Effect of Different Sources of Fertilizer Nutrients And Different Rates of Fertilizer Applications on Yields of Vegetable Canning Crops

Beets

Cabbage

Peas

Sweet Corn

Tomatoes

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Effect of Different Sources of Fertilizer Nutrients and Different Rates of Fertilizer Applications on Yields of Vegetable Canning Crops: Beets, Cabbage, Peas, Sweet Corn, and Tomatoes

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ABSTRACT

In a 6-year fertilizer experiment on vegetable canning crops, four fields were used so that four crops could be grown each year with 10 fertilizer treatments replicated four times on each field. Each specific fertilizer treatment was applied to the same plot every year so that the cumulative effects of the fertilizers could be determined. Crops were rotated on each field, including a legume sod every 4 years, and rye or ryegrass cover crops after every cultivated crop. Three- or 4-year yield records were obtained for beets, cabbage, peas, sweet corn, and tomatoes.

Fertilizer treatments for all crops included three rates of application of one fertilizer mixture plus a no-fertilizer treatment and two rates of each of the following formulas of the same ratio: (a) a regular-grade mixture composed entirely of inorganic sources of nitrogen, superphosphate, and muriate of potash; (b) a premium-priced mixture in which 40 per cent of the nitrogen was from organic sources, the phosphorus from superphosphate, and half the potash from sulfate of potash-magnesia; (c) a similar mixture in which all the nitrogen was from inorganic sources, the phosphorus from superphosphate, and half the potash from muriate and half from Sul-Po-Mag; and (d) a high-analysis mixture in which all the nitrogen was from inorganic sources, all the phosphorus from double superphosphate, and all the potash from muriate of potash.

Statistical analyses of the yield records show that there were significant differences due to rates of application, but there were no significant differences in yields of any of these crops due to differences in fertilizer formulas. Considering fertilizer costs and crop response, inorganic forms of nitrogen proved better than organic sources; double superphosphate gave as good crop yields with less bulk to handle and less transportation costs than 20 per cent superphosphate; and muriate of potash gave as good yields as sulfate of potash-magnesia.

[1]The authors wish to express their appreciation to the International Minerals and Chemical Corporation for a grant which partially financed these investigations, and to Dr. J. F. Davis, now at Michigan State College, who helped design the experiment and supervised the field work and yield records in 1945.

SCOPE OF EXPERIMENT

THE EXPERIMENTS reported herein were designed primarily to compare the following fertilizer treatments for each of five vegetable canning crops grown on typical western New York soils:

1. Low cost inorganic sources of nitrogen in a mixed fertilizer vs. a similar grade in which 40 per cent of the nitrogen was derived from higher cost organic sources.
2. A high analysis mixture (lacking gypsum) vs. a regular grade mixture of the same ratio.
3. Muriate of potash vs. sulfate of potash-magnesia.
4. Four different rates of applying one fertilizer mixture.
5. The cumulative effect of annual applications of these fertilizers at the various rates in a good canning crops rotation.

Years ago most mixed fertilizers contained substantial amounts of organic sources of nitrogen, but now most mixed fertilizers are composed entirely of inorganic ingredients. This trend is shown in Table 1, which illustrates the rise and decline in the total *amount* of organic nitrogen fertilizers and the rapidly accelerating decline in the *proportion* of organic sources of nitrogen used in fertilizers. This also shows the rapid increase both in total amount and in proportion of inorganic nitrogen used in fertilizers. However, there continues to be so much interest in organic fertilizers that some fertilizer manufacturers and dealers are offering premium-priced fertilizer mixtures containing some of the higher cost organic materials. This has resulted in many inquiries from growers and fertilizer dealers regarding the relative merits of different fertilizer materials. One object of this experiment was to determine whether or not these premium-priced fertilizers will produce additional increases in yields of vegetable canning crops.

TABLE 1.—*Total Amounts and Proportions of Organic and Inorganic Nitrogen Used in Fertilizers per Year.**

YEAR	ORGANIC NITROGEN USED, TONS	TOTAL NITROGEN USED, TONS	ORGANIC NITROGEN, PER CENT
1850	2,400	2,400	100
1875	14,000†	15,000	93
1900	63,000	72,000	88
1925	65,000	269,000	24
1950	34,000	920,000‡	4

*Prepared for the National Fertilizer Association by A. L. Mehring, Senior Chemist of the Division of Fertilizers and Agricultural Lime, Bureau of Plant Industry, United States Department of Agriculture.
†Partly estimated.
‡1950 consumption to June 30, 1950.

As pointed out by Volk and Tidmore (28)[2], in most experiments comparing different sources of nitrogen fertilizer, it has been found that any differences in crop response were due principally to the effect of the nitrogen sources on the acidity of the soil. In most cases where this acidity was corrected with neutralizing materials, the differences in crop yields resulting from the application of different sources of nitrogen were eliminated. The soils used in the experiments reported herein were slightly alkaline so that no injurious effect from acidifying action of the fertilizer would be expected. Therefore, any difference in crop responses due to the source of nitrogen presumably would be due to the greater availability or more effective rate of availability of the nitrogen from the different sources.

A second object of the experiment reported here was to compare the relative merits of 20 per cent superphosphate and double superphosphate (11, 13). With increasingly higher freight rates and higher costs of storage and handling, there is a considerable saving in cost per unit of plant food by using higher analysis mixtures. In many mixed fertilizers the percentage of phosphorus pentoxide (P_2O_5) is higher than the percentage of the other ingredients. The phosphorus material most commonly used in mixed fertilizers is superphosphate, but the highest grade of this material is only 20 per cent phosphoric acid (P_2O_5). Consequently, a rather low limit on the total available plant food is placed on mixtures containing superphosphate as the sole source of phosphorus. Other phosphorus compounds are now obtainable, such as "double superphosphate", which contain from 45 to 50 per cent available phosphoric acid. By using such materials, much higher analyses of mixed fertilizers can be formulated. However, there is no gypsum (calcium sulfate) in double superphosphate, whereas half the weight of 20 per cent superphosphate is gypsum. Both calcium and sulfur are essential plant nutrients which, in gypsum, are in a form readily available to plants.

In some experiments on sandy soils Tidmore and Williamson (25) reported that where a high analysis fertilizer mixture was used in which the phosphorus source (mono-ammonium phosphate) contained no gypsum, there was a very significant reduction in the yield of cotton. But when gypsum was added to the mixture the yields were equal to the high yields obtained where superphosphate (con-

[2]Refers to Literature Cited, page 29.

taining gypsum) was used as the source of phosphorus. They reported that a small amount of gypsum on sandy soils may mean the difference between a successful crop of cotton and a crop failure.

McGeorge (9) states further that gypsum is a major corrective for improving heavy soils. He states it will improve the soil structural conditions regardless of what causes the poor structure. He recommends the application of 200 pounds of gypsum per acre annually as a sound practice.

Bartholomew (3), on the other hand, reported no detrimental effect in average yields in 13 years' results where mixtures composed of various phosphorus compounds lacking gypsum were used.

Consequently, it is important to determine whether a high analysis fertilizer mixture formulated with double superphosphate would give as good results with vegetable crops over a period of years as a lower analysis mixture containing 20 per cent superphosphate (and gypsum) as the source of phosphorus.

There are many experiments showing the importance of sulfur (14, 27) and of magnesium (4, 5, 23) in fertilizers. On the other hand, Garner, *et al.* (7) reported that in a comparison of muriate vs. sulfate of potash for tobacco the chlorine in the muriate of potash had a marked effect in increasing the water content of the leaves of the tobacco plant throughout the growing season thus giving the plant greater resistance to drought. This would be an important consideration that seemed worthy of investigation if it would also hold true for canning crops.

Later, Garner, *et al.* (8) reported that a mixture containing one-half the potash from muriate of potash and one-half from sulfate of potash-magnesia gave the best results. This mixture was therefore included in the experiments reported herein. Consequently, a third object of this experiment was to compare the relative merits of muriate of potash (the usual potash ingredient in mixed fertilizers) with a potash salt which supplies potash in the sulfate form and also supplies magnesium (sulfate of potash-magnesia).

Bear and Prince (4) state that the plow depth of an ideal soil should contain about 250 pounds of exchange magnesium per acre, and that in a loam soil the ideal ratio of magnesium to calcium to potassium would be approximately 4:43:6. They further point out that the total milliequivalents of the three cations, magnesium, calcium, and potassium, in any crop plant tend to be constant, but the relative proportion of each element absorbed by the crop may vary greatly and is influenced by the relative amounts of these elements in exchange form in the soil. If excessive amounts of potassium are applied to the soil, the absorption of potassium by the plant may be so great as virtually to exclude the absorption of magnesium. Also, excessive amounts of calcium may reduce the uptake of magnesium by the plant. Therefore, although the magnesium content of the soils used in this experiment was high, the very high calcium content of the soils plus the moderately high content of potassium combined with the liberal application of potash in the fertilizers used could conceivably interfere with the absorption of an optimum amount of magnesium by the plant. For that reason, it seemed worthwhile to determine whether a magnesium fertilizer would improve the yields of vegetables grown under these conditions.

Ordinary mixed fertilizers supply sulfur from the gypsum in superphosphate and from ammonium sulfate; but, in high analysis mixed fertilizers, phosphorus sources lacking sulfur would have to be used. This would greatly reduce the amount of sulfur supplied in the fertilizer. If nitrogen sources other than ammonium sulfate also were used, sulfur deficiency troubles in crop growth might occur (14, 27).

McGeorge (10) points out that many vegetable crops, including cabbage, require three times as much sulfur as phosphorus. In the high analysis fertilizers used in this experiment (treatments E and F, Table 3) and in the regular grade fertilizers (treatments A and B) and also in treatments G, I, and J, ammonium sulfate was the principal source of nitrogen. Furthermore, the proportion of nitrogen from this source was constant so that the only variation in sulfur content of these mixtures was due to the difference in the phosphorus ingredient.

A fourth object of this experiment was to obtain further information regarding the most profitable rate of applying these fertilizers for vegetable canning crops on a soil typical of the principal canning crops producing sections of western New York, and to determine the cumulative effect of annual applications of these fertilizers at the various rates in a good canning crops rotation.

This experiment was started in 1945. The first six years' results are presented in this bulletin. It is a comparison of four fertilizer mixtures, each containing equivalent amounts of nitrogen, phosphorus, and potash but formulated from different sources or ingredients. Each of these mixtures was compared at two rates of application and one was compared at three rates. A "no fertilizer" treatment was also included in the experiment, thus giving a total of 10 fertilizer treatments (Tables 2 and 3).

TABLE 2.—*Fertilizer Treatments Compared in this Experiment.*

TREATMENT	DESCRIPTION	RATE OF APPLICATION *	SOURCE OF NUTRIENTS †		
			N	P_2O_5	K_2O
A	Common	Low	All inorganic	Super	All muriate
B	Common	Medium	All inorganic	Super	All muriate
C	Organic N and Mg	Low	40% organic	Super	Half Sul-Po-Mag
D	Organic N and Mg	Medium	40% organic	Super	Half Sul-Po-Mag
E	High analysis	Low	All inorganic	Double	All muriate
F	High analysis	Medium	All inorganic	Double	All muriate
G	Inorganic N and Mg	Low	All inorganic	Super	Half Sul-Po-Mag
I	Inorganic N and Mg	Medium	All inorganic	Super	Half Sul-Po-Mag
J	Inorganic N and Mg	High	All inorganic	Super	Half Sul-Po-Mag
H		None	——	——	——

*Low, medium, and high rates are, respectively, 600, 1,200, and 1,800 pounds of 5–10–10, and 375 and 750 pounds of 8–16–16 per acre for beets, cabbage, and sweet corn; 300, 600, and 900 pounds of 5–10–10, and 187 and 375 pounds of 8–16–16 per acre for peas; and 750, 1,500, and 2,250 pounds of 4–12–8, and 500 and 1,000 pounds of 6–18–12 per acre for tomatoes.

†Sources of N-P_2O_5–K_2O as used in treatments A and B are inorganic nitrogen, 20 per cent superphosphate, and 60 per cent muriate of potash. In treatments C and D, 40 per cent of the nitrogen is supplied by organic carriers; in treatments E and F, all of the P_2O_5 is supplied by double superphosphate; and in treatments C, D, G, I, and J, half of the potash is supplied by sulfate of potash-magnesia and half by muriate of potash. See Table 3 for detailed ingredients.

TABLE 3.—*Composition of Fertilizer Formulas, 1-2-2 Ratio.*

MATERIAL	ANALYSIS, PER CENT			POUNDS PER TON OF MIXED FERTILIZER FOR TREATMENT			
	N	P_2O_5	K_2O	A and B common	C and D Org. N and Mg	E and F high analysis	G, I, and J Inorg. N and Mg
Ammonium nitrate	33.5	—	—	63	63	101	63
Ammonium sulfate	20.7	—	—	354	202	567	354
Cyanamid.	22.0	—	—	30	——	48	30
Cottonseed meal. . .	7.0	—	—	——	200	——	——
Hynite tankage. . . .	8.4	—	—	——	300	——	——
Superphosphate. . .	—	19.5	—	1,015	314	——	872
Double phosphate.	—	47.0	—	——	300	696	60
Muriate of potash	—	—	60.0	334	167	534	167
Sul-Po-Mag.	—	—	22.0	——	454	——	454
Filler.	—	—	—	204	——	54	——
Total.				2,000	2,000	2,000	2,000

EXPERIMENTAL PROCEDURE

For all crops except tomatoes, the ratio of N, P_2O_5, and K_2O was 1–2–2, whereas with tomatoes the ratio was 1–3–2. Formulation details of the four mixtures with the 1–2–2 ratio are given in Table 3. Similar materials were used in making up the 1–3–2 fertilizer mixtures for tomatoes.

Four fields, designated as I, II, III, and IV, respectively, at the Station's Canning Crops Research Farm near Geneva, were used for this experiment each year. Fields I and II are classified as Honeoye silt loam and fields III and IV are Ovid silt loam. Honeoye is a moderately well-drained soil formed from highly alkaline, unassorted glacial drift composed of limestones, sandstones, shales, and crystallines. Ovid is an imperfectly drained soil formed from moderately alkaline unassorted glacial drift composed of Medina sandstone, shale, limestone, and crystallines. Pertinent information regarding the soils used in this experiment is given in Table 4.

TABLE 4.—*Chemical Characteristics of Soils Used in This Experiment.* *

Factor †	Honeoye silt loam		Ovid silt loam	
	Field I	Field II	Field III	Field IV
pH	7.74	7.59	7.42	6.81
Ammonia N	31	26	25	23
Nitrate N	10	7	25	5
P	39	31	28	15
K	144	67	76	56
Ca	7,600	6,700	—	—
Mg	638	538	662	390

*Analyses were made by the Department of Agronomy, Cornell University, Ithaca, N. Y. in accordance with the methods described by Peech and English (19). Data are from soil samples taken in August, 1949, from the no-fertilizer plots (treatment H), except calcium which was from samples taken in 1947.

†Pounds per acre for all except pH.

Soils of similar type are common throughout the principal canning crops producing areas of western New York; which include, roughly, all but the southern tier counties south of Lake Ontario.

For six years before this experiment was begun these fields had been used for a fertilizer ratio experiment in a vegetable canning crops rotation (20). From that experiment it was concluded that phosphorus was the principal limiting element on these soils and that the application of phosphorus greatly increased the yields. Nitrogen appeared to be second in importance in increasing yields. The largest yields were obtained where nitrogen, phosphorus, and potash were all applied liberally.

For that experiment the long axis of the plots extended east and west. At the conclusion of the experiment crop rotation was continued, but the fields were uniformly fertilized lightly for three years to even out the residual effect of the different fertilizer treatments. Then the present experiment was laid out with the long axis of the plots at right angles to the previous plots so that each new plot extended across five of the plots of the earlier experiment. Consequently, any residual effect of previous treatments could not appreciably influence the yields of the current experiment.

Each field was divided into four blocks and the 10 different fertilizer treatments were randomized within each block, thus giving four replications of each fertilizer treatment in each of the four fields. Individual plots were 15 feet wide by 100 feet long. The same designated fertilizer mixture (Tables 2 and 3) was applied each year to each specific plot and the crops were rotated on the four fields so that the cumulative effect of 6 years' continuous application of each fertilizer treatment could be determined. All fertilizers were applied 3 to 4 inches deep with a disc grain drill just prior to planting each crop. The long-term effect of the different fertilizer treatments on the nitrogen, phosphorus, potash, and magnesium content and pH of the soil is given elsewhere (26).

Details of the crop sequence for each field for the period of this experiment are given in Table 5.

TABLE 5.—*Crop Sequence of the Four Fields for the Period of this Experiment.*

YEAR	FIELD I	FIELD II	FIELD III	FIELD IV
1945	Tomatoes (rye)	Ryegrass*	Cabbage (rye)	Beets (rye)
1946	Cabbage (rye)	Tomatoes (rye)	Beets (rye)	Peas (red clover)
1947	Beets (rye)	Cabbage (rye)	Ryegrass*	Tomatoes (rye-grass)
1948	Peas (alfalfa)	Sweet corn (rye-grass)	Tomatoes (rye-grass)	Cabbage (rye-grass)
1949	Alfalfa	Peas (alfalfa)	Cabbage (rye-grass)	Sweet corn (rye-grass)
1950	Sweet corn (rye-grass)	Alfalfa	Beets (rye)	Peas (alfalfa)

*Experiment started too late to plant peas in 1945, and the soil was too wet in the spring of 1947. Both years the soil in these fields was kept fallow till early August when ryegrass was planted.

Transplanted crops (cabbage and tomatoes) were set with a one-row transplanter which applied ½ cup of water to each cabbage plant and ½ cup of starter solution to each tomato plant. The starter solution applied to tomatoes was made by dissolving 3 pounds of completely soluble 15–30–14 fertilizer in 50 gallons of water. Cabbage plants were set approximately 18 inches apart in 3-foot rows, or 9,680 plants per acre. Tomatoes were spaced 3 feet apart in 5-foot rows, or 2,900 plants per acre. Beets were seeded in 2-foot rows and sweet corn in 3-foot rows. Sweet corn stands averaged 13,360 plants per acre. Border rows were discarded to eliminate any effect of the fertilizer treatments on adjoining plots. Yields per acre were calculated from actual yields of the interior rows.

Varieties used in this experiment were Detroit Dark Red beets, Marion Market cabbage, and Golden Cross Bantam sweet corn. John Baer tomatoes were grown in 1945, 1946, and 1947 and Red Jacket in 1948. Surprise peas were grown on all plots in 1946, but because of the time involved in vining 40 individual plots in one day, two varieties of different maturity dates were used in succeeding years, planting one variety on two replications and the other variety on the other two replications. Varieties so used were Surpass and Yukon in 1948, Pacemaker and Wyola in 1949, and Bonneville and Surprise in 1950.

Monthly precipitation records for the six years covered by this report are summarized in Table 6, while in Fig. 1 precipitation is broken down into 10-day periods for the six months of the growing season.

TABLE 6.—*Monthly Precipitation at Geneva, 1945-1950.*

MONTH	1945	1946	1947	1948	1949	1950	33-YEAR AVERAGE 1918–50
Jan.	2.09	1.05	3.26	1.70	2.45	3.46	2.30
Feb.	2.22	1.75	0.51	1.45	1.33	3.63	2.19
Mar.	3.05	0.69	1.78	2.50	1.04	3.30	2.74
Apr.	2.89	1.35	4.10	3.78	2.39	1.35	2.92
May	4.26	3.16	5.29	5.07	2.08	1.53	3.15
June	3.16	3.46	2.77	3.50	1.24	3.03	3.32
July	2.69	2.98	3.70	1.54	4.24	4.83	3.25
Aug.	1.37	3.55	5.85	3.11	2.64	2.04	2.85
Sept.	7.81	3.61	2.35	1.73	1.60	2.05	2.80
Oct.	4.40	3.80	0.82	2.84	0.67	4.48	2.77
Nov.	4.93	2.32	2.88	3.27	1.91	4.46	2.90
Dec.	1.11	1.99	1.51	1.61	0.95	2.30	2.38
Total	39.98	29.71	34.82	32.10	22.54	36.47	33.57

These data indicate that April was dry in 1946 and 1950 and wet in 1947 and 1948; May was dry in 1949 and 1950 and wet in 1945, 1947, and 1948; June was dry in 1949; July was dry in 1948 and wet in 1949 and 1950; August was dry in 1945 and wet in 1947; and September was dry in 1948 and 1949 and very wet in 1945. In general, for the important six months of the growing season, 1945 and 1947 were wetter than normal, 1946 and 1948 were about normal, and 1949 and 1950 were considerably drier than normal.

EXPERIMENTAL RESULTS

Fertilizer treatments H, G, I, and J (Table 2), form a comparison of four different rates of fertilization; while treatments A, B, C, D, E, F, G, and I form a factorial combination of two different rates of application of each of four different fertilizer formulas or sources. Analysis of variance has been used to analyze the data for both of these combinations. Results are discussed separately by crops.

There were four replications of 10 treatments or 40 plots of each crop each year it was grown in this experiment. Detailed records of the 160 individual plots of beets, 160 plots of cabbage, 160 plots of peas, 120 plots of sweet corn, and 160 plots of tomatoes are available, but for the convenience of the reader, only the average yields of each treatment for each year have been tabulated and summarized in this bulletin.

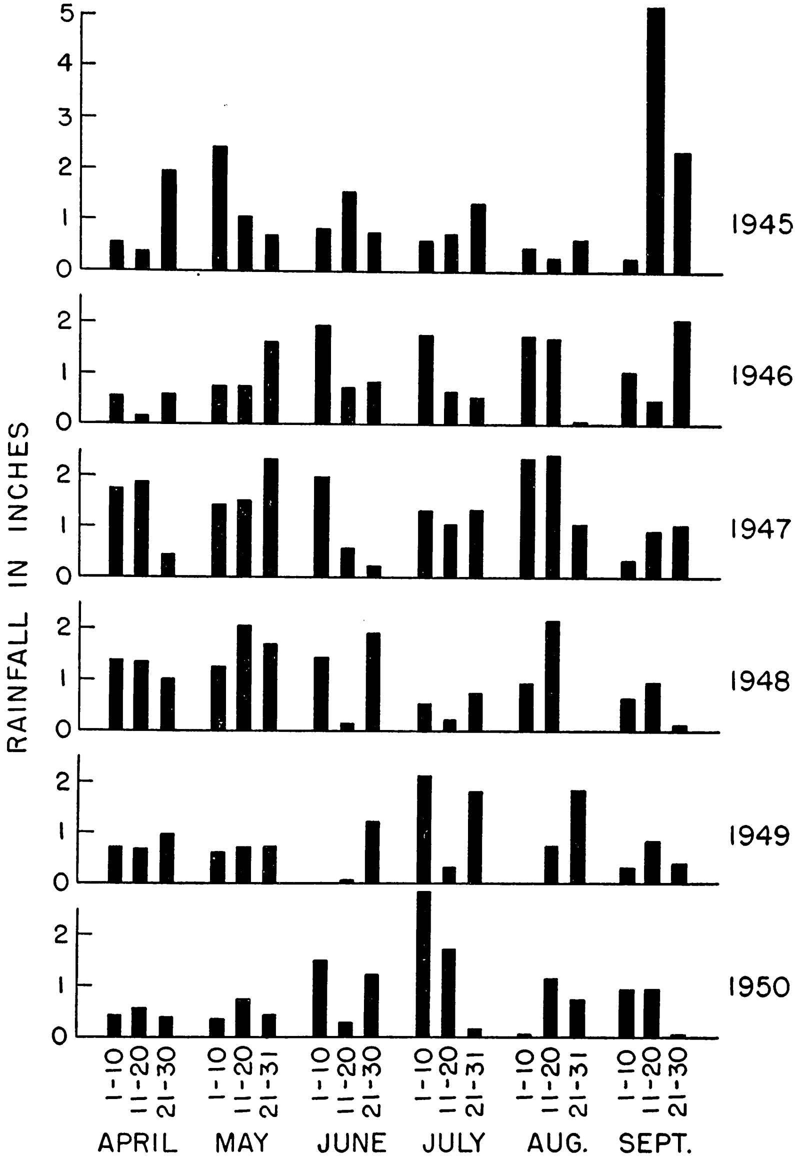

FIG. 1.—*Precipitation by 10-day periods for the six months of each growing season, 1945 to 1950, inclusive.*

RESULTS WITH BEETS

Detroit Dark Red beets were grown in this experiment in 1945, 1946, 1947, and 1950. In addition to the specified fertilizer treatments (Table 2), all beet plots received 50 pounds of borax per acre.

Comparing the four rates of application of 5–10–10 fertilizer (Table 7, A), the 4-year average shows a significant increase in yield

TABLE 7.—*Beet yields: Summary of Four Years' Results, Canning Crops Farm, Geneva, N. Y.*

FERTILIZER TREATMENT†		YIELD, TONS PER ACRE‡				
Code	Pounds per acre	1945	1946	1947	1950	Average 4 years
A. Comparison 4 Rates of Application of One Fertilizer Mixture						
H	0	9.6	14.7	5.8	5.2	8.8
G	600	9.9	16.8	6.8	7.1	10.2
I	1,200	11.6	20.2	7.4	7.6	11.7
J	1,800	12.3	21.1	8.4	8.6	12.6
L.S.D. (19:1)		1.0	3.3	0.7	1.4	0.9
B. Comparison of Low and Medium Rates§						
Low	600	10.3	16.9	6.4	7.1	10.2
Medium	1,200	11.7	18.1	7.1	7.8	11.2
L.S.D. (19:1)		0.8	N.S.	0.4	0.7	0.4
C. Comparison of Four Sources of Fertilizer Materials¶						
Common		11.2	17.1	6.7	7.5	10.6
Organic N + Mg		11.0	17.0	6.5	7.3	10.4
High analysis		11.1	17.3	6.7	7.6	10.7
Inorganic N + Mg		10.8	18.5	7.1	7.4	10.9
L.S.D. (19:1)		N.S.‖	N.S.	N.S.	N.S.	N.S.
D. Interaction						
Sources × rates		N.S.	*	N.S.	N.S.	N.S.

†For details of treatment, refer to footnotes of Table 2.
‡Average of 4 replications each year.
§Each entry is the average of four different kinds of fertilizer.
¶Each entry is the average of two different rates of application.
‖Differences not significant.
*Significant (19:1).

from each increasing increment of fertilizer (Fig. 2), though in two of these years the increases from the first 600 pounds of fertilizer were not significant; and in the other two years, the increases from 1,200 pounds as compared with 600 pounds were not significant. In only one year and in the 4-year average did the 1,800 pounds of fertilizer give a significant increase over 1,200 pounds. In every year 1,200 pounds of this fertilizer produced a significant increase over no

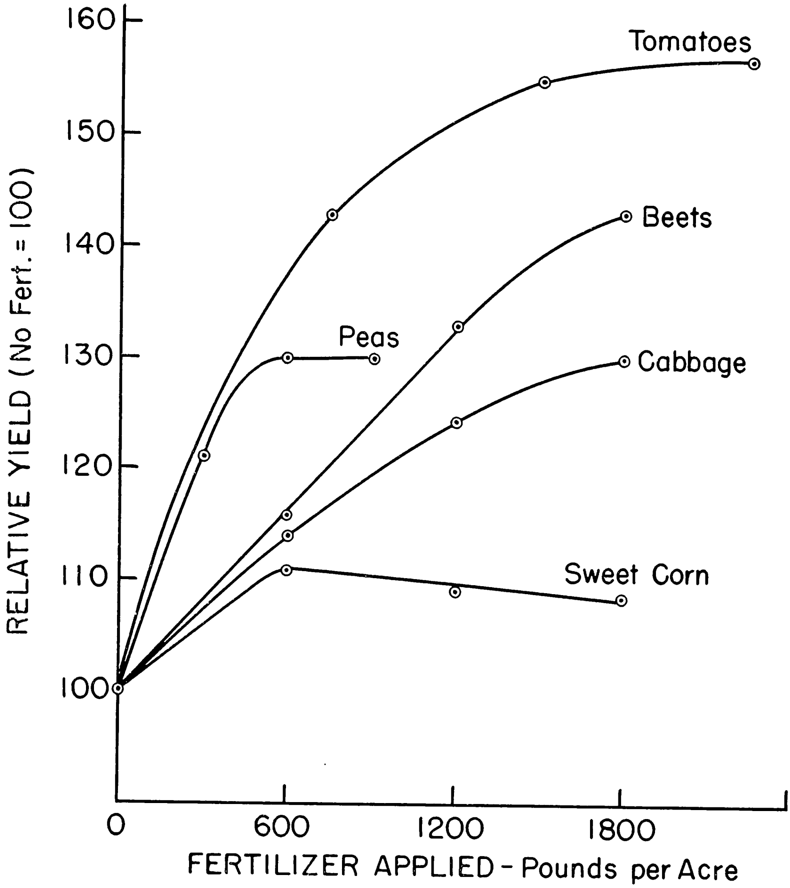

FIG. 2.—*Effect of increasing amounts of fertilizer on the yield of beets, cabbage, peas, sweet corn, and tomatoes.*

fertilizer and 1,800 pounds produced a significant gain over 600 pounds. Considering the value of the increase and the cost of the fertilizer, these results indicate that at least 1,200 pounds per acre of this fertilizer may be applied with profit and that up to 1,800 pounds is likely to be the most profitable rate of application.

When all four fertilizers of different composition but the same ratio (1–2–2) are averaged (Table 7, B), the 1,200 pounds per acre rate of application produced a significantly larger yield than the 600 pounds per acre rate.

Comparing fertilizers of the same ratio (1–2–2) but with four different compositions (Table 7, C), there was no significant difference any year in yields of beets due to the different fertilizer ingredients. In 2 of the 4 years and in the 4-year average the fertilizer formula used in treatments G, I, and J, in which all of the nitrogen was from low-cost inorganic sources, all of the phosphorus from superphosphate, and half the potash from sulfate of potash-magnesia and half from muriate of potash, gave slightly, but not significantly, higher yields than the other formulas used.

In 3 of the 4 years and also in the 4-year average the lowest yield was obtained from the fertilizer in which 40 per cent of the nitrogen was from organic sources (treatments C and D), but the decrease was not significant. However, since the only difference in the composition of the fertilizer used in treatments C and D as compared with treatments G, I, and J was that in treatments C and D 40 per cent of the nitrogen was in organic form whereas in treatments G, I, and J all of the nitrogen was in inorganic form, the obvious conclusion must be that the lower cost inorganic nitrogen sources were superior to the organic sources as fertilizers for beets.

Analysis of variance indicates a significant interaction in 1946 between sources of fertilizer materials and rates of application (Table 7, D). This interaction is evident from the data given in Table 8.

TABLE 8.—*Significant Interaction of Fertilizer Sources and Rates in 1946 Beet Yields.*

Fertilizer composition	Yields, tons per acre		
	Low rate	Medium rate	Increase or decrease for medium rate
Common	15.9	18.3	2.4
Organic N + Mg	16.8	17.1	0.3
High analysis	18.0	16.7	-1.3
Inorganic N + Mg	16.8	20.2	3.4
Average	16.9	18.1	—

RESULTS WITH CABBAGE

Yields of Marion Market cabbage obtained in this experiment are summarized in Table 9 and Fig. 2. Comparing the four rates of application of the 5–10–10 fertilizer (Table 9, A), the 4-year average shows that 600 pounds per acre of this fertilizer produced a significant increase of 2.5 tons per acre over no fertilizer. Also, 1,200 pounds of

TABLE 9.—*Cabbage Yields: Summary of Four Years' Results, Canning Crops Farm, Geneva, N. Y.*

Fertilizer treatment*		Yield, tons per acre†				
Code	Pounds per acre	1946	1947	1948	1949	Average 4 years
A. Comparison of Four Rates of Application of One Fertilizer Mixture						
H	0	27.7	13.3	14.8	16.3	18.0
G	600	30.3	15.1	17.8	18.8	20.5
I	1,200	31.8	16.0	20.8	21.1	22.4
J	1,800	32.5	17.5	22.0	21.5	23.4
L.S.D. (19:1)		N.S.‡	N.S.	3.3	2.5	1.4
B. Comparison of Low and Medium Rates§						
Low	600	29.2	15.6	18.0	19.2	20.5
Medium	1,200	31.9	16.6	20.4	20.6	22.4
L.S.D. (19:1)		1.7	N.S.	1.1	N.S.	0.7
C. Comparison of Four Sources of Fertilizer Materials¶						
Common		31.8	16.7	19.4	19.9	21.9
Organic N + Mg		29.1	16.0	19.3	19.8	21.1
High analysis		30.3	16.2	18.8	19.9	21.3
Inorganic N + Mg		31.1	15.5	19.3	20.0	21.5
L.S.D. (19:1)		N.S.	N.S.	N.S.	N.S.	N.S.
D. Interaction						
Sources × rates		N.S.	N.S.	N.S.	N.S.	N.S.

*For details of treatments, refer to footnotes of Table 2.
†Average of four replications each year.
‡Differences not significant.
§Each entry is the average of four different kinds of fertilizer.
¶Each entry is the average of two different rates of application.

fertilizer per acre produced an additional 1.9 tons of cabbage per acre which was also a significant gain over the 600-pound rate of application. However, adding the third 600-pound increment of this fertilizer produced only 1 ton per acre additional yield which was not a significant gain. Therefore, it must be concluded that, under the conditions of this experiment, yields of cabbage were significantly increased by applications of 5–10–10 fertilizer up to 1,200 pounds per acre, but above that rate of fertilizing the small additional increase was not significant (Fig. 2).

This is confirmed in Table 9, B, in which the yields from the 600-pound rate of the four different formulas of the 1–2–2 ratio fertilizer are averaged together and compared with the average yields from the 1,200-pound rate of these four formulas. The 4-year average yields show an added increase of 1.9 tons of cabbage per acre from the additional 600 pounds of fertilizer.

Comparing the four different formulas of the 1–2–2 ratio fertilizer for cabbage (Table 9, C), there was no significant difference in yield due to the fertilizer ingredients in any year nor in the 4-year average. However, in 3 of the 4 years and also in the 4-year average the largest yield was obtained from the 1–2–2 ratio fertilizer mixture composed of inorganic sources of nitrogen, 20 per cent superphosphate, and muriate of potash. There was no advantage in using organic forms of nitrogen or the sulfate form of potash, or magnesium, or gypsum.

It is interesting to note (Table 9, D) that in no case was the interaction between sources and rates of fertilizer significant. In other words, the increase in yields with increasing rates of application was independent of the source of nitrogen, phosphorus, or potash in the mixed fertilizer.

The effect of the different fertilizer treatments on premature bursting of cabbage heads is described in Bulletin No. 750 of this Station.

RESULTS WITH PEAS

Pea yields for 4 years are summarized in Table 10 and Fig. 2. It is evident that as increments of fertilizer were added, yields increased significantly up to and including the 600-pound per acre rate of application (treatment I, Table 10), but further addition of fertilizer above the 600-pound rate (treatment J, Table 10) did not increase the yield.

When the four fertilizers of different composition are averaged (Table 10, B), it is seen that 600 pounds of the 5–10–10 per acre produced an average yield of 2,554 pounds of shelled peas per acre, which was a significant gain of 124 pounds above the 2,430 pounds which was the average yield for 300 pounds of fertilizer per acre. As with the other crops, there was no yield difference between the four fertilizers of different composition (Table 10, C). In no case was the interaction of fertilizer sources and rates significant (Table 10, D).

TENDEROMETER READINGS

The tenderometer is a machine which measures the tenderness of shelled peas by recording the pressure required to crush a certain volume of peas through a set of steel grids. The harder and more mature the peas, the higher the tenderometer reading; and conversely, the more tender and less mature the peas, the lower the tenderometer reading. In general, as peas become older, the yields increase to a certain maturity and the price of the peas per ton declines rapidly as the tenderometer readings increase. A high yield of

TABLE 10.—*Pea Yields: Summary of Four Years' Results, Canning Crops Farm, Geneva, N. Y.*

Fertilizer treatment*		Yield, pounds per acre†				
Code	Pounds per acre	1946	1948	1949	1950	Average 4 years‡
A. Comparison of Four Rates of Application of One Fertilizer Mixture						
H	0	4,630	1,530	1,500	950	1,991
G	300	5,090	1,890	1,710	1,630	2,411
I	600	5,200	2,140	1,880	1,770	2,584
J	900	5,310	2,100	1,820	1,800	2,587
L.S.D. (19:1).........		N.S.§	N.S.	N.S.	530	162
B. Comparison of Low and Medium Rates¶						
Low.....	300	4,900	1,880	1,770	1,780	2,430
Medium.	600	5,100	2,100	1,860	1,800	2,554
L.S.D. (19:1).........		N.S.	170	N.S.	N.S.	118
C. Comparison of Four Sources of Fertilizer Materials‖						
Common.............		4,980	1,990	1,870	1,770	2,494
Organic N + Mg......		4,980	1,970	1,820	1,810	2,490
High analysis.........		4,890	1,990	1,780	1,880	2,486
Inorganic N + Mg....		5,140	2,010	1,790	1,700	2,497
L.S.D. (19:1).........		N.S.	N.S.	N.S.	N.S.	N.S.
D. Interaction						
Sources × rates.......		N.S.	N.S.	N.S.	N.S.	N.S.

*For details of treatments, refer to footnotes of Table 2.
†Average of three replications in 1946 and four replications in 1948, 1949, and 1950.
‡Weighted average of 15 replications.
§Differences not significant.
¶Each entry is the average of four different kinds of fertilizer.
‖Each entry is the average of two different rates of application.

low tenderometer reading (preferably below 100 on the tenderometer scale) brings the highest net returns.

Tenderometer readings were taken from the peas grown in this experiment in 1948, 1949, and 1950 and the results summarized in Table 11. Although the results are not statistically significant at the 5 per cent level, there was a definite trend toward lower tenderometer readings (more valuable peas) as the fertilizer rate increased (Table 11, A). As with yields, however, the four fertilizers of different composition (Table 11, C), had no effect on tenderometer grades, and the interaction of fertilizer sources and rates was not significant (Table 11, D).

TABLE 11.—*Pea Tenderometer: Summary of Three Years' Results, Canning Crops Farm, Geneva, N. Y.*

FERTILIZER TREATMENT*		TENDEROMETER READING			
Code	Pounds per acre	1948	1949	1950	Average 3 years†
A. Comparison of Four Rates of Application of One Fertilizer Mixture					
H	0	126	134	101	119
G	300	116	132	103	116
I	600	116	141	99	116
J	900	111	133	97	112
L.S.D. (19:1)		N.S.‡	N.S.	N.S.	N.S.
B. Comparison of Low and Medium Rates§					
Low	300	118	132	102	116
Medium	600	117	135	102	116
L.S.D. (19:1)		N.S.	N.S.	N.S.	N.S.
C. Comparison of Four Sources of Fertilizer Materials¶					
Common		117	132	102	116
Organic N + Mg		118	133	103	116
High analysis		118	134	103	117
Inorganic N + Mg		116	136	101	116
L.S.D. (19:1)		N.S.	N.S.	N.S.	N.S.
D. Interaction					
Sources × rates		N.S.	N.S.	N.S.	N.S.

*For details of treatment, refer to footnotes in Table 2.
†Average of four replications in 1948 and 1950, three replications in 1949.
‡Differences not significant.
§Each entry is the average of four different kinds of fertilizer.
¶Each entry is the average of two different rates of application.

RESULTS WITH SWEET CORN

Sweet corn yields obtained in this experiment are summarized in Table 12 and Fig. 2. Comparing the yields from no fertilizer and from 600, 1,200, and 1,800 pounds per acre of 5–10–10 fertilizer, it is apparent that only in one year and in the 3-year average was there a significant increase in yield due to the fertilizer (Table 12, A). In no case was there any gain from more than 600 pounds per acre of this fertilizer. This result agrees with many other experiments on this soil, indicating that in a good rotation including a legume sod, very little, if any, fertilizer is required for sweet corn.

Comparing the four different compositions of this same ratio (1–2–2) at the 600- and 1,200-pound rates per acre (Table 12, C), there was no significant difference any year in the yield of sweet corn

TABLE 12.—*Sweet Corn Yields: Summary of Three Years' Results, Canning Crops Farm, Geneva, N. Y.*

FERTILIZER TREATMENT*		YIELD, TONS PER ACRE†			
Code	Pounds per acre	1948	1949	1950	Average 3 years
A. Comparison of Four Rates of Application of One Fertilizer Mixture					
H	0	3.70	4.01	5.27	4.33
G	600	4.28	4.63	5.48	4.80
I	1,200	4.58	4.60	5.01	4.73
J	1,800	4.39	4.64	5.06	4.70
L.S.D. (19:1)		0.55	N.S.‡	N.S.	0.34
B. Comparison of Low and Medium Rates§					
Low	600	4.30	4.44	5.29	4.68
Medium	1,200	4.40	4.69	5.12	4.74
L.S.D. (19:1)		N.S.	N.S.	N.S.	N.S.
C. Comparison of Four Sources of Fertilizer Material¶					
Common		4.38	4.58	5.15	4.70
Organic N + Mg		4.30	4.44	5.21	4.65
High analysis		4.29	4.63	5.21	4.71
Inorganic N + Mg		4.43	4.62	5.24	4.76
L.S.D. (19:1)		N.S.	N.S.	N.S.	N.S.
D. Interaction					
Sources × rates		N.S.	N.S.	N.S.	N.S.

*For details of treatments, refer to footnotes of Table 2.
†Average of four replications each year.
‡Differences not significant.
§Each entry is the average of four different kinds of fertilizer.
¶Each entry is the average of two different rates of application.

due to the different fertilizer ingredients. Obviously, the conclusion from these results is that, if any fertilizer is used on sweet corn, the lowest cost formula is likely to give the best net results.

As with the other crops, the interaction of fertilizer sources × rates was in no case significant (Table 12, D).

RESULTS WITH TOMATOES

Summaries of the four years results obtained with tomatoes are given in Table 13 and Fig. 2. Comparing no fertilizer with 750, 1,500, and 2,250 pounds per acre of 4–12–8 fertilizer (Table 13, A), there was a progressive increase in yield with increasing amounts of fertilizer, but the gain from the last 750-pound increment was not significant, indicating no advantage in applying more than 1,500 pounds per acre of this fertilizer. Again, averaging together the four different formulas of the 1–3–2 ratio (Table 13, B) showed a significant gain from the 1,500-pound rate of application as compared with the 750-pound rate.

Comparing the effects of the different fertilizer ingredients in the four different 1–3–2 ratio formulas, there was no significant difference any year due to the fertilizer materials (Table 13, C). In the 4-year average, the two formulas which contained sulfate of potash-magnesia produced larger yields than the other two formulas which contained only the muriate form of potash, but the differences were not statistically significant. Also, the lowest average yield for the 4 years was obtained from the formula containing no gypsum (all the phosphorus from double phosphate), but this difference was not significant.

TABLE 13.—*Tomato Yields: Summary of Four Years' Results, Canning Crops Farm, Geneva, N. Y.*

FERTILIZER TREATMENT †		YIELD, TONS PER ACRE ‡				
Code	Pounds per acre	1945 §	1946	1947	1948	Average 4 years
A. Comparison of Four Rates of Application of One Fertilizer Mixture						
H	0	2.28	9.41	4.44	3.52	4.91
G	750	3.24	11.86	6.00	6.99	7.02
I	1,500	3.51	12.92	6.31	7.75	7.62
J	2,250	3.56	13.26	6.42	7.60	7.71
L.S.D. (19:1)		0.55	1.18	N.S.¶	1.73	0.58
B. Comparison of Low and Medium Rates‖						
Low	750	3.02	12.29	5.75	5.83	6.72
Medium	1,500	3.56	12.84	6.17	7.33	7.47
L.S.D. (19:1)		0.24	N.S.	N.S.	0.98	0.37
C. Comparison of Four Sources of Fertilizer Materials‡‡						
Common		3.45	12.72	5.56	6.26	7.00
Organic N + Mg		3.23	12.65	6.40	6.48	7.19
High analysis		3.10	12.51	5.73	6.20	6.88
Inorganic N + Mg		3.38	12.39	6.16	7.37	7.32
L.S.D. (19:1)		N.S.	N.S.	N.S.	N.S.	N.S.
D. Interaction						
Sources × rates		*	N.S.	N.S.	N.S.	N.S.

†For details of treatments, refer to footnotes of Table 2.
‡Average of four replications each year.
§The very low yield of tomatoes in 1945 was due to the fact that the plants were not transplanted to the field until almost 4 weeks later than normal due to unavoidable circumstances.
¶Differences not significant.
‖Each entry is the average of four different kinds of fertilizer.
‡‡Each entry is the average of two different rates of application.
*Significant (19:1).

Interaction of fertilizer sources and rates was significant in 1945, but not in any of the other years or for the 4-year average (Table 13, D). This may have been due to the very late planting and poor yields in 1945. This interaction is evident from the data in Table 14.

TABLE 14.—*Significant Interaction of Fertilizer Sources and Rates in 1945 Tomato Yields.*

Sources	Acre yield, tons		
	750 pounds fertilizer per acre	1,500 pounds fertilizer per acre	Increase for medium rate
Low analysis	3.10	3.80	0.70
Organic N + Mg	3.20	3.26	0.06
High analysis	2.54	3.66	1.12
Inorganic N + Mg	3.24	3.51	0.27
Average	3.02	3.56	0.54

DISCUSSION AND PRACTICAL APPLICATIONS

COMPARISON OF PHOSPHORUS SOURCES

The four different formulas used were compounded so as to compare the effectiveness of certain specific ingredients. For example, the fertilizer used in treatments A and B (Tables 2 and 3) differs from that used in treatments E and F only in the source of phosphorus. This also furnished a comparison of low analysis vs. high analysis mixtures. The nitrogen and potash sources were identical in these treatments, but in treatments A and B all of the phosphorus is in the form of 20 per cent superphosphate, whereas in treatments E and F the phosphorus is in the form of double superphosphate (47 per cent P_2O_5). Superphosphate contains approximately 50 per cent gypsum (calcium sulfate) while double superphosphate contains no gypsum, this being an important difference between these two formulas. Since the soils used in this experiment were alkaline and contained limestone, no effect from the calcium in the gypsum was expected, but conceivably the sulfur might have a beneficial effect. Also, the gypsum might have some cumulative effect in improving the soil structure. However, the 6 years results showed no significant differences in yield due to the source of phosphorus in the fertilizers. Each year with all crops (Tables 7, 9, 10, 12, and 13) the yields from equal amounts of plant nutrients were almost identical where superphosphate was the source of phosphorus (treatments A and B) and in the high analysis mixture where double superphosphate was the source of phosphorus (treatments E and F).

At the time this experiment was begun there was considerable evidence from experiments elsewhere (25, 27) indicating the importance of gypsum in mixed fertilizers and suggesting that if phosphorus sources other than superphosphate (which contains gypsum) were used as the phosphorus ingredient that poor results would be obtained unless gypsum were added as a separate ingredient. Subsequent experiments have indicated that in some cases (14) the beneficial effect of the gypsum was due to its sulfur content. However, this essential element can also be supplied from sulfate of ammonia which is used in most mixed fertilizers to supply part of the nitrogen.

Mehring and Bennett (12) give the average percentage content of sulfur in terms of sulfur tri-oxide (SO_3) for all important fertilizer materials. More than three-fourths of the tonnage of all fertilizers consumed in the year ended June 30, 1948, contained more SO_3 than the sum of the total amounts of N, P_2O_5, and K_2O combined. They state that the principal fertilizer materials supplying sulfur are superphosphate, ammonium sulfate, ammoniated superphosphate, potassium sulfate, and Sul-Po-Mag. Sulfur may also be supplied in the form of elemental sulfur (10, 14). Furthermore, considerable sulfur is deposited on the soil in rainfall (27), particularly in the vicinity of industrial areas. Consequently, it is evident that gypsum is not essential for supplying sulfur in mixed fertilizers, particularly if some sulfate of ammonia is used.

Another benefit claimed for gypsum is that it is an important source of calcium as a plant nutrient and that this would be a most important consideration on acid soils (2). Recently, however, Schmehl, Peech, and Bradfield (22) have shown that the cause of poor growth of plants on acid soils was not due to the lack of calcium but to toxic concentrations of manganese, aluminum, and iron. Furthermore, Fried and Peech (6) showed that, although the application of gypsum greatly increased the calcium content of the soil solution, the concentrations of manganese, iron, and aluminum were also increased very markedly by gypsum owing to the concurrent increase in soil acidity and the replacement of exchangeable manganese, iron, and aluminum by calcium. Consequently, poor results are often obtained by adding gypsum to acid soils.

The soils used in the experiment reported herein were slightly alkaline and were well supplied with calcium. Under these conditions there was no difference in the growth of any of the five crops where regular grade fertilizer (containing gypsum in the 20 per cent superphosphate) was used as compared with the high analysis fertilizer containing no gypsum. It seems reasonable to expect that similar results would be obtained on acid soils in the light of the experiments of Schmehl, Peech, and Bradfield (22), since they and Peech and English (19) have shown that in New York State even the soils with low pH values have an ample supply of exchangeable calcium for plant growth. This is also supported by experiments in Indiana (1), Ohio (17), and Pennsylvania (15) which showed that gypsum had no apparent effect on crop yields on acid soils. Therefore, the conclusion is that double superphosphate (lacking gypsum) is just as good as 20 per cent superphosphate (containing gypsum) as the phosphorus ingredient in mixed fertilizers.

COMPARISON OF NITROGEN SOURCES

Contrasting treatments C and D with treatments G and I (Tables 2 and 3), there is a direct comparison of different nitrogen ingredients. These fertilizer mixtures were identical in regard to the kind and amounts of phosphorus and potash and differed only in the kinds of nitrogen constituents used. The total amount of nitrogen was the same in each fertilizer. In treatments C and D, 40 per cent of the nitrogen was from organic sources and the balance from inorganic ingredients, but in treatments G and I all of the nitrogen was in the form of inorganic materials. Since the inorganic materials are less expensive, the organic forms would have to produce a significantly larger yield to justify their use. In each year with every crop and with 6 years continuous use of each kind of fertilizer, there was no significant difference in yields due to the source of nitrogen (Tables 7, 9, 10, 12, and 13); but in most years and the 4-year average of each crop, the yields were slightly larger where the less expensive inorganic sources of nitrogen were used. Since a previous experiment on this field (20) had shown a significant increase in yield from nitrogen fertilizer, it is logical to assume that the yields of the crops in this experiment were increased by the nitrogen fertilizers used, and that the lack of significant differences in yields where different nitrogen sources were used was due to an equal response from each form of nitrogen rather than lack of any nitrogen response due to the supply of nitrogen already in the soil. Consequently, these results show no justification for buying organic nitrogen fertilizers.

This agrees with the results reported by Paden (18) in experiments in which five organic sources of nitrogen and six inorganic sources were applied individually for 20 years at equal rates of nitrogen and uniform amounts of phosphorus and potash. After 20 years continuous application of these fertilizers averaging together the yields of seed cotton from all nitrogen sources showed an average increase due to the nitrogen of over 45.6 per cent on unlimed plots and over 47.6 per cent on limed plots. Yet there were no significant differences in the 20-year average yields between any of the 11 different sources of nitrogen.

Similar results were obtained by Volk and Tidmore (28) in experiments with corn and cotton comparing eight different sources of fertilizer nitrogen for 13 years at each of three locations on different soil types. Two of the sources of nitrogen were organic and six were inorganic. Each of the nitrogen fertilizers gave very significant increases in yields of corn and seed cotton as compared with no nitrogen, but the differences in yields due to the different sources of nitrogen were very small. The highest average yield of each crop was obtained from an inorganic form of nitrogen, and the lowest yield of corn from an organic source of nitrogen.

Similar results were also reported by Terman, *et al.* (24), comparing different sources of nitrogen for potatoes. They concluded that, "there is no advantage in using organic forms of nitrogen for potatoes."

COMPARISON OF POTASH SOURCES

In comparing treatments A and B with treatments G and I (Tables 2 and 3) there is a direct comparison of two sources of potash, one of which also contained magnesium. These fertilizer mixtures were identical in regard to the kind and amounts of the nitrogen and phosphorus ingredients, but differed only in the source of potash. In treatments A and B all of the potash was in the form of muriate of potash. In treatments G and I only half the potash was in this form and half in the form of the double salt sulfate of potash-magnesia (Sul-Po-Mag). This not only supplied the sulfate form of potash but also magnesium. The soils used in this experiment are similar to those found in much of the canning crops producing areas of western New York; but since they contained abundant amounts of available magnesium (Table 4), it could hardly be expected that there would be any important gain from the application of magnesium fertilizers unless a larger readily available supply of magnesium were needed to supply a better nutrient balance between bases (4). Any yield difference from this fertilizer treatment would probably be due to the sulfate form of potash. However, in none of the 6 years of this experiment nor in the 4-year average with any crop was there any significant difference due to the sulfate of potash-magnesia (Tables 7, 9, 10, 12, and 13).

This agrees with results reported by Odland and Cox (16) who compared the relative effectiveness of muriate of potash, sulfate of potash, sulfate of potash-magnesia, and kainit as sources of potash for eight vegetable crops and hay and cereals over a period of 17 years. They concluded that, "no one of the different sources of potash proved superior for all crops or for any crop every year," and "the best general guide in the selection of a source for fertilizer potash is the relative cost per unit of actual potash. . . . The most fertilizer value can be obtained at present from high-grade muriate of potash."

Results obtained[3] by Doctor Nelson Shaulis of this Experiment Station indicate that on very acid soils of coarse texture in Chautauqua County, some species of crops, notably red currants, are very susceptible to chlorine toxicity. Under such soil conditions the chlorine-sensitive crops may give poor results from muriate of potash and will give strikingly better results from other potash sources such as the sulfate forms.

However, the soils used in this experiment were of entirely different texture and acidity. Furthermore, the vegetable crops used in this experiment have not been shown to be sensitive to chlorine toxicity and beets have been shown to respond most favorably to chloride fertilizers (21).

OPTIMUM RATES OF APPLICATION

It is of interest to note that for most of the crops grown, average yields have been above the State average for the same crops grown the same years (Table 15). In other words, either the cultural practices were above average; or, the soils on which this experiment was conducted were above average in soil fertility, though they are of similar type to soils in large areas of the important canning crops producing sections of New York. This fact must be kept in mind

[3]Unpublished data.

when making fertilizer recommendations for other soils which may be considerably lower in soil fertility.

TABLE 15.—*Comparison of Yield of No-fertilizer and High-fertilizer Plots with State Average Yields for the Same Years, 1945–49.*

CROP	NO FERTILIZER (TREATMENT H)	STATE AVERAGE	HIGH FERTILIZER (TREATMENT J)
Beets, tons	8.8	10.1	12.6
Cabbage, tons	18.0	10.6	23.4
Peas, pounds	1,991	1,830	2,587
Sweet corn, tons	4.33	2.70	4.70
Tomatoes, tons	4.91	6.35	7.71

ADVANTAGES OF HIGH ANALYSIS MIXTURES

Because the fertilizers of different composition have given equal responses, the cheapest per unit of plant nutrients within the range of materials used would be the best for the farmer to buy. Therefore, since the more concentrated analyses (8–16–16 and 6–18–12) are cheaper, under present price relationships, than the corresponding 5–10–10 and 4–12–8 analyses, the most economical fertilizers for these soils and crops would be 375 pounds of 8–16–16 per acre for peas and sweet corn, 750 to 1,125 pounds of 8–16–16 for beets and cabbage, and 1,000 pounds of 6–18–12 for tomatoes.

CONCLUSIONS

1. In a good canning crops rotation which included a winter cover crop each year and legume sod every 4 years, comparing no fertilizer with 600, 1,200, and 1,800 pounds per acre of 5–10–10 fertilizer for beets, cabbage, and sweet corn; with 300, 600, and 900 pounds per acre of 5–10–10 fertilizer for peas; and with 750, 1,500, and 2,250 pounds per acre of 4–12–8 fertilizer for tomatoes, it was found that:

   A. For beets and cabbage up to 1,200 pounds per acre of 5–10–10 fertilizer, or its equivalent, 750 pounds of 8–16–16 fertilizer, produced significant increases in yields. Above that rate, an additional 600 pounds of 5–10–10 fertilizer resulted in further slight increases in yield which were not significant for cabbage and barely significant for beets.

   B. For peas, significant increases in yield were obtained up to 600 pounds per acre of 5–10–10, or its equivalent, 375 pounds of 8–16–16 fertilizer; but an additional 300 pounds per acre of 5–10–10 fertilizer did not result in a further increase in yield.

C. Sweet corn gave the least response to fertilizer of any of the crops in this experiment. Only the lowest rate of application (600 pounds of 5–10–10, or its equivalent, 375 pounds of 8–16–16) gave a significant increase in yield of sweet corn, and the difference was significant only in 1 of 3 years and in the 3-year average.

D. For tomatoes, applications of 4–12–8 fertilizer at rates up to 1,500 pounds per acre, or its equivalent, 1,000 pounds per acre of 6–18–12 fertilizer, produced significant increases in yield. Above that rate an additional 750 pounds of 4–12–8 fertilizer produced a further slight increase in yield, but this additional increase was not significant.

2. Comparing a 5–10–10 fertilizer with a higher analysis equivalent (8–16–16), in which the nitrogen and potash sources were the same in each fertilizer mixture but all the phosphorus in the 5–10–10 fertilizer was in the form of 20 per cent superphosphate and all the phosphorus in the higher analysis mixture was in the form of 47 per cent double superphosphate, there was no significant difference in yield of any of these crops. Consequently, since there would be one-third less material for the grower to handle and one-third less freight charges on the higher analysis mixture, it would be preferable, if the costs of equivalent amounts of nitrogen, phosphorus, and potash were equal, to use the higher analysis fertilizer mixtures.

3. Comparing fertilizer mixtures in which the sources and amounts of phosphorus and potash were uniform and in which the *amounts* of nitrogen were the same but which differed only in that in one mixture all the nitrogen was derived from inorganic sources while in the other mixture 40 per cent of the nitrogen was obtained from organic sources, there were no significant differences in yields of any of these crops due to the kind of nitrogen fertilizer over a period of 6 years. The yields were slightly better on all crops where the inorganic sources of nitrogen were used and since these ingredients were also much cheaper there was nothing to justify the use of the higher cost organic nitrogen fertilizer material.

4. Comparing fertilizers that were identical in kinds and amounts of nitrogen and phosphorus and in amount of potash but differed only in that in one mixture all of the potash was supplied by muriate of potash whereas in the other mixture only half the potash was in the muriate form and half was in the form of sulfate of potash-

magnesia, there were no significant differences in yield of any of these crops due to the kind of potash fertilizer. It should be noted that the soils used in this experiment were not low in magnesium, consequently, little benefit from the magnesium could be expected, but neither was there any benefit from the sulfate form of potash.

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