rate of 100 pounds per acre gave slightly better yields, on the average, than at the rate of 60 pounds per acre. However, a three-year experiment indicated that the 80-pound rate was adequate on the soil.

There was a significant benefit from magnesia, as the soluble salt, at rates up to 67 pounds of MgO per acre. Dolomitic limestone was also effective, when used in an amount approximately equivalent to the acid effects of the fertilizer materials.

The fertilizer requirements of sweet potatoes, as grown on a very sandy soil, were studied in a five-year experiment. Best results were obtained from a fertilizer supplying 24 pounds of nitrogen, 72 pounds of phosphoric acid and 120 pounds of potash, per acre. The fertilizer was more effective when applied as a side-dressing than when broadcast before setting.