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THE USE OF COMMERCIAL FERTILIZERS IN GROWING ROSES

By F. W. MUNCIE

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Summary of Bulletin No. 196

1. Brown silt loam, the type of soil at the Illinois Station, will not produce a maximum crop of roses without fertilization. Page 515

2. Grafted stock more than paid for the increase in initial cost by its larger production during the first year. Page 519

3. Dried blood in amounts exceeding 8 pounds per 100 square feet of bench space caused a decrease in production with own-root and grafted Brides and grafted Killarneys. Page 520

The effect of dried blood upon weekly production was found to be a decrease during fall months, no difference during winter, and an increase in the spring. Page 528

4. Acid phosphate gave a greatly increased production with all types used in the experiment except grafted Brides. Page 521

Further experiments showed that 20 pounds of acid phosphate per 100 square feet of bench space gave a profit of $176 per 1,000 plants; four times this quantity may be used without injury from overfeeding. Page 555

The beneficial effect was continuous thruout the year. Page 557

5. No benefit was obtained from the use of potassium sulfate under the conditions of the experiment. Pages 522–523

6. A definite relation was found to exist between the variation in hours of sunshine and the subsequent production of flowers. Page 526

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THE USE OF COMMERCIAL FERTILIZERS IN GROWING ROSES

By F. W. MUNCIE, Associate in Floricultural Chemistry

Since the fall of 1910, experiments have been carried on by the Horticultural Department of this station with regard to the use of commercial fertilizers in growing first-year roses. The commercial fertilizers used during 1910-13 were dried blood, acid phosphate, and potassium sulfate. During 1913-15, ammonium sulfate was used instead of dried blood. Assuming, as is ordinarily done, that the element deficient in the soil and so limiting plant growth is nitrogen, phosphorus, or potassium, the choice of fertilizers (dried blood or ammonium sulfate supplying nitrogen; acid phosphate, phosphorus; and potassium sulfate, potassium) is wide enough to establish the order of relative abundance of the elements in compounds available to the plants, and to form a basis for study of the effect of these fertilizers upon yearly and weekly production.[1]

The experimental work reported in this bulletin deals with a general investigation (1910-13) with each of the three fertilizers mentioned, alone and in various combinations, and a supplementary one upon the use of acid phosphate with and without lime (1913-15).

DESCRIPTION OF THE EXPERIMENT, 1910-13

Bride and Killarney were the varieties grown, the first being a typical tea rose and the latter a hybrid tea; half the plants of each variety were own-root stock and half were grafted. Under the conditions of fertilizing prescribed by the plan of the experiment, comparisons can also be made between the varieties used and between own-root and grafted stock.

One greenhouse 28 feet by 105 feet, containing four benches 4 feet wide, 100 feet long, and 5 inches deep, with an area of 1,600 square feet, was used; the experiment begun in 1910-11 was repeated during 1911-12 and 1912-13. The roses propagated about December 1 of the previous year were successively potted into 2-inch and 4-inch pots, and set in the benches about July 10. The dates of setting the plants in the benches were as follows: July 6, 1910; July 13, 1911; July 10, 1912.

[1]In ordinary practice, the soil used in growing greenhouse crops is partially or entirely replaced each year. Also the gross returns with the average crop grown in a greenhouse are estimated to be as high as $40,000 per year per acre of enclosed space. Under these circumstances, the florist is concerned with producing the maximum crop upon the soil without consideration of soil depletion and with relatively little for the cost of the fertilizer used—always a small item in comparison with the crop returns.

The soil used was of that type common to the part of the state in which the Experiment Station is located, the brown silt loam, the average composition of which is as follows:[1]

Nitrogen	5,000 lbs.	per surface layer of 6⅔ inches (2,000,000 lbs.)
Phosphorus	1,200 lbs.	
Potassium	36,000 lbs.	

The soil had been planted to corn for a number of years, had lain fallow since 1909, and had been twice plowed during the spring previous to its use. Before being put in the benches, it was thoroly pulverized and a uniform mixture was secured by preparing the soil according to the methods described in the bulletin, "The Use of Commercial Fertilizers in Growing Carnations."[2]

The dried blood used contained approximately 14 percent nitrogen, the acid phosphate 7 percent phosphorus, and the potassium sulfate 41 percent potassium, as shown by the analyses given below:

TABLE 1.—ANALYSES OF FERTILIZERS USED, 1910-13

Year	Nitrogen in dried blood	Phosphorus in acid phosphate	Potassium in potassium sulfate
	percent	*percent*	*percent*
1910-11	13.70	7.03	41.9
1911-12	14.07	7.03	41.9
1912-13	14.09	6.62	39.7

NOTE.—These analyses were made by the Department of Agronomy.

In order to make a comparison of the various kinds and proportions of fertilizers, the benches were laid off into sections 10 feet in length, giving an area of 40 square feet to each, with room for 32 plants. To each of these were added manure and the fertilizers in the amounts shown in Tables 3 and 4. Of the 32 plants in each section, 16 own-root and 16 grafted were placed in alternate ends of the sections in alternate years, the own-root and grafted plants receiving the same quantities of fertilizer per section. On account of the larger root area of the grafted plants, however, they really received proportionately heavier applications. The arrangement of sections during 1910-11 and 1911-12 is shown in Fig. 1, and that during 1912-13 in Fig. 2.

The fertilizers were applied and the plants set in the following manner: The benches were filled with the uniformly mixed soil, a straight-edge being used to secure even filling. To each section well-rotted manure (containing about 50 percent moisture) was applied at the rate of 115 pounds per 100 square feet of bench space. The fertilizers were then added in the amounts shown in Tables 3 and 4, only one-fourth of the total amount of dried blood, however, being

[1]Hopkins, Soil Fertility and Permanent Agriculture, p. 82.
[2]Ill. Agr. Exp. Sta. Bul. 176, p. 366.

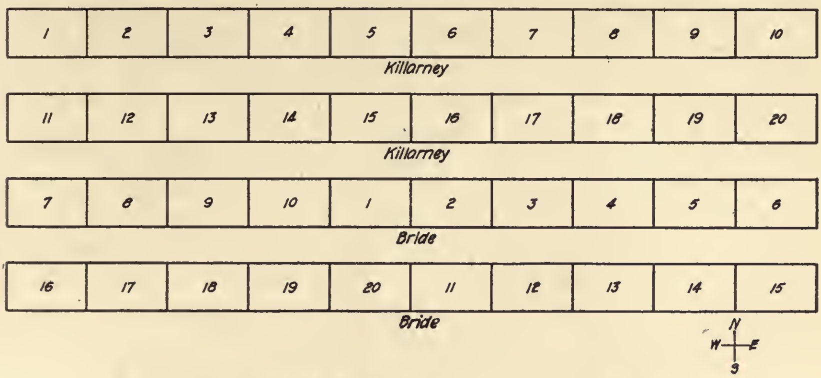

FIG. 1.—ARRANGEMENT OF SECTIONS, 1910-11 AND 1911-12

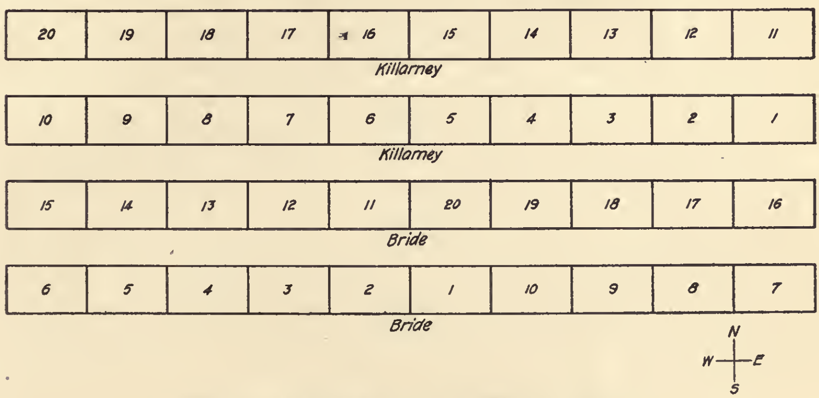

FIG. 2.—ARRANGEMENT OF SECTIONS, 1912-13

applied at this time. The remainder was added in three equal portions as a top-dressing at different times during the year, and was worked into the soil lightly with hand cultivators to a depth of one inch. At the time of planting, the fertilizers were well mixed with the soil by using hand trowels, after which the soil was tramped down into the benches, thoroly moistened with water, and left to stand overnight. The roses were set on the benches the next morning at distances twelve inches apart across the bench and sixteen inches the long way, and were arranged carefully so as to secure as nearly as possible a uniform distribution with respect to vigor thruout the house, with small and large plants alternating in each section. They were then planted and thoroly watered. The methods used during the next few days were those followed by every careful grower to prevent too rapid transpiration before the roses take hold of the soil. Thruout the year, watering, fumigating, disbudding, weeding, etc., were looked after as in a commercial greenhouse. All flowers were cut back to the second or third leaf above the previous break, but no attempt was made to control the time of cropping by pinching the buds, since normal growth served better as a measure of the effects of the fertilizers.

The temperature in the rose house was regulated as carefully as the heating system permitted; at times of very cold weather, however, a rise of several degrees above the temperature of the outer end of the house occurred in the end next the cross house. The arrangement of sections was changed in 1912-13 to equalize this effect as far as possible. On cloudy days, when artificial heat was depended upon altogether, the temperature was kept as near as possible to 68° F., while on sunny days it was allowed to rise as high as 75° or over. From sundown it was lowered gradually until nine o'clock, when it reached 63°, a temperature which was maintained until midnight. Between this time and morning it was allowed to drop two or three degrees lower, but very seldom below 60°. During cold weather, temperature was regulated entirely by steam coils, without ventilation.

Records were kept of the number of flowers produced and the length of stem of each flower during the seasons November to May inclusive (7 months), 1910-11, and October to May inclusive (8 months) the remaining two years. It was not known whether the number of flowers produced would be an accurate standard of measurement of the money value of the crop, since length of stem largely determines the price of roses. To overcome this difficulty, the "total stem length" produced by the plant, that is, the total number of inches of stem (found by adding the stem length of all flowers produced) was used as an additional standard of measurement. It is evident that this value is an approximate measure of the total amount of vegetation produced by the plant, particularly with Killarney, which has no blind wood. Records were kept by the week, so that not only the total number of flowers and the total stem length produced during the season, but the production at various times during the season might be compared.

EFFECT OF FERTILIZATION UPON YEARLY PRODUCTION, 1910-13

During the seasons of 1910-13, records were kept on 3,840 plants, one-fourth of which were own-root Bride, grafted Bride, own-root Killarney, and grafted Killarney, respectively. A complete summary of the number of plants grown, the number of flowers, and the total number of inches of stem length produced, is given in Table 2.

The 3,840 plants produced a total of 95,013 roses, an average of about 25 flowers per plant per season. This may be considered a satisfactory yield for first-year plants, since a considerable number of them were injured by overfeeding as a result of the attempt to determine the maximum amount of fertilizer that might safely be used. Of these 95,013 flowers, 45,135 were Killarneys and 49,878 Brides (the Brides producing about 5 percent more than half the total yield). Of the flowers produced by Killarney, 21,297 were produced from own-root stock and 23,838 from grafted. Of the Brides, 23,019 were produced from own-root stock and 26,859 from grafted. Results indicate, then, that in production of flowers the plants rank as follows: grafted Bride, grafted Killarney, own-root Bride, own-root Killarney.

A summary of the results obtained by applying commercial fertilizers to the sections in differing amounts is given in Tables 3 and 4, showing the number of flowers produced during 1910-13 in the season when records were kept (Table 3), and the total stem length during the same time (Table 4). In these tables, which also give the amounts of the fertilizers applied to each section, it is shown that three sections (4, 10, 16) had no commercial fertilizer applied, while Sections 1, 7, and 13 had applied to each, 8 pounds of dried blood, 2 pounds of acid phosphate, and 2 pounds of potassium sulfate per 100 square feet of bench space (5 inches deep). The remaining sections received applications of dried blood varying from 8 to 32 pounds, of acid phosphate from 2 to 8 pounds, and of potassium sulfate from 2 to 8 pounds per 100 square feet in various combinations. A comparison of the average results from the unfertilized sections with those from all fertilized sections is presented in Table 5. From these figures, in spite of the fact that the more heavily fertilized sections were somewhat injured by overfeeding, it is evident that the soil was not capable of producing a maximum crop without fertilization.

COMPARATIVE EFFECTS UPON OWN-ROOT AND GRAFTED STOCK

From Table 2 it is seen that the 960 plants of grafted Killarney produced 23,838 flowers, compared with 21,297 flowers from the same number of plants of own-root stock. Similarly, 960 grafted Bride plants produced 26,859 flowers, compared with 23,019 flowers from the same number of own-root Brides. The balance in favor of grafted Killarneys is 2,541 flowers (from 960 plants), and in favor of grafted Brides is 3,840 flowers. The average length of stem of own-root Killarneys was 10.6 inches and of grafted Killarneys 10.5 inches, while that of own-root Brides was 14.6 inches, compared with 14.9 inches, the average length of stem of grafted Brides. The quality of the flowers, measured in this manner, was about the same in the own-root and grafted Killarneys, while the quality of grafted Brides was somewhat better than that of own-root Brides. The important question of whether it pays to grow grafted stock, with the larger initial investment, can be answered within the conditions of the experiment by a study of these figures and the wholesale prices for flowers of such

TABLE 2.—SUMMARY, EXPERIMENTS WITH DRIED BLOOD, ACID PHOSPHATE, AND POTASSIUM SULFATE ON ROSES, 1910-13

Year	Killarney		Bride		Killarney and Bride		Own-root and grafted		Killarney and Bride own-root and grafted
	Own-root	Grafted	Own-root	Grafted	Own-root	Grafted	Killarney	Bride	
					Number of Plants				
1910-11	320	320	320	320	640	640	640	640	1280
1911-12	320	320	320	320	640	640	640	640	1280
1912-13	320	320	320	320	640	640	640	640	1280
1910-13	960	960	960	960	1920	1920	1920	1920	3840
					Number of Flowers				
1910-11	6771	8019	7658	8685	14429	16704	14790	16343	31133
1911-12	7578	7623	7574	8646	15152	16269	15201	16220	31421
1912-13	6948	8196	7787	9528	14735	17724	15144	17315	32459
1910-13	21297	23838	23019	26859	44316	50697	45135	49878	95013
					Total Stem Length (Expressed in inches)				
1910-11	77768.00	89269.00	117934.50	130389.55	195702.50	220658.55	167037.00	248324.05	415361.05
1911-12	79830.00	80934.09	107062.97	132868.90	186892.97	213802.99	160764.09	239931.87	400695.96
1912-13	69820.00	80741.25	110639.50	136594.00	180459.50	217335.25	150561.25	247233.50	397794.75
1910-13	227418.00	250944.34	335636.97	399852.45	563054.97	650796.79	478362.34	735489.42	1213851.76
					Average Production per Plant				
					Number of Flowers				
1910-11	21.1	25.1	23.9	27.1	22.5	26.1	23.1	25.5	24.3
1911-12	23.7	23.8	23.6	27.0	23.6	25.4	23.7	25.3	24.5
1912-13	21.7	25.6	24.3	29.8	23.0	27.7	23.6	27.1	25.3
1910-13	22.2	24.8	23.9	28.0	23.0	26.4	23.5	26.0	24.8
					Total Stem Length (Expressed in inches)				
1910-11	242.7	278.9	368.5	407.46	305.79	344.78	260.99	388.01	324.50
1911-12	249.4	252.9	334.5	415.21	292.02	334.07	251.18	374.89	313.04
1912-13	218.1	252.3	345.8	426.85	281.97	339.59	235.25	386.27	310.78
1910-13	236.8	261.4	349.6	416.51	293.26	339.06	249.14	383.07	316.11

TABLE 3.—NUMBER OF FLOWERS PRODUCED, 1910-13
(Average per 16 plants)

Fertilizer[1] (Pounds per 100 square feet)			Section	Killarney		Bride		Killarney and Bride		Own-root and grafted		Killarney and Bride own-root and grafted (Average)
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	Own-root	Grafted	Killarney	Bride	
8	2	2	1	298.3[2]	429.3	398.6	470.6	348.5	450.0	363.8	434.6	399.2
16	2	2	2	361.0	383.3	383.6	472.6	372.3	428.0	372.1	428.1	400.1
32	2	2	3	391.0	383.6	339.3	405.6	365.2	394.6	387.3	372.4	379.9
0	0	0	4	311.0	373.0	343.0	394.3	327.2	383.6	342.0	368.6	355.4
8	4	2	5	352.0	409.3	416.3	483.3	384.2	446.3	380.6	449.8	415.2
8	8	2	6	383.0	470.0	485.6	479.6	434.3	474.8	426.5	482.6	454.5
8	2	2	7	368.3	384.0	401.0	499.3	384.6	441.6	376.1	450.1	413.1
8	2	4	8	333.0	374.3	398.6	459.3	365.8	416.8	353.6	428.9	391.3
8	2	8	9	317.0	382.0	382.0	448.6	349.5	415.3	349.5	415.3	382.4
0	0	0	10	338.0	406.3	312.6	409.0	325.3	407.6	372.1	360.8	366.4
16	4	2	11	415.0	423.6	419.6	490.0	417.3	456.8	419.3	454.8	437.0
32	8	2	12	403.6	413.0	340.0	430.3	371.8	421.6	408.3	385.1	396.7
8	2	2	13	382.6	418.0	373.3	478.6	378.0	448.3	400.3	425.9	413.1
16	2	4	14	353.3	372.6	404.6	447.3	379.0	410.0	362.9	425.9	394.5
32	2	8	15	315.6	363.3	360.6	377.3	338.2	370.3	339.4	368.9	354.2
0	0	0	16	333.3	387.6	319.0	362.3	326.2	375.0	360.4	340.6	350.6
8	4	4	17	359.3	416.6	409.6	477.0	384.5	446.8	387.9	443.3	415.6
8	8	8	18	351.3	414.3	386.0	478.6	368.6	446.5	382.8	432.3	407.5
16	4	4	19	367.3	357.3	422.6	455.0	395.0	406.3	362.3	438.8	400.6
32	8	8	20	364.6	382.3	376.0	437.3	370.3	409.8	373.4	406.6	390.0
Average of Combined Sections												
8	2	2	1-7-13	375.5	410.4	391.0	482.8	383.3	446.6	392.9	436.9	414.9
0	0	0	4-10-16	327.4	389.0	325.0	388.5	326.2	388.7	358.2	356.7	357.4
8 to 32	2 to 8	2 to 8	All fertilized sections	388.5	398.6	359.8	458.0	374.2	428.3	393.6	408.9	401.3

[1]In addition to the treatments noted here, each section received 46 pounds of manure.

[2]On account of the exceptionally low production in Section 1, own-root Killarney, and the wide difference between it and the production in Sections 7 and 13, the data from it were omitted in computing the averages here and in following tables.

TABLE 4.—TOTAL STEM LENGTH OF ROSES, 1910-13
(Average per 16 plants; expressed in inches)

Fertilizer[1] (Pounds per 100 square feet)			Section	Killarney		Bride		Killarney and Bride		Own-root and grafted		Killarney and Bride own-root and grafted (Average)
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	Own-root	Grafted	Killarney	Bride	
8	2	2	1	3206.33[2]	4404.28	6049.47	7010.22	4627.90	5723.92	3821.97	6529.84	5175.91
16	2	2	2	3798.75	3870.08	5531.16	7251.50	4664.95	5510.79	3834.41	6341.33	5087.87
32	2	2	3	3797.50	3948.92	4736.92	5913.30	4267.21	4931.11	3873.21	5325.11	4599.16
0	0	0	4	3147.83	3827.90	4458.49	6199.85	3803.16	5013.87	3487.86	5329.17	4408.51
8	4	2	5	3864.33	4308.38	6290.21	7316.71	5077.27	5797.80	4086.35	6788.72	5437.53
8	8	2	6	4314.42	5190.84	7129.59	7295.65	5722.00	6243.25	4752.63	7212.62	5982.62
8	2	2	7	4075.42	3973.82	5928.06	7581.65	5001.74	5777.73	4024.62	6754.85	5389.73
8	2	4	8	3594.75	4014.59	6020.67	7175.79	4807.71	5595.19	3804.67	6598.23	5201.45
8	2	8	9	3349.33	3999.98	5596.83	6628.13	4722.29	5314.05	3923.86	6112.48	5018.17
0	0	0	10	3454.66	4179.91	4484.25	5377.42	3969.45	4793.66	3833.95	4929.16	4381.55
16	4	2	11	4442.00	4375.63	6205.75	7233.93	5323.87	5804.78	4408.81	6719.84	5564.32
32	8	2	12	4360.08	4340.46	4820.75	6073.70	4590.41	5207.08	4350.27	5447.22	4898.74
8	2	2	13	4268.25	4470.60	5692.66	7426.00	4980.45	5948.30	4369.42	6559.33	5464.37
16	2	4	14	3895.58	3898.23	5912.25	6669.53	4903.91	5283.88	3896.90	6290.89	5093.89
32	2	8	15	3328.83	3951.18	5072.50	5493.10	4200.66	4757.90	3675.77	5282.80	4479.26
0	0	0	16	3323.25	3944.03	4569.83	5126.88	4220.16	4535.45	3633.64	5121.98	4377.80
8	4	4	17	3847.66	4439.25	6268.92	7138.94	5058.29	5789.09	4143.45	6703.92	5423.69
8	8	8	18	3867.75	4637.69	5660.00	7080.61	4763.87	5859.15	4252.72	6370.30	5311.51
16	4	4	19	4025.00	3863.77	6206.75	6879.63	5115.87	5371.70	3944.38	6543.19	5243.78
32	8	8	20	3844.25	4008.54	5303.92	6411.57	4574.08	5210.05	3926.39	5857.74	4892.06
			Average of Combined Sections									
8	2	2	1-7-13	4171.84	4282.90	5890.06	7339.29	5030.95	5816.65	4227.37	6614.67	5421.02
0	0	0	4-10-16	3308.58	3983.94	4686.61	5568.05	3997.59	4775.99	3646.26	5127.33	4386.78
8 to 32	2 to 8	2 to 8	All fertilized sections	3914.22	4217.42	5786.25	6855.91	4850.24	5536.66	4065.82	6321.08	5193.45

[1]In addition to the treatments noted here, each section received 46 pounds of manure.
[2]See Note 2 to Table 3.

TABLE 5.—COMPARISON OF UNFERTILIZED AND FERTILIZED SECTIONS, 1910-13
(Average per 16 plants)

Sections	Killarney Own-root	Killarney Grafted	Bride Own-root	Bride Grafted	Average
Number of Flowers					
Unfertilized	327.4	389.0	325.0	388.5	357.4
Fertilized	388.5	398.6	359.8	458.0	401.3
Total Stem Length (Expressed in inches)					
Unfertilized	3308.58	3983.94	4686.61	5568.05	4386.78
Fertilized	3914.22	4217.42	5786.25	6855.91	5193.45

quality. The latter may be obtained from Table 6, which shows the quoted wholesale prices of Killarneys during 1912 (June to October omitted)[1].

TABLE 6.—PRICE OF KILLARNEYS PER 100, 1912

Jan.	3,	$4 to	$12	Mar.	27,	$3 to	$12	Oct.	9,	$3 to	$10
”	10,	4 ”	12	Apr.	3,	3 ”	15	”	16,	3 ”	10
”	17,	3 ”	15	”	10,	3 ”	10	”	23,	3 ”	10
”	24,	4 ”	15	”	17,	3 ”	10	”	30,	3 ”	10
”	31,	6 ”	15	”	24,	3 ”	10	Nov.	6,	3 ”	8
Feb.	7,	5 ”	15	May	1,	3 ”	10	”	13,	3 ”	8
”	14,	5 ”	15	”	8,	3 ”	10	”	20,	3 ”	8
”	21,	5 ”	15	”	15,	3 ”	10	”	27,	3 ”	10
”	28,	4 ”	12	”	22,	3 ”	10	Dec.	4,	3 ”	12
Mar.	6,	3 ”	10	”	28,	3 ”	10	”	11,	3 ”	12
”	13,	3 ”	12					”	18,	4 ”	15
”	20,	3 ”	12	Oct.	2,	3 ”	10	”	24,	8 ”	25

The excess production of flowers from grafted Killarney plants over those from own-root stock is somewhat greater during the fall and spring months than during midwinter (page 520). To make allowance for this fact, the conservative value of $4 per 100 flowers is chosen as a basis for calculation. Such a price would be conservative for Brides also, since their average stem length somewhat exceeds that of Killarneys. At this price the excess production from grafted Killarneys would net the grower a profit per 1,000 plants of $105.80, while the excess production per 1,000 plants from grafted Brides would be valued at $160. The difference in cost between own-root and grafted stock from 2¼-inch pots, or the additional cost of manetti and labor for making grafted stock, is less than half the increased value of the crop during the first year alone. The increased production from grafted stock during 1913-15 with Killarney and Richmond was considerably larger, being in the neighborhood of 5,700 and 8,000 flowers per 960 plants.

[1]The Florists' Review, 1912.

The relation of the season of the year to the larger production from grafted stock compared with own-root stock is shown in Fig. 3 (page 529). Each unit at the bottom of the graph from left to right represents a week of the season, while the number of flowers produced is shown by the row of figures extending vertically on the left.

The largest differences between the curves are for the periods October 7 to November 12, and April 14 to June 26. Other periods where an excess production of grafted stock over own-root is shown are December 9 to December 30, and March 24 to April 7. During January and February the production was practically the same.

EFFECT OF INCREASING AMOUNTS OF DRIED BLOOD

In Sections 1, 7, and 13, 8 pounds of dried blood were used with 2 pounds each of acid phosphate and potassium sulfate. In Sections 2 and 3, 16 and 32 pounds of dried blood were added, respectively, together with the amounts of acid phosphate and potassium sulfate used in the first sections. A comparison between these sections would show the effect of increasing amounts of dried blood, an increasing production with larger applications being an indication that the dried blood was the limiting factor of plant growth in this soil mixture. The results are presented in Table 7.

TABLE 7.—EFFECT OF INCREASING AMOUNTS OF DRIED BLOOD, 1910-13
(Average per 16 plants)

Fertilizer (Pounds per 100 square feet)			Section	Killarney		Bride		Average
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	
Number of Flowers								
8	2	2	1-7-13	375.5	410.4	391.0	482.8	414.9
16	2	2	2	361.0	383.3	383.6	472.6	400.1
32	2	2	3	391.0	383.6	339.3	405.6	379.9
Total Stem Length (Expressed in inches)								
8	2	2	1-7-13	4171.84	4282.90	5890.06	7339.29	5421.02
16	2	2	2	3798.75	3870.08	5531.16	7251.50	5087.87
32	2	2	3	3797.50	3948.92	4736.92	5913.30	4599.16

With all types of plants except own-root Killarneys, for which the results are not consistent, a decrease in number of flowers produced and in total stem length resulted from increasing applications of dried blood. The effect was particularly noticeable when 32 pounds of dried blood were applied, and the percentage drop was greater in Brides than in Killarneys. The decidedly injurious effect of this heavy application of dried blood will be pointed out in the discussion of the results of increasing the amounts of two or three of the fertilizers together (pages 523-525). Clearly 8 pounds of dried blood was the heaviest application that could be made without lowering production.

Since 8 pounds of dried blood was the minimum amount used, the question whether a smaller quantity of dried blood would have been beneficial was not determined. Further evidence in regard to its use is, however, brought out on page 527.

EFFECT OF INCREASING AMOUNTS OF ACID PHOSPHATE

To Sections 5 and 6 were applied respectively 4 and 8 pounds of acid phosphate per 100 square feet. These may also be compared with the average of Sections 1, 7, and 13, to which only 2 pounds were applied, since all of them received the same quantities of dried blood (8 pounds) and of potassium sulfate (2 pounds). The results are given in Table 8.

TABLE 8.—EFFECT OF INCREASING AMOUNTS OF ACID PHOSPHATE, 1910-13
(Average per 16 plants)

Fertilizer (Pounds per 100 square feet)			Section	Killarney		Bride		Average
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	
Number of Flowers								
8	2	2	1-7-13	375.5	410.4	391.0	482.8	414.9
8	4	2	5	352.0	409.3	416.3	483.3	415.2
8	8	2	6	383.0	470.0	485.6	479.6	454.5
Total Stem Length (Expressed in inches)								
8	2	2	1-7-13	4171.84	4282.90	5890.06	7339.29	5421.02
8	4	2	5	3864.33	4308.38	6290.21	7316.71	5437.53
8	8	2	6	4314.42	5190.84	7129.59	7295.65	5982.62

In this series, grafted Brides were the exceptional plants. With the others, an increase was produced by the heaviest application of acid phosphate. The results are consistent both for number of flowers and for total stem length. With grafted Brides the yield, both of flowers and of total stem length, remained practically unchanged in all the sections.

The data indicate that phosphorus was the limiting element, and the much larger increase when 8 pounds rather than 2 pounds were applied points out the possibility that much larger applications of acid phosphate would have increased the crop in still greater measure. The much smaller size of the root system of a rose plant heavily fertilized with it is evidence of this need, as is the fact often observed in experiments where acid phosphate has been applied as a top-dressing, that the roots grow toward the surface of the soil instead of being evenly distributed thru it.

EFFECT OF INCREASING AMOUNTS OF POTASSIUM SULFATE

Sections 8 and 9, to which the same amounts of fertilizers were applied as to Sections 1, 7, and 13, except that the amounts of potassium sulfate were increased respectively to 4 and 8 pounds per 100 square feet, may be compared with them, to determine the advisability of using potassium sulfate as a fertilizer. The soil used in this experiment (see page 512) contained some 36,000 pounds of potassium per acre of surface soil. In spite of the fact that only a small proportion of this is available for the immediate nutrition of the plant, being largely in the form of insoluble granitic and feldspathic particles, the conditions provided by the greenhouse are those which would promote the rapid decomposition of these particles into forms sufficiently soluble to be of use to the plant. Thus, a moderate and fairly constant amount of moisture is maintained, ample supplies of organic matter are present, and the temperature never varies beyond the range of bacterial action. It is not to be expected that a soil which under farming conditions[1] shows little response to applications of potassium for farm crops would show a need of potassium under given conditions, unless roses required an unusually large amount. The results from these sections are presented in Table 9.

TABLE 9.—EFFECT OF INCREASING AMOUNTS OF POTASSIUM SULFATE, 1910-13
(Average per 16 plants)

Fertilizer (Pounds per 100 square feet)			Section	Killarney		Bride		Average
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	
Number of Flowers								
8	2	2	1-7-13	375.5	410.4	391.0	482.8	414.9
8	2	4	8	333.0	374.3	398.6	459.3	391.3
8	2	8	9	317.0	382.0	382.0	448.6	382.4
Total Stem Length (Expressed in inches)								
8	2	2	1-7-13	4171.84	4282.90	5890.06	7339.29	5421.02
8	2	4	8	3594.75	4014.59	6020.67	7175.79	5201.45
8	2	8	9	3349.33	3999.98	5596.83	6628.13	5018.17

With the exception of own-root Brides, each series shows not only no gain with increasing applications of potassium sulfate, but a loss which is usually greatest with the heaviest application. In no case does the production when the heaviest application is made equal that when only two pounds are applied. The exceptional behavior of own-root Brides—an increase upon application of four pounds of potassium sulfate—is seen with both standards of measurement, but the increase is not large enough to stand out as significant evidence

[1]C. G. Hopkins, Soil Fertility and Permanent Agriculture, p. 459.

in favor of the use of potassium sulfate. Certain soils of the state[1], viz., the peaty and sandy swamp soils of northern Illinois, have been shown to be deficient in potassium for farm crops. The experiments described in this bulletin are, of course, of no value in judging the need for potassium on such soils. Neither sandy nor peaty soils are suited to rose growing, however, so that no consideration need be given these types.

EFFECT OF INCREASING AMOUNTS OF BOTH DRIED BLOOD AND ACID PHOSPHATE

An increase in the amounts of both dried blood and acid phosphate in successive sections furnishes a method of testing out the conclusions reached from the study of the effect of increasing each separately. In general these conclusions were that larger quantities of dried blood than 8 pounds per 100 square feet of bench space (5 inches deep) were harmful, the largest application (32 pounds) being especially so; that increasing applications of potassium sulfate caused a decrease in production; and that increasingly larger production resulted from an increase in application of acid phosphate. A comparison of Sections 1, 7, and 13 with Sections 11 and 12, to which were applied respectively 8 pounds, 16 pounds, and 32 pounds of dried blood, and 2 pounds, 4 pounds, and 8 pounds of acid phosphate, with a constant quantity of potassium sulfate, shows the results of the opposing effects of acid phosphate and dried blood.

TABLE 10.—EFFECT OF INCREASING AMOUNTS OF BOTH DRIED BLOOD AND ACID PHOSPHATE, 1910-13

Fertilizer (Pounds per 100 square feet)			Section	Number of flowers (Average per 16 plants)				
				Killarney		Bride		Average
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	
8	2	2	1-7-13	375.5	410.4	391.0	482.8	414.9
16	4	2	11	415.0	423.6	419.6	490.0	437.0
32	8	2	12	403.6	413.0	340.0	430.3	396.7

On the whole, the different types of plants follow the results shown in the figures for average production, that is, an increase of production as the application of both fertilizers is doubled, followed by a drop in production with larger applications, because of injury from overfeeding with dried blood.

Applications of 16 pounds of dried blood with 4 pounds of acid phosphate gave larger yields than where dried blood remained at 8 pounds, as is shown by Sections 11 and 5 in Table 11. Increasing the application of acid phosphate to 8 pounds (with dried blood 8

[1]Ill. Agr. Exp. Sta. Bul. 157.

pounds) caused a still larger production with grafted Killarney and own-root Bride (Section 6, Table 11), those types that gave largest increases with an increase of acid phosphate alone (Table 8).

TABLE 11.—EFFECT OF INCREASING AMOUNTS OF DRIED BLOOD AND ACID PHOSPHATE, 1910-13

Fertilizer (Pounds per 100 square feet)			Section	Number of flowers (Average per 16 plants)				
				Killarney		Bride		Average
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	
16	4	2	11	415.0	423.6	419.6	490.0	437.0
8	4	2	5	352.0	409.3	416.3	483.3	415.2
8	8	2	6	383.0	470.0	485.6	479.6	454.5

EFFECT OF INCREASING AMOUNTS OF BOTH DRIED BLOOD AND POTASSIUM SULFATE

Large applications of both of these fertilizers intensified the injury resulting from large applications of either fertilizer (see Table 12).

TABLE 12.—EFFECT OF INCREASING AMOUNTS OF DRIED BLOOD AND POTASSIUM SULFATE, 1910-13

Fertilizer (Pounds per 100 square feet)			Section	Number of flowers (Average per 16 plants)				
				Killarney		Bride		Average
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	
8	2	2	1-7-13	375.5	410.4	391.0	482.8	414.9
16	2	4	14	353.3	372.6	404.6	447.3	394.5
32	2	8	15	315.6	363.3	360.6	377.3	354.2

EFFECT OF INCREASING AMOUNTS OF BOTH ACID PHOSPHATE AND POTASSIUM SULFATE

All the plants so treated were vigorous in growth, but the data show that the production remained about the same as before. The results of this treatment are presented in Table 13.

TABLE 13.—EFFECT OF INCREASING AMOUNTS OF ACID PHOSPHATE AND POTASSIUM SULFATE, 1910-13

Fertilizer (Pounds per 100 square feet)			Section	Number of flowers (Average per 16 plants)				
				Killarney		Bride		Average
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	
8	2	2	1-7-13	375.5	410.4	391.0	482.8	414.9
8	4	4	17	359.3	416.6	409.6	477.0	415.6
8	8	8	18	351.3	414.3	386.0	478.6	407.5

EFFECT OF INCREASING AMOUNTS OF DRIED BLOOD, ACID PHOSPHATE, AND POTASSIUM SULFATE

The results presented in Table 14 show that the heaviest applications of the three fertilizers resulted in decreased production. In every case heavy applications of the three fertilizers gave lower yields than heavy applications of acid phosphate alone (see Table 8).

TABLE 14.—EFFECT OF INCREASING AMOUNTS OF DRIED BLOOD, ACID PHOSPHATE, AND POTASSIUM SULFATE, 1910-13

Fertilizer (Pounds per 100 square feet)			Section	Number of flowers (Average per 16 plants)				
				Killarney		Bride		Average
Dried blood	Acid phosphate	Potassium sulfate		Own-root	Grafted	Own-root	Grafted	
8	2	2	1-7-13	375.5	410.4	391.0	482.8	414.9
16	4	4	19	367.3	357.3	422.6	455.0	400.6
32	8	8	20	364.6	382.3	376.0	437.3	390.0

DISCUSSION OF RESULTS

These experiments indicate that own-root Killarney plants are uninjured by larger quantities of dried blood than grafted Killarneys or Brides of either stock. Larger applications of acid phosphate increased the production of flowers in all cases except that of grafted Brides. There seems to be an inverse relation between the size of the root system and the extent to which applications of commercial fertilizer may be made with profit and safety. For grafted Brides, with the largest root system of the types grown, were injured by increasing applications of dried blood to a much greater extent than own-root Killarneys, with a smaller root system. Also, acid phosphate had no effect upon the crop from grafted Brides, but increased the production from the own-root Brides and both own-root and grafted Killarneys.

The results, then, indicate that, in general, applications of dried blood and of potassium sulfate above 8 and 2 pounds, respectively, per 100 square feet of bench space, caused a decrease in production; that applications of acid phosphate up to the largest amount used caused an increase in production; and that combinations of these fertilizers caused an increase or decrease, depending upon the relative effect of the fertilizers in the combination.

It should be pointed out that while no evidence is found to favor the use of potassium sulfate, in this experiment every section which received any commercial fertilizer received a minimum application of this fertilizer and of dried blood and acid phosphate. No data are available regarding the effects of these initial quantities excepting those given in Tables 3 and 4[1] in which comparisons are made between sections fertilized only with a certain quantity of manure, and those

[1]Averages of Sections 4, 10, and 16 and Sections 1, 7, and 13 are compared.

having in addition the minimum quantities of these three fertilizers. Also while definite results were obtained with regard to the maximum quantities of dried blood that may profitably be used, increased production resulted from the largest applications of acid phosphate made, so that the maximum amount of this fertilizer that is profitable was not determined by this experiment.[1]

EFFECT OF FERTILIZATION UPON WEEKLY PRODUCTION, 1910-13

The wide variation in the price of roses during the year makes the study of the response of the plants to fertilization at different periods of the year an important one. The proper time to apply each fertilizer also will depend upon the response of the plants to it during the different periods of the year. In order to make this comparison possible, the production of each section during the season of 1912-13—both number of flowers and total stem length—was summed up at the end of each week, and the average stem length for the week calculated. The results were then plotted as shown in the following figures (pages 529 to 541), each division of the abscissa corresponding to a week of the season, while the divisions upon the ordinate correspond to the number of flowers shown by the figures at the left. A rise in the curve connecting the points representing the production each week corresponds to an increased production, and vice versa. In every case the first week ended October 7.

Typical Rate of Production

Fig. 4 shows the production of flowers in all sections of grafted Killarney during the season of 1912-13. The general form of the curve indicates a maximum production about November 1 followed by a drop to a minimum about February 15, and in turn succeeded by a gradual increase to a second maximum about May 15. The months of lowest production were January and February.

Relation of Sunshine to Production

A correlation between this variation of production and the amount of sunshine during the year is shown in Fig. 5, where the solid line represents the production of flowers per week by grafted Killarney and the broken one the hours of sunshine per week. The general form of the curves is the same, the periods of large or small amount of sunshine being succeeded in two or three weeks by periods of corresponding variation in production.

Relation of Time of Year to Stem Length

The relation of the average weekly stem length to the time of year is shown by the broken line in Fig. 6 (for moderately fertilized

[1]See page 541 for further experiments.

own-root Brides), while its relation to the number of flowers produced each week is shown by comparison with the solid line. The curve shows the relation for first-year roses only. With older stock the period in early fall during which short stems were produced would doubtless be less pronounced. In the latter part of the season there was a slight drop from the maximum stem length found during the 19th to 22nd weeks (February 10 to March 3).

Relation of One Year's Production to Another

It was stated on page 511 that the experiment of 1910-11 was continued during the two succeeding years; the data were based on the average of these years. Fig. 7 shows the curves for the production of flowers by grafted Killarney during these years. With the exception of the period during the 6th to 10th weeks of 1910-11, the curves are in fair accord and indicate the degree of accuracy that can be obtained by interpreting the results upon weekly production during 1912-13 alone.

General Relation of Fertilizing to Weekly Production

The solid line of Fig. 8 represents the average number of flowers produced per section upon all the sections to which commercial fertilizer was applied, while the average production of all sections unfertilized with commercial fertilizer is given for comparison by the broken line. The significant part of the curves is the distinct and continued increase in production of the fertilized over the unfertilized sections largely from the 24th to 34th weeks (March 17 to June 1). The effects of dried blood, of moderate fertilizing, and of acid phosphate upon this weekly production are considered in the following paragraphs.

Relation of Fertilizing to Variation in Stem Length

Fig. 9, giving the variation of average stem length of own-root Brides in moderately fertilized sections (broken line) compared with the stem length of flowers from the unfertilized sections (solid line), shows that the average stem length was practically unaffected by fertilization.

Effect of Heavy Fertilizing with Dried Blood

It has been pointed out (page 520) that the largest amounts of dried blood used (32 pounds per 100 square feet of bench space 5 inches deep) produced marked injury to all plants, excepting own-root Killarneys, and decreased production. With Killarneys of this stock the results were not consistent. Figs. 10 to 13, inclusive, illustrate the production of the sections heavily fertilized with dried blood (Sections 3, 12, 15, 20) compared with that from the unfertilized sections[1]. In each case, during the latter part of the season, the heavily fertilized sections showed an increase in production. In early fall, own-root Killarneys alone where fertilized showed an increase in number of flowers; the other types showed a decrease. The production during the winter months was about the same whether the plants were fertilized or not. It may be concluded from this study that, in general, fertilization with dried blood is undesirable in the fall, useless in the winter, but beneficial in the spring.

EFFECT OF MODERATE FERTILIZING

The series of curves shown in Figs. 14 to 21, inclusive, shows the production of flowers and of total stem length of each type where the production of moderately fertilized sections (solid line) is compared with the production of unfertilized sections (broken line). In own-root stock of each variety, nearly the whole excess production of the fertilized sections over the unfertilized sections can be accounted for during the last few weeks of the season. For instance, the excess production of fertilized own-root Brides for the entire year over those unfertilized is 123 flowers. During the last six weeks of the season the excess production from the fertilized sections amounts to 105 flowers. At no other time of the year is there a continued increased production traceable to fertilization. In the case of grafted stock, not so large a proportion can be traced, but here again the greater part of the increase consists of that during the spring months.

EFFECT OF ACID PHOSPHATE

The effect of larger applications of acid phosphate upon weekly production is indicated by the series of figures (22 to 25 inclusive) showing the number of flowers produced weekly in the section to which a rather heavier application of acid phosphate was made (Section 6[2]) compared with the average production of the moderately fertilized sections (1, 7, and 13), to which the same quantities of dried blood and potassium sulfate but a smaller quantity of acid phosphate were applied. The solid line shows the production with larger amounts of acid phosphate, the broken one, without this quantity. Owing to the fact that there was but one section so fertilized, the results do not give as regular a curve as would result from a larger number of plants. One significant feature, however, is evident. The increase in production is not traceable to the last few weeks of the year, but extends thruout fall, winter, and spring.

[1]Since there were only three unfertilized sections, viz., 4, 10, and 16, the results are multiplied by 4/3 to make them comparable.

[2]The results from this section are multiplied by 3 to make them comparable with the others.

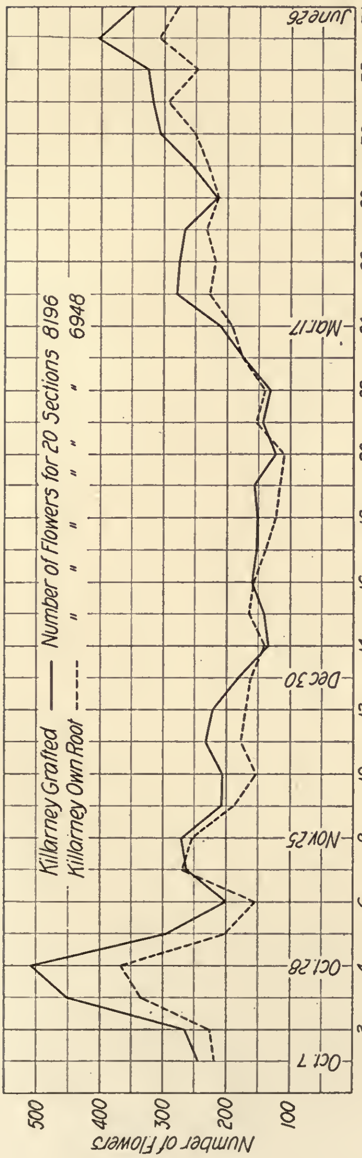

FIG. 3.—COMPARATIVE EFFECTS OF FERTILIZING UPON OWN-ROOT AND GRAFTED KILLARNEY, 1912-13

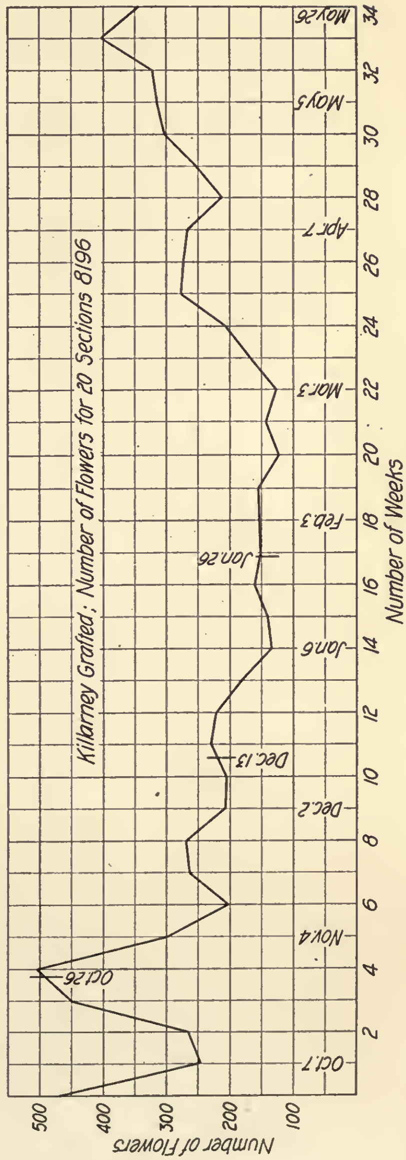

FIG. 4.—TYPICAL RATE OF PRODUCTION; GRAFTED KILLARNEY, 1912-13

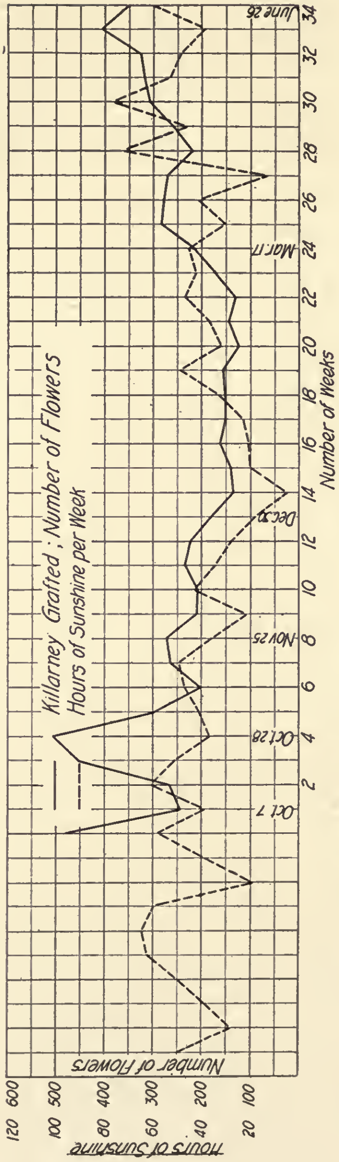

FIG. 5.—RELATION OF SUNSHINE TO PRODUCTION; GRAFTED KILLARNEY, 1912-13

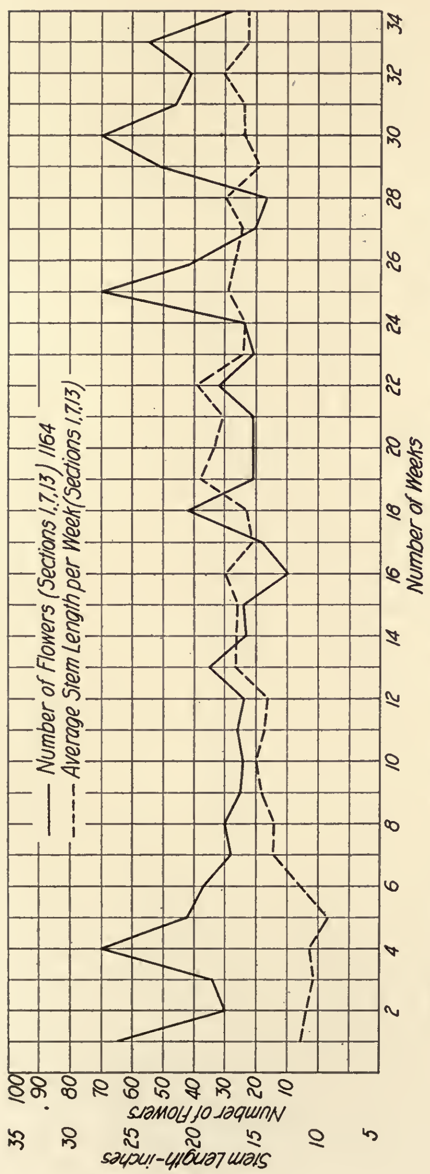

FIG. 6.—RELATION OF TIME OF YEAR TO STEM LENGTH; OWN-ROOT BRIDE, 1912-13

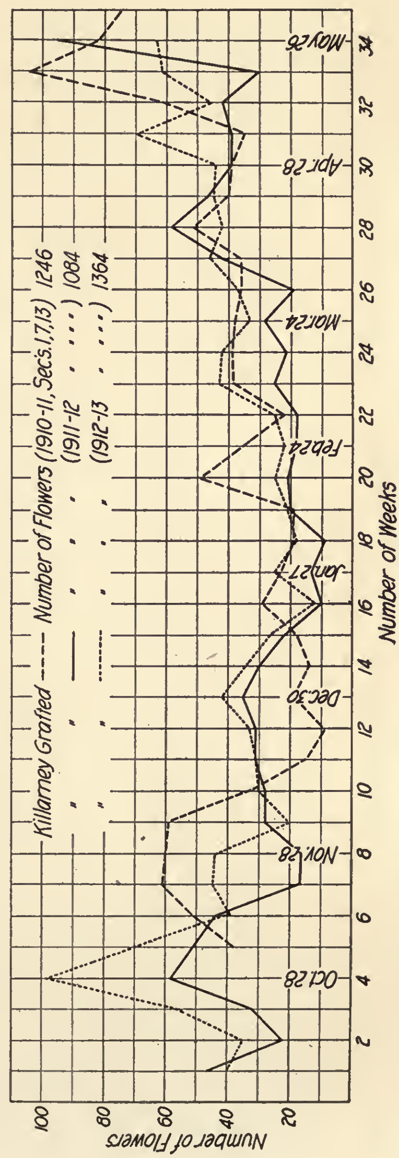

FIG. 7.—RELATION OF ONE YEAR'S PRODUCTION TO ANOTHER; GRAFTED KILLARNEY, 1910-13

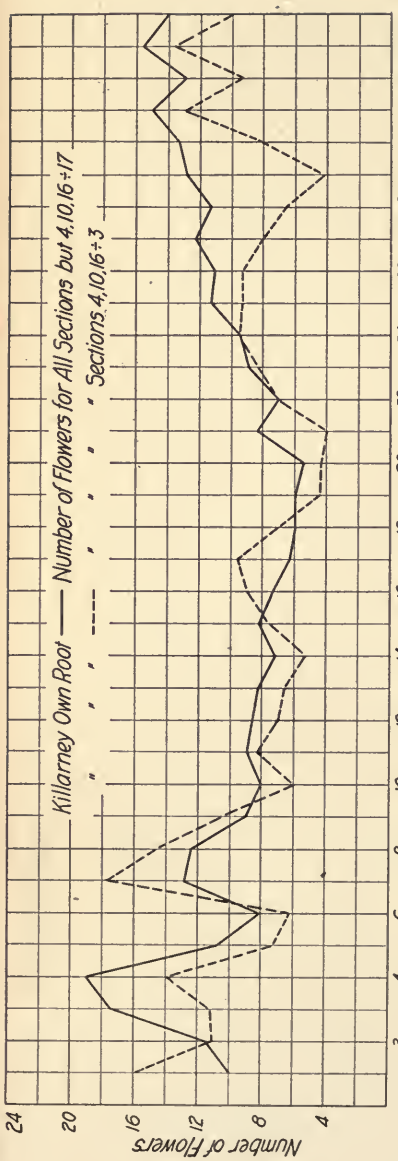

FIG. 8.—RELATION OF FERTILIZING TO WEEKLY PRODUCTION; OWN-ROOT KILLARNEY, 1912-13

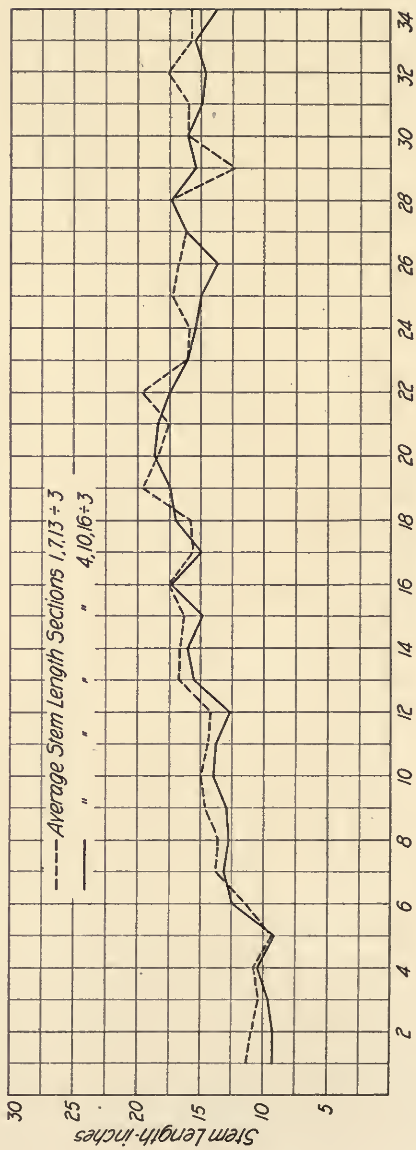

FIG. 9.—RELATION OF FERTILIZING TO VARIATIONS IN STEM LENGTH; OWN-ROOT BRIDE, 1912-13

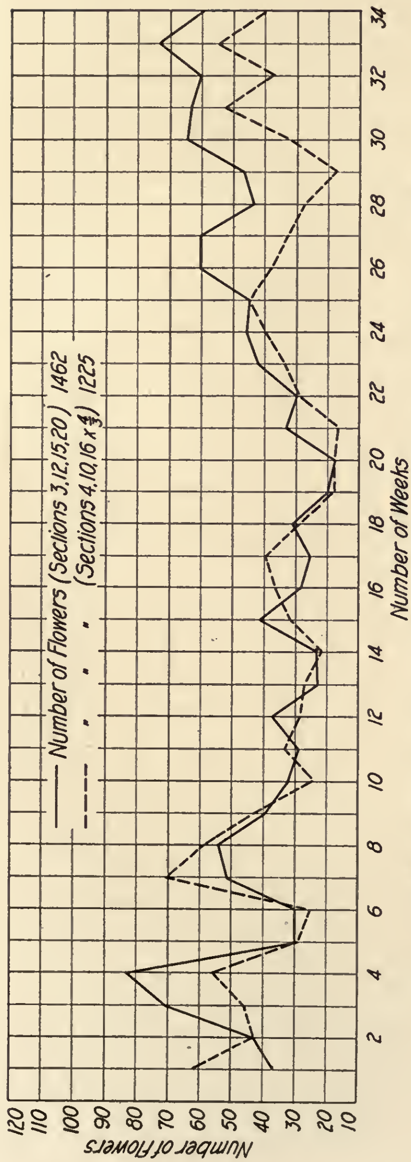

FIG. 10.—HEAVY FERTILIZING WITH DRIED BLOOD; OWN-ROOT KILLARNEY, 1912-13

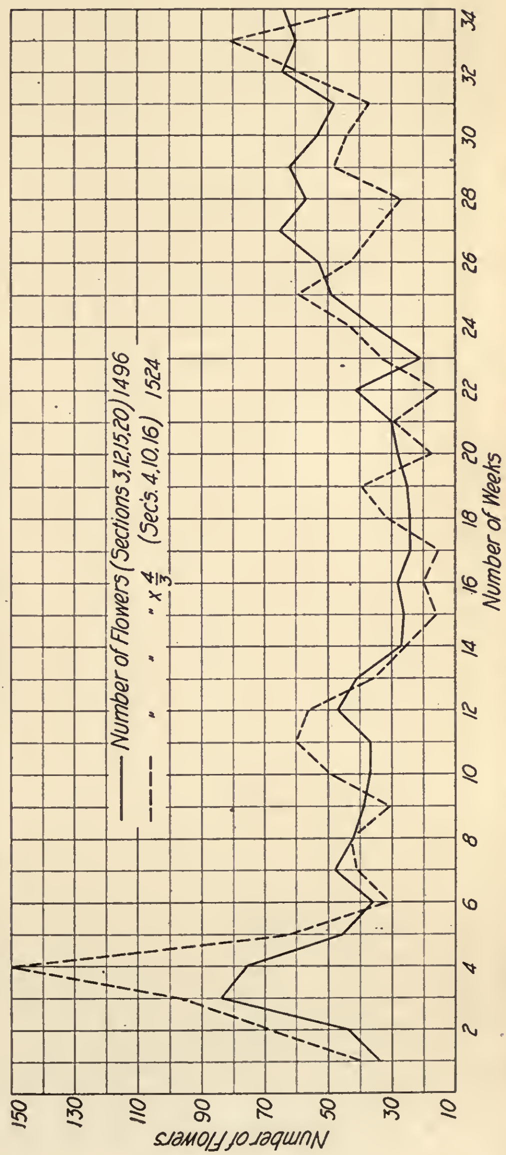

FIG. 11.—HEAVY FERTILIZING WITH DRIED BLOOD; GRAFTED KILLARNEY, 1912-13

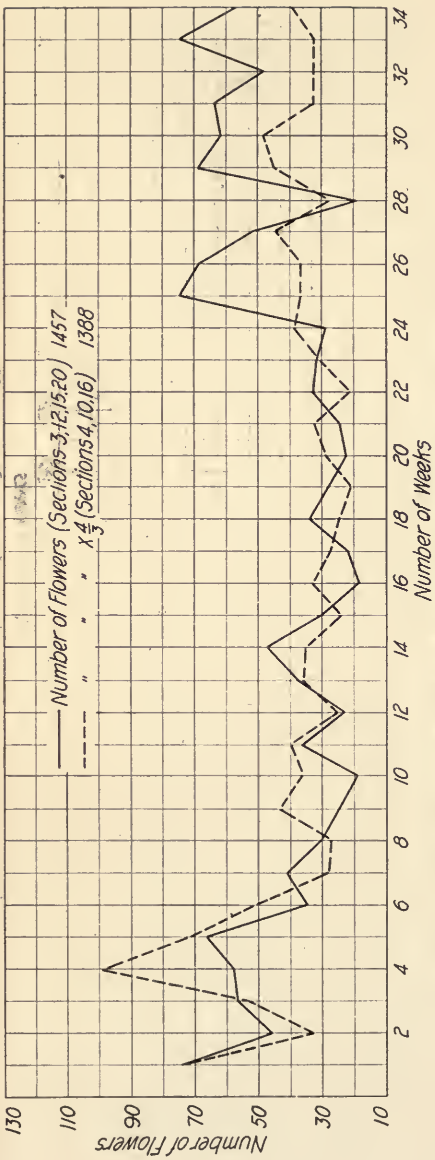

FIG. 12.—HEAVY FERTILIZING WITH DRIED BLOOD; OWN-ROOT BRIDE, 1912-13

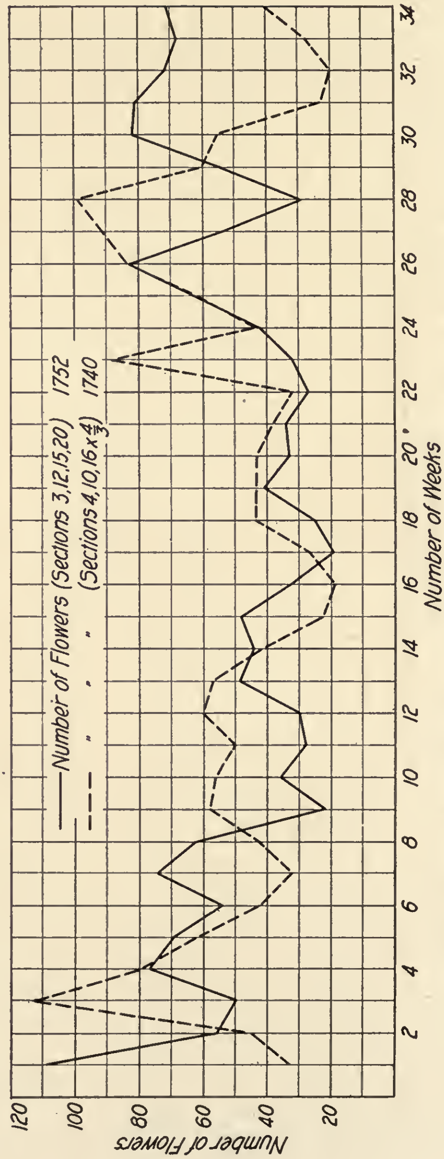

FIG. 13.—HEAVY FERTILIZING WITH DRIED BLOOD; GRAFTED BRIDE, 1912-13

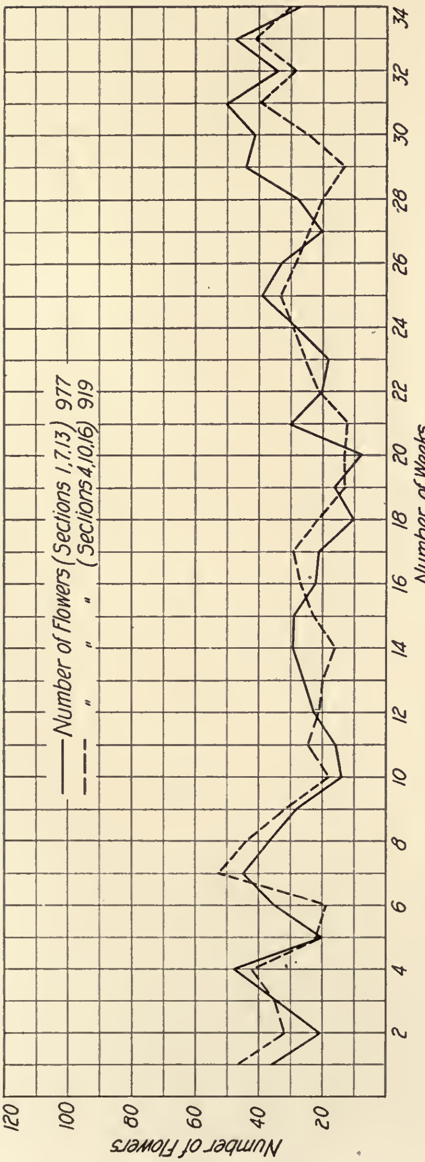

FIG. 14.—MODERATE FERTILIZING; NUMBER OF FLOWERS, OWN-ROOT KILLARNEY, 1912-13

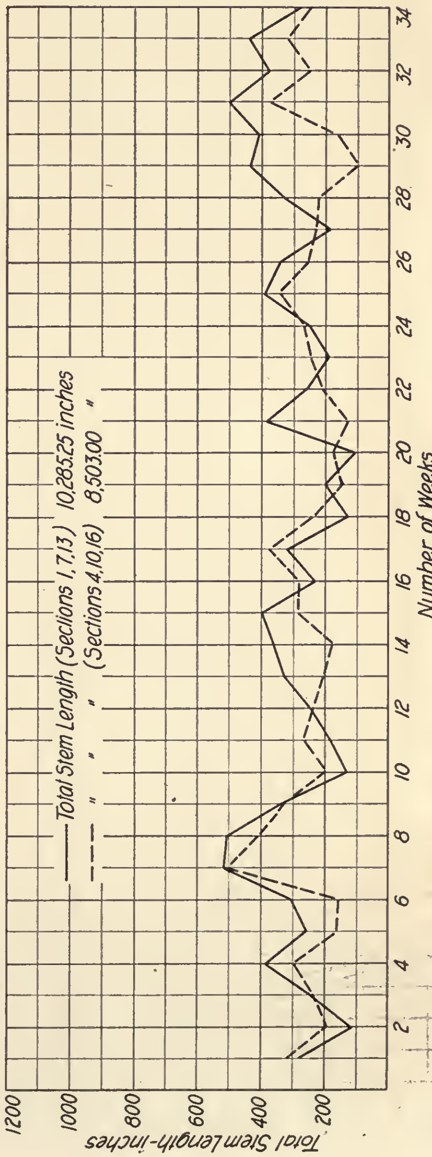

FIG. 15.—MODERATE FERTILIZING; TOTAL STEM LENGTH, OWN-ROOT KILLARNEY, 1912-13

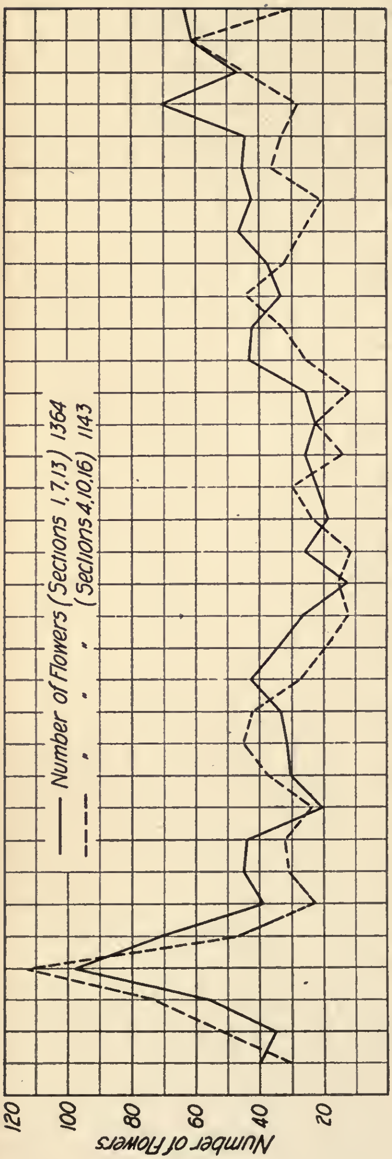

FIG. 16.—MODERATE FERTILIZING; NUMBER OF FLOWERS, GRAFTED KILLARNEY, 1912-13

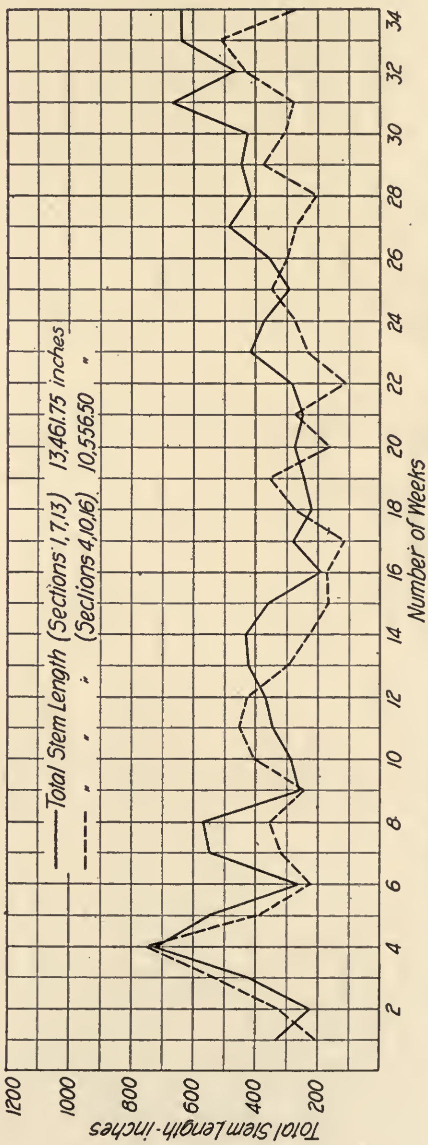

FIG. 17.—MODERATE FERTILIZING; TOTAL STEM LENGTH, GRAFTED KILLARNEY, 1912-13

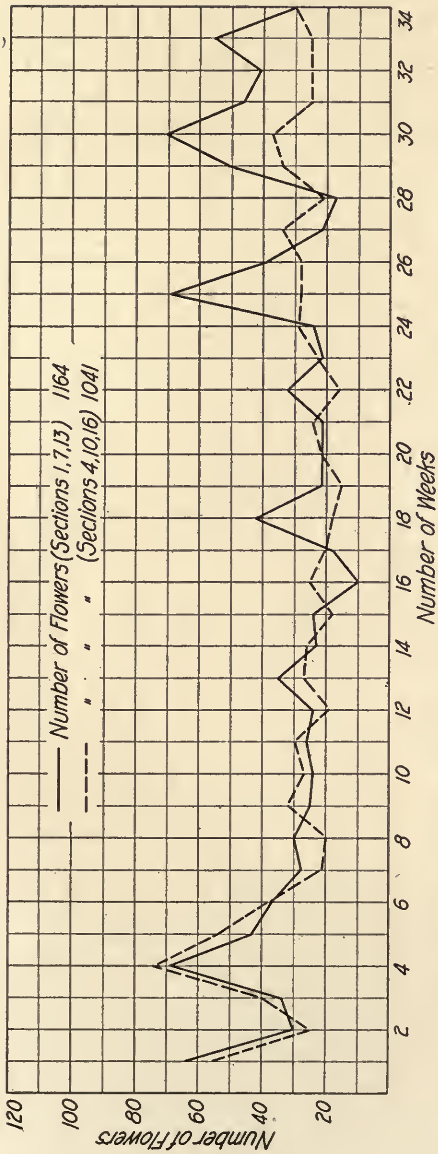

FIG. 18.—MODERATE FERTILIZING; NUMBER OF FLOWERS, OWN-ROOT BRIDE, 1912-13

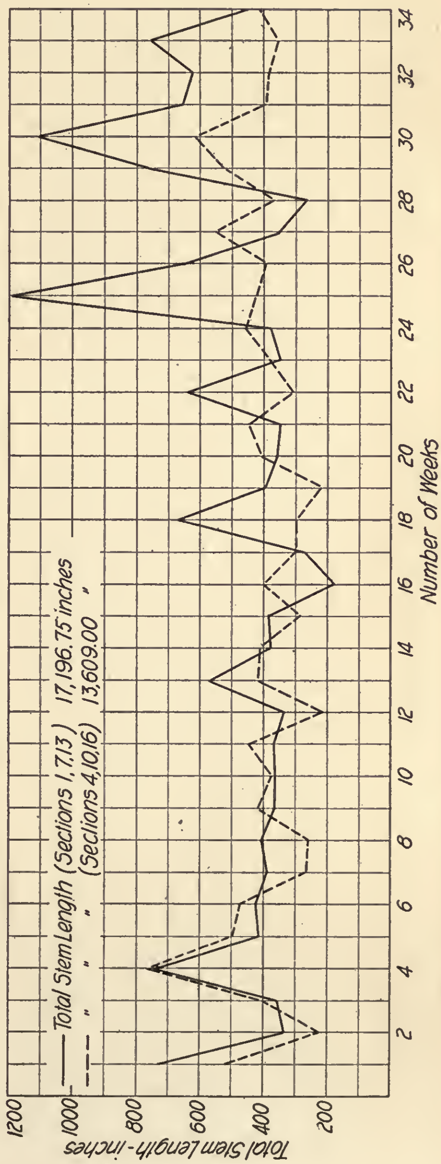

FIG. 19.—MODERATE FERTILIZING; TOTAL STEM LENGTH, OWN-ROOT BRIDE, 1912-13

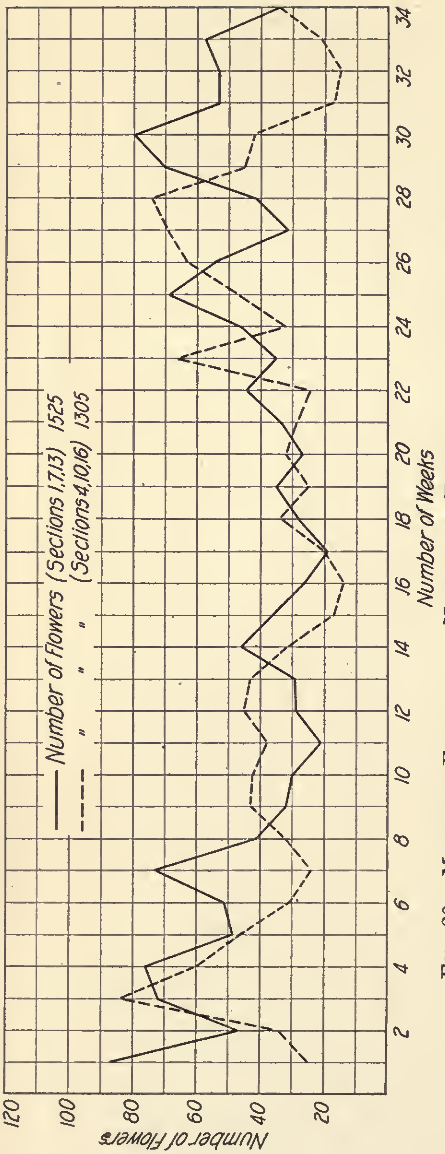

FIG. 20.—MODERATE FERTILIZING; NUMBER OF FLOWERS, GRAFTED BRIDE, 1912-13

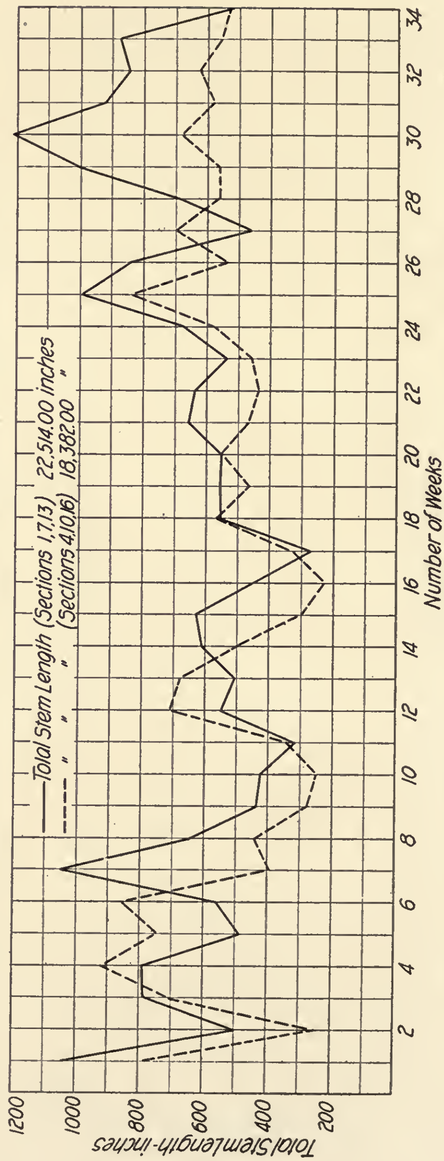

FIG. 21.—MODERATE FERTILIZING; TOTAL STEM LENGTH, GRAFTED BRIDE, 1912-13

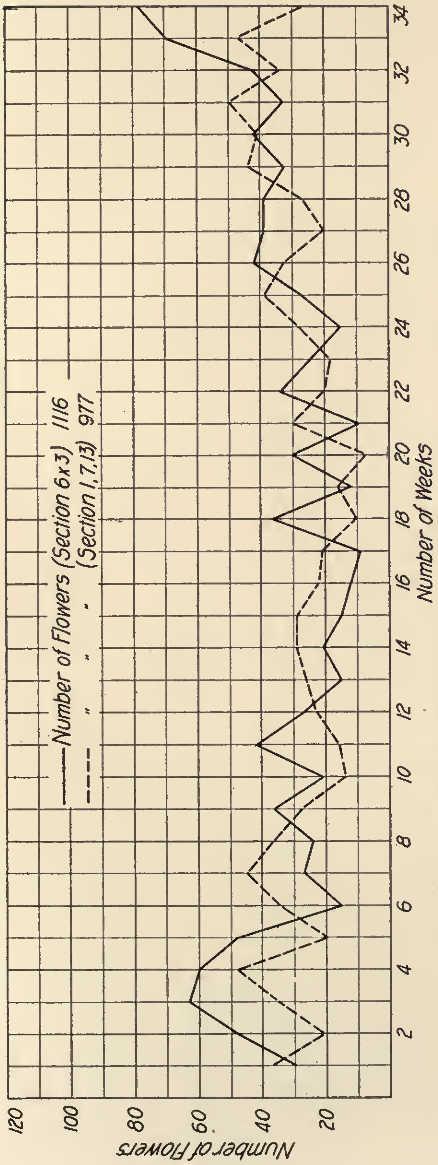

FIG. 22.—EFFECT OF ACID PHOSPHATE; OWN-ROOT KILLARNEY, 1912-13

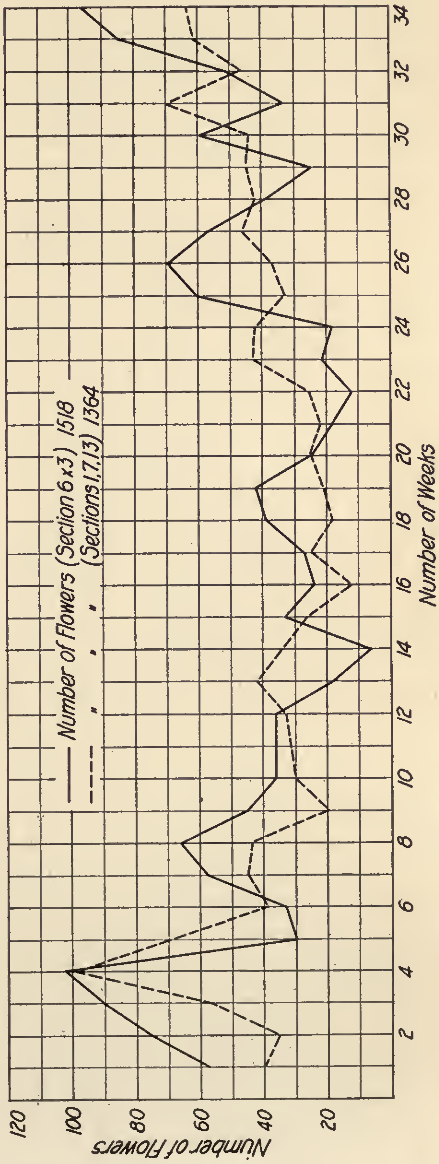

FIG. 23.—EFFECT OF ACID PHOSPHATE; GRAFTED KILLARNEY, 1912-13

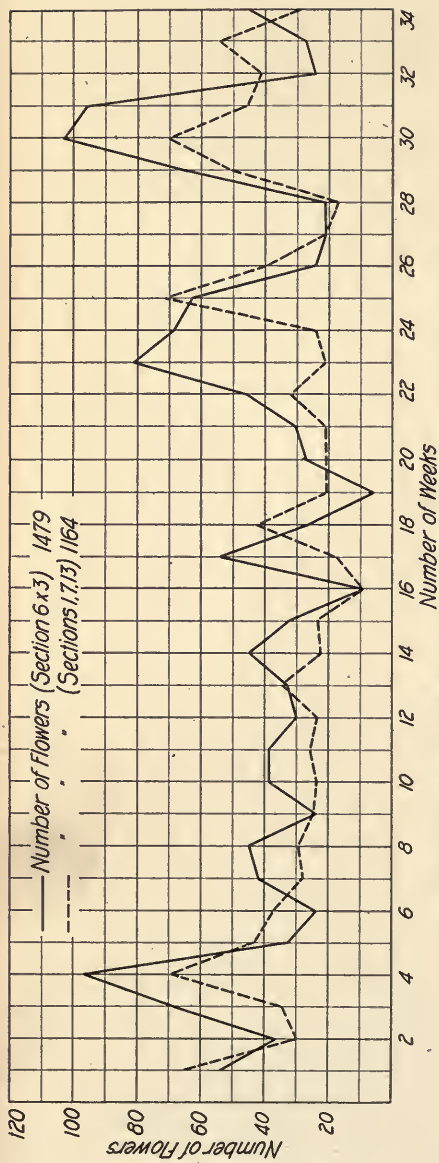

FIG. 24.—EFFECT OF ACID PHOSPHATE; OWN-ROOT BRIDE, 1912-13

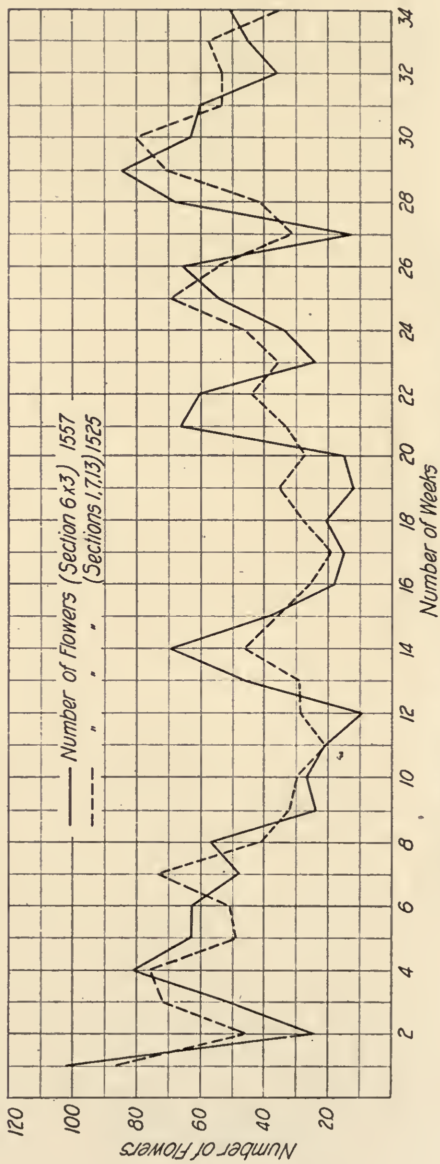

FIG. 25.—EFFECT OF ACID PHOSPHATE; GRAFTED BRIDE, 1912-13

DISCUSSION OF RESULTS

A study of the effect of the application of these commercial fertilizers upon the weekly production of flowers shows that the application of dried blood was harmful in the fall, without result during the winter, and beneficial in the spring. Acid phosphate, on the other hand, gave a consistent increase in production thruout the year. This latter result is important because of the increased value of roses during the winter months. It points also to the advisability of mixing this fertilizer with the soil before filling the benches.

DESCRIPTION OF THE EXPERIMENT, 1913-15

The experiments of 1910-13 showed acid phosphate to be, on the whole, the most profitable of the commercial fertilizers used, while a need for nitrogenous fertilizer amounting to about eight pounds of dried blood per 100 square feet of bench space, particularly in the spring of the year, was made evident also. With regard to acid phosphate, the maximum application that might be made with subsequent profit and safety could not be determined from the data, since the largest amounts employed still gave increased returns over those from the use of smaller quantities.

It was considered advisable in the experimental work of 1913-15 to study the use of acid phosphate in more detail, varying quite widely the quantities applied to the different sections in order to reach the limit of practical application, and increasing the number of plants grown under each treatment by decreasing the number of treatments, in order that the averages of the data might afford a more reliable comparison. In addition, records were kept of the individual production of a number of moderately fertilized plants, for the purpose of calculating the probable error involved in comparing the production from the different sections. Certainty was given further by using a series of six treatments in which the quantity of acid phosphate was successively increased. To obviate that error due to unequal conditions of illumination, temperature, and humidity in different parts of the greenhouses, six repetitions of the treatments in each series were made progressively thru the house, and data for comparison were secured from the set of six thus differently located. Ammonium sulfate (approximately 21 percent nitrogen) was used in the place of dried blood in these experiments. To half the sections used for each treatment finely ground limestone was applied as top-dressings, or mixed with the soil, in order to test the efficiency of this material in fertilizing roses[1].

[1]Upon acid soils (Rept. N. J. Sta. 1893 seq.) air-slaked lime has been found to benefit sweet peas, comet asters, poppies, and legumes, while dilute solutions of citric acid were found by Maxwell [Jour. Amer. Chem. Soc. 20 (1893) 103] to affect unfavorably the growth of some legumes and grasses, and all crucifers

The rose house used in this work measures 28 feet by 105 feet and contains 1,600 square feet of bench space 5 inches deep. It extends east and west and is a part of a range connected by a cross house at its west end, so that the east end is exposed. The temperature variations in different parts of the house proved rather complex under changing conditions of force and direction of wind, sunshine, outside temperature, heating arrangements, and methods of ventilation, but, as an average, the temperature of the inner end of the house was approximately five degrees above that of the exposed end, during cold weather.

Each bench was divided into eighteen 5-foot sections, separated from each other by a double partition with a 2-inch air space between, and with a "buffer" section about 3 feet long at each end growing roses upon which no records were kept. These end sections were not fertilized[1] and served as a sort of check on the experimental sections, altho conditions were hardly the same on account of the more rapid drying of the soil at the ends of the benches.

Killarneys were grown in the two north benches, and Richmonds in the south; each section, which held four rows of plants 12x15 inches apart, contained two rows of own-root and two of grafted stock, or eight plants of each type. The plants were all first-year stock, potted into 4-inch pots on March 2-14 and into 5-inch pots on June 5-9. The plants were set in the benches on August 4, 1913, and on July 9, 1914.

Each two benches, comprising thirty-six sections in all, were made up of six sets of six sections each, numbered in rotation from one bench to another. In numbering the sections the first (or unit) figure was carried from 1 to 6 and each represented a treatment. The second (or ten) figure, from 0 to 5, indicated the location of the section in the house. The arrangement of the sections alternated progressively.

The soil used during these years was of the same type and was prepared in the same manner as that described on page 512. Fertilizers were applied in 1913-14 in the amounts given in Table 15.

The whole of the manure and the potassium sulfate was applied at the time of preparation of the soil (August 4, 1913). One-third of the amount of acid phosphate and ammonium sulfate was applied at this time, also, with another third on November 30, 1913, and the remainder on April 14, 1914. Limestone was used for top-dressings on August 9, 1913, and March 4, 1914.

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and clovers. On the other hand, azaleas, rhododendrons, begonias, lupines, some grasses, the heaths, gorse, broom, foxglove, vetches, etc. [Ibid and Abs. Jour. Chem. Soc. (Lond.) II (1909) 429] have been found by experiment or experience of gardeners to grow better in acid soils. Lime or limestone is often recommended for roses, carnations, and chrysanthemums, yet, so far as the author is aware, there is no extensive experimental work proving that it is a benefit to these crops.

[1]In 1913-14 a small amount of manure was applied.

TABLE 15.—APPLICATIONS OF FERTILIZERS TO ROSES, 1913-14
(Pounds per 100 square feet of bench space[1])

Section	Manure	Ammonium sulfate	Acid phosphate	Potassium sulfate	Limestone[2]
1 – 1	115	15	0	2	10
1 – 2	115	15	10	2	10
1 – 3	115	15	20	2	10
1 – 4	115	15	40	2	10
1 – 5	115	15	80	2	10
1 – 6	115	15	160	2	10

[1]Pounds per 100 square feet of bench space multiplied by 2 gives approximate pounds per 100 cubic feet, and when divided by 5 gives the application in tons per acre.

[2]Applied to alternate series only, viz., –0–, –2–, –4–.

In addition to obtaining the data regarding the production of flowers and their quality, which were secured during 1913-14, it was observed that the end sections, to which no fertilizer except manure had been applied, grew plants up to the middle of the winter with no signs of nitrogen starvation, which can be so easily detected by the unhealthy growth and the yellow color of the foliage. The second application of ammonium sulfate (November 30, 1913) was soon followed by a prolonged period of cloudy weather. While no signs of injury were noticed on the well-developed foliage, the young growth, which came on about January 1, showed marked chlorosis (whitening) of the leaflets, and in many cases drooping and blackening at the ends of the young shoots. This is to be distinguished from the dropping of leaves as a result of a disturbance of the root system, which has been observed to follow too deep cultivation, but which affects the oldest leaves first, while injury from overfeeding reaches the tender, most rapidly growing portions of the plant. As a result of overfeeding with ammonium sulfate at this time, no accurate records were secured during the midseason of the year. Tests made upon the soil at the time of the second top-dressing of limestone (March 4, 1914) showed the soil to be quite acid at any depth greater than one-half inch below the surface. In the upper half-inch the soil seemed acid or neutral, depending on the evenness of the previous application of limestone. It was evident that top-dressings with limestone had not corrected acidity in that portion of the soil penetrated by the roots. The top-dressing with acid phosphate caused a wide-spread surface growth of roots, instead of a more desirable penetration of the entire soil by the root system.

In fertilizing the soil for the experiment of 1914-15, the ammonium sulfate was applied on July 8, 1914 and April 27, 1915, omitting the midwinter application; limestone was worked into the soil before setting in the plants, in addition to a top-dressing in the spring, while in Sections 2, 3, and 4 of each series, two-thirds of the acid phosphate was worked into the soil before setting in the plants. No potassium sulfate was used. The schedule of fertilizers is given in Table 16.

TABLE 16.—APPLICATIONS OF FERTILIZERS TO ROSES, 1914-15
(Pounds per 100 square feet of bench space)

Section	Manure	Ammonium sulfate	Acid phosphate[1]	Limestone[2]
1 – 1	115	10	0	20
1 – 2	115	10	10	20
1 – 3	115	10	20	20
1 – 4	115	10	40	20
1 – 5	115	10	80	20
1 – 6	115	10	160	20

[1]Applied July 8, December 21, and April 27 to Sections 1–5 and 1–6; on July 8 and April 27 to Sections 1–2, 1–3, and 1–4.
[2]Applied only to series –0–, –2–, –4–.

The growth of the roses was satisfactory thruout the year excepting that, judging from the color of the plants, the last application of ammonium sulfate should have been made about a week earlier.

Records for both years (1913-14, 1914-15) were taken daily, excepting Sunday, upon the number of flowers produced in each section and the stem length of each flower. They were also grouped into classes according to stem length, firsts being those with a stem length over 18 inches; seconds, 12 to 18 inches; thirds, 6 to 12 inches; and fourths, under 6 inches. The roses in Sections 1 and 6 of each set were allowed to remain on the plant until fully open, and the size of each was measured, in order to test the effect of acid phosphate on the length of the petals of the flowers.

ON THE ACCURACY OF THE RESULTS

Record was kept of the number and stem length of the flowers produced by each plant in Sections 123 and 134 (Richmond) and Sections 124 and 133 (Killarney) during the approximate periods from November 1 to June 1, 1913-14, and from October 1 to June 1, 1914-15. The results are given in Table 17. Plants 1 to 8 were own-root and Plants 9 to 16 grafted stock in each case.

The data in Table 17 were used for determining to what extent differences between the results from sections compared were due to the variation in production of individual plants and not to the influence of the treatment. It is necessary to assume that the variation among plants in the moderately fertilized sections is representative of that in other sections, that is, that neither low nor high fertilizing affected the variability in production among the plants. The maximum standard deviation obtained from any set of

TABLE 17.—INDIVIDUAL PRODUCTION BY ROSE PLANTS

Plant No.	Killarney				Plant No.	Richmond			
	Number of flowers					Number of flowers			
	Section 133		Section 124			Section 134		Section 123	
	1913-14	1914-15	1913-14	1914-15		1913-14	1914-15	1913-14	1914-15
1	32	43	26	45	1	29	32	8	32
2	19	37	19	14	2	17	15	14	23
3	19	27	17	35	3	11	25	17	22
4	16	47	24	39	4	22	17	13	25
5	22	44	29	42	5	15	26	23	31
6	20	27	24	37	6	13	22	15	15
7	15	25	14	29	7	23	15	18	27
8	23	60	19	28	8	16	32	10	27
Total (own-root)	166	310	172	269	Total (own-root)	146	184	118	202
9	38	35	29	39	9	40	30	21	49
10	18	42	25	33	10	24	37	25	26
11	36	32	18	45	11	19	34	20	34
12	31	40	34	28	12	41	34	27	30
13	34	30	46	51	13	30	43	29	40
14	20	38	30	41	14	42	38	30	29
15	27	32	18	27	15	26	25	19	26
16	19	39	24	47	16	26	46	34	29
Total (grafted)	223	288	224	311	Total (grafted)	248	287	205	263

NOTE.—These sections were chosen because they received moderate applications of acid phosphate.

32 plants is only 1.09 higher than the standard deviation found by grouping the four sets of 32 each, and the minimum from any set of 32 plants is 3.9 lower than the standard deviation from the combined group. It would thus seem reasonable that in using 10.68 for a standard deviation to predict a probable error for the entire experiment, the prediction would tend to be too large rather than too small. If resulting differences are found significant under a criterion which used values too large for the probable error, the differences would be all the more significant with a more accurate estimate. While the accuracy that might have been secured by an individual record of production for each plant is not to be had after these assumptions, the figure for probable error thus secured is an indication of the reliability of the results.

The frequency distribution for each variety of root stock is shown in Table 18, which contains also the arithmetical means and their probable errors, the standard deviations, and the coefficients of variability[1]. The frequency distribution for Killarney and Richmond roses is shown graphically in Fig. 26.

[1]Calculations are made according to methods described in Ill. Agr. Exp. Sta. Bul. 119 (1907), and Jour. Agr. Sci. vol. 3 (1910), p. 417.

TABLE 18.—FREQUENCY DISTRIBUTION OF ROSE PRODUCTION, 1913-1915

Richmond				Killarney				Total
No. of flowers	Number of plants			No. of flowers	Number of plants			
	Own-root	Grafted	Both		Own-root	Grafted	Both	
7–14	6	—	6	6–15	3	—	3	14
15–21	10	4	14	16–25	12	7	19	39
22–28	11	8	19	26–35	8	13	21	45
29–35	5	11	16	36–45	7	9	16	23
36–42	—	6	6	46–55	1	3	4	6
43–49	—	3	3	56–65	1	—	1	1
M	20.80	30.60	25.70		28.10	32.50	30.30	27.70
E	±.81	±.99	±.75		±1.39	±1.13	±.89	±.63
D	6.88	8.36	8.93		11.77	9.16	10.68	10.68
C	33.10	27.30	33.70		41.90	28.10	35.30	38.60
E′	±45.50	±55.30	±41.70		±77.70	±60.60	±50.00	±35.30

NOTE.—The following abbreviations are used: M (Mean); E (Probable Error); D (Standard Deviation); and C (Coefficient of Variability).

The production by any two treatments is nearly enough the same that a probable error (E′) for use in a comparison of them may be secured by multiplying the corresponding E of Table 18 by $\sqrt{2}$ and dividing by the square root of the number of plants from which data were secured for the comparison. Since, in the succeeding tables, the production of all plants in a single treatment (48) is used as a basis

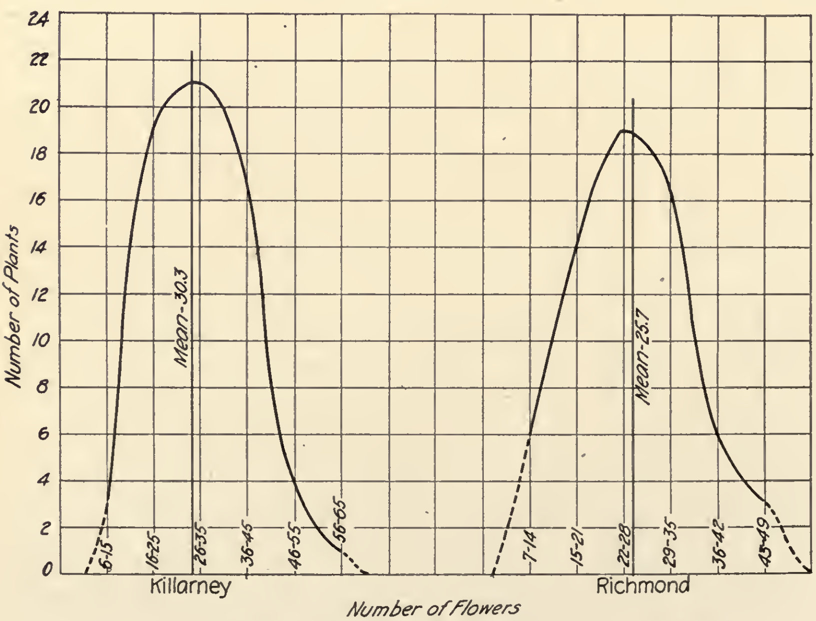

FIG. 26.—FREQUENCY DISTRIBUTION OF PRODUCTION, 1913-1915

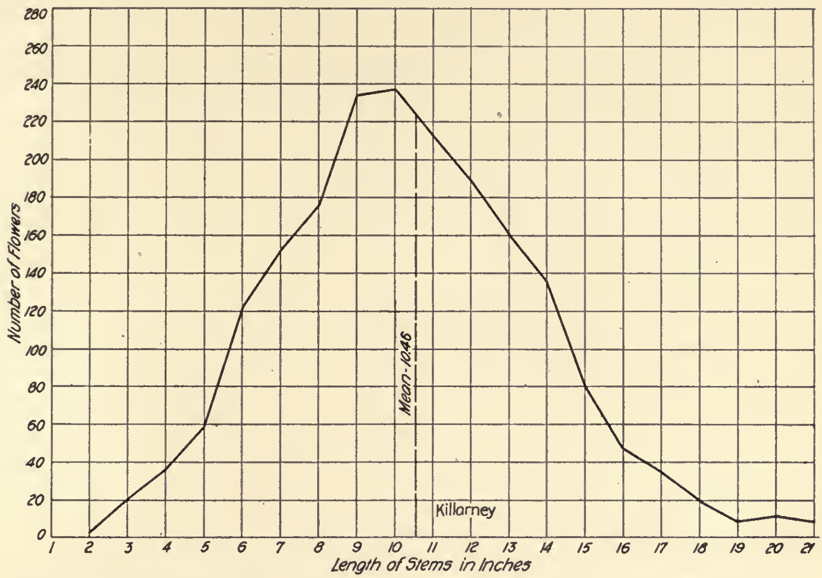

FIG. 27.—FREQUENCY DISTRIBUTION OF STEM LENGTH IN KILLARNEY ROSES

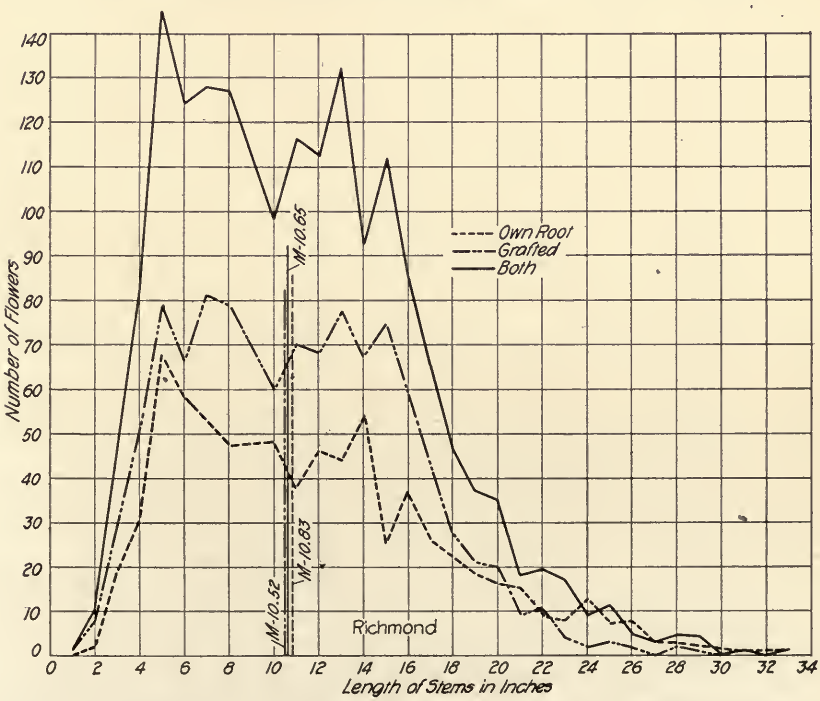

FIG. 28.—FREQUENCY DISTRIBUTION OF STEM LENGTH IN RICHMOND ROSES

for comparison, the value for E′ so secured is multiplied by 48 in order to obtain a probable error expressed in the same unit as the values to be compared. Thus, if the difference in production per 48 plants in two treatments of 48 plants each amounted to 45.5 flowers (own-root Richmond), the chances would be even that the difference resulted from the treatments given the series and not from variation in productivity of the plants chosen for the experiment. In the case of the combined data from both varieties and types of root stock, which were secured from 192 plants in each treatment, the probable error in comparison of average production per 48 plants amounts to 35.3 flowers.

The frequency distribution of stem length of the flowers produced (Figs. 27 and 28) is given in Table 19, which also presents the mean stem lengths with their probable errors, the standard deviations, and the coefficients of variability. E′ (season) and E′ (year) are calculated upon a basis of comparison between two sets of 400 flowers and 1,200 flowers respectively, these being the approximate productions for the season and the year.

The results calculated for probable errors indicate that in comparing two series of plants (48 plants each) which have received different applications of fertilizer, the difference in average stem length of flowers must equal from .117 to .258 inches, depending on the variety

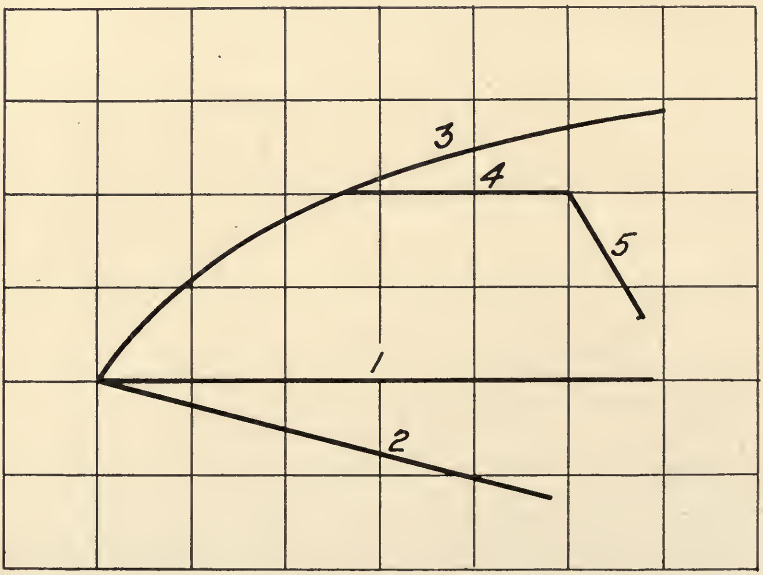

FIG. 29.—TYPES OF CURVES INDICATING THE EFFECT OF FERTILIZER APPLICATIONS UPON FLOWER PRODUCTION

TABLE 19.—FREQUENCY STEM-LENGTH DISTRIBUTION OF ROSES

Stem length (inches)	Number of flowers						
	Killarney			Richmond			Total
	Own-root	Grafted	Both	Own-root	Grafted	Both	
.6–1.5	...	...	...	0	1	1	1
1.6–2.5	1	3	4	2	8	10	14
2.6–3.5	7	13	20	19	29	48	68
3.6–4.5	14	23	37	30	51	81	118
4.6–5.5	26	32	58	67	78	145	203
5.6–6.5	60	63	123	58	66	124	247
6.6–7.5	71	80	151	47	81	128	279
7.6–8.5	79	95	174	48	79	127	301
8.6–9.5	95	135	230	38	60	98	328
9.6–10.5	107	130	237	46	70	116	353
10.6–11.5	86	126	212	44	68	112	324
11.6–12.5	94	95	189	54	78	132	321
12.6–13.5	66	94	160	25	67	92	252
13.6–14.5	69	66	135	37	75	112	247
14.6–15.5	44	37	81	26	59	85	166
15.6–16.5	28	17	45	22	43	65	110
16.6–17.5	21	15	36	18	28	46	82
17.6–18.5	13	9	22	16	21	37	59
18.6–19.5	5	4	9	15	20	35	44
19.6–20.5	8	2	10	9	9	18	28
20.6–21.5	6	2	8	8	11	19	27
21.6–22.5	3	2	5	13	4	17	22
22.6–23.5	1	1	2	7	2	9	11
23.6–24.5	0	0	0	8	3	11	11
24.6–25.5	1	1	2	3	2	5	7
25.6–26.5	0	0	0	3	0	3	3
26.6–27.5	1	0	1	2	2	4	5
27.6–28.5	...	...	...	0	1	1	1
28.6–29.5	...	...	...	1	0	1	1
29.6–30.5	...	...	...	0	0	0	0
30.6–31.5	...	...	...	1	0	1	1
Total	906	1045	1951	667	1016	1638	3634
M	10.7500	10.2100	10.4600	10.830	10.520	10.6500	10.5500
E	±.1130	±.0960	±.0740	±.199	±.140	±.1140	±.0660
D	3.6300	3.3300	3.4700	5.480	4.740	5.0100	4.2600
C	33.6000	32.8000	33.2000	50.600	45.100	47.0000	40.3000
E′ (Season)	±.1730	±.1590	±.1170	±.258	±.227	±.1690	±.1030
E′ (Year)	±.0998	±.0918	±.0676	±.151	±.131	±.0974	±.0586

or type compared (see Table 19) before the chances become equal that the difference is not due to the error inherent in a comparison of two averages secured from the measurement of a limited number of flowers. In comparing the average stem length of a year's production from two treatments or in the combined data from the different varieties and types of root stock, the probable error is decreased because of the larger number of flowers used in making the comparison.

It was thought likely that a simple relation could be secured between the relative production of the sections and their positions in the house, on account of unequal conditions of temperature and humidity at different places in the house. The study of these conditions proved more complex than a simple drop in temperature and rise in relative humidity toward the exposed end of the house, however, and no progressive rise or drop in production in the series could be obtained.

In interpreting the results from a series of sections upon which successively increasing amounts of acid phosphate had been applied, a curve of one of five types would be expected, as shown in Fig. 29. A curve of the first type would indicate that neither benefit nor injury resulted from application of the fertilizer; of the second, injury; of the third, continued benefit up to the maximum application according to Mitscherlich's Law of Diminishing Returns[1]; of the fourth, benefit up to a certain maximum application, with neither increased yield nor decrease from injury with greater amounts; of the fifth, increased yield up to a maximum, with a decrease thereafter due to injury from overapplication of the fertilizer.

EFFECT OF ACID PHOSPHATE ON WEEKLY AND YEARLY PRODUCTION

A record of the data secured from the experiment, arranged in seasons, and totaled for the year, is given in Table 20 for 1913-14, and in Table 21 for 1914-15. In Table 20 the records of the second season are not included, except in the totals, since the roses were injured during the greater part of the season by overfeeding with ammonium sulfate.

TABLE 20.—NUMBER OF FLOWERS PRODUCED, 1913-14
(Average per 48 plants)

Section	Acid phosphate (lbs. per 100 sq. ft.)	Own-root			Grafted		
		Season I	Season III	Year	Season I	Season III	Year
			Killarney				
1	0	358	493	1065	428	616	1308
2	10	390	619	1233	470	708	1460
3	20	369	620	1241	520	760	1599
4	40	382	650	1264	529	793	1594
5	80	405	645	1300	478	811	1584
6	160	385	612	1244	472	790	1549
			Richmond				
1	0	467	479	1085	571	697	1450
2	10	487	565	1175	583	814	1581
3	20	472	605	1219	624	845	1674
4	40	466	631	1239	603	867	1722
5	80	484	650	1284	555	819	1567
6	160	470	553	1181	535	798	1549

[1]Russell, Soil Conditions and Plant Growth (1912), page 24 (Longmans, Green, and Company, Monographs on Biochemistry).

TABLE 21.—NUMBER AND QUALITY OF FLOWERS PRODUCED, 1914-15

Section	Acid phosphate (lbs. per 100 sq. ft.)	Production of flowers[1] (per 48 plants) Total number	1st	2nd	3rd	4th	Average size of flowers[2]	Stem length Total	Stem length Average
				Own-root Killarney					
				Season I					
			percent	percent	percent	percent	inches	inches	inches
1	0	467	0.8	23.8	63.1	12.2	4.53	4476	9.58
2	10	497	0.8	30.3	60.1	8.8		5037	10.13
3	20	537	1.2	29.0	64.0	5.7		5595	10.41
4	40	512	1.5	28.4	63.6	6.4		5232	10.22
5	80	555	1.8	29.4	59.9	9.1		5729	10.32
6	160	495	1.0	23.5	62.1	13.5	4.51	4708	9.51
				Season II					
1	0	318	2.5	37.8	57.0	2.8	4.48	3637	11.43
2	10	370	4.0	41.9	52.7	1.3		4408	11.91
3	20	382	4.7	43.2	51.4	.7		4498	11.25
4	40	380	3.4	38.7	54.5	3.4		4346	11.43
5	80	391	4.1	39.0	53.8	2.1		4548	11.63
6	160	326	1.8	35.0	56.0	6.1	4.35	3579	10.97
				Season III					
1	0	547	2.2	30.8	62.1	4.7	4.23	5906	10.79
2	10	585	1.2	35.4	63.6	3.5		6211	10.61
3	20	678	2.6	36.1	58.7	3.3		7606	11.21
4	40	616	4.2	33.4	59.4	3.4		6875	11.16
5	80	644	3.5	37.9	56.9	2.1		7323	11.43
6	160	564	1.6	29.4	61.9	4.4	4.25	5994	10.62
				Year					
1	0	1332	1.8	30.0	61.2	6.9	4.39	14020	10.52
2	10	1452	1.8	35.0	60.5	4.8		15656	10.78
3	20	1598	2.7	35.4	57.8	3.5		17699	11.07
4	40	1508	3.1	33.1	59.0	4.4		16454	10.91
5	80	1590	3.0	36.4	56.5	4.5		17600	11.07
6	160	1385	1.4	28.6	64.5	8.8	4.37	14282	10.31
				Grafted Killarney					
				Season I					
1	0	600	0.3	25.0	65.1	9.3	4.47	5890	9.81
2	10	608	0.1	22.9	67.1	9.8		6012	9.88
3	20	604	0.9	24.4	64.5	10.2		5898	9.76
4	40	579	0.3	20.6	70.8	8.6		5544	9.58
5	80	598	0.1	18.4	70.0	11.7		5527	9.24
6	160	639	0.0	13.0	73.2	13.9	4.50	5533	8.66
				Season II					
1	0	378	1.0	32.9	63.5	2.7	4.38	4117	10.89
2	10	401	2.2	32.2	63.7	1.9		4452	11.10
3	20	448	2.7	39.0	55.4	2.9		5083	11.34
4	40	446	1.8	39.4	56.2	2.6		5040	11.30
5	80	455	.6	31.6	69.5	2.4		4971	10.95
6	160	383	.5	30.6	64.2	3.7	4.35	4063	10.61

[1]Flowers are grouped in classes as follows: 1st, length 18 inches and over; 2nd, 12 to 18 inches; 3rd, 6 to 12 inches; 4th, under 6 inches.

[2]Size was determined of flowers from Sections 1 and 6 only.

TABLE 21.—*Continued*

Section	Acid phosphate (lbs. per 100 sq. ft.)	Production of flowers (per 48 plants) Total number	1st	2nd	3rd	4th	Average size of flowers	Stem length Total	Average
Season III									
			percent	*percent*	*percent*	*percent*	*inches*	*inches*	*inches*
1	0	668	1.5	29.6	64.2	4.4	4.21	6977	10.44
2	10	744	1.6	28.8	65.8	3.6		7840	10.53
3	20	736	1.7	32.8	61.9	3.3		8045	10.93
4	40	732	1.3	36.6	58.1	3.8		8056	11.00
5	80	793	1.1	27.7	66.8	4.2		8332	10.50
6	160	784	.6	22.7	69.7	7.1	4.22	7849	10.01
Year									
1	0	1646	1.0	28.7	64.6	5.8	4.34	16985	10.32
2	10	1753	1.3	27.5	65.8	5.4		18304	10.44
3	20	1788	1.7	31.5	61.3	5.6		19027	10.64
4	40	1757	1.1	31.9	61.8	5.1		18640	10.61
5	80	1846	.7	25.7	62.4	6.2		18831	10.20
6	160	1806	.4	21.0	69.9	8.8	4.35	17445	9.66
Own-root Richmond									
Season I									
1	0	429	2.7	21.4	53.8	21.6	3.65	3951	9.21
2	10	431	7.6	21.5	50.9	19.9		4334	10.05
3	20	511	4.2	25.3	50.5	20.2		4983	9.75
4	40	501	6.3	22.2	49.5	22.0		4899	9.78
5	80	485	4.7	20.4	51.2	23.8		4532	9.34
6	160	518	5.2	24.7	50.5	19.8	3.65	4998	9.64
Season II									
1	0	225	10.2	38.2	41.7	9.7	3.60	2645	11.76
2	10	254	12.6	43.7	36.6	7.0		3176	12.50
3	20	279	9.2	43.0	41.7	5.7		3376	12.10
4	40	273	16.7	41.2	35.2	6.9		3525	12.91
5	80	236	13.5	41.2	35.5	10.1		2906	12.31
6	160	270	13.3	40.8	36.6	9.3	3.76	3352	12.41
Season III									
1	0	412	15.2	21.3	40.7	22.5	3.65	4633	11.24
2	10	419	12.8	32.6	40.5	13.8		4963	11.84
3	20	492	13.6	28.8	43.2	14.2		5808	11.80
4	40	443	15.3	29.3	41.5	13.7		5313	11.99
5	80	417	16.7	33.5	39.0	10.5		5215	12.50
6	160	462	10.3	30.9	44.5	14.0	3.83	5278	11.42
Year									
1	0	1066	9.4	24.8	46.1	19.1	3.64	11230	10.53
2	10	1104	10.8	30.9	43.7	14.7		12474	11.29
3	20	1282	9.7	30.4	45.8	14.8		14168	11.05
4	40	1217	12.0	29.1	43.5	15.6		13738	11.20
5	80	1138	11.0	29.5	43.4	16.1		12655	11.12
6	160	1250	8.9	30.5	45.3	15.4	3.83	13628	10.90
Grafted Richmond									
Season I									
1	0	490	7.7	30.6	47.8	14.3	3.71	5277	10.77
2	10	603	7.1	35.4	47.3	10.2		6758	11.20
3	20	630	7.4	28.0	51.2	13.5		6781	10.76
4	40	617	5.5	27.4	49.2	17.8		6257	10.12
5	80	603	5.8	27.2	51.5	15.5		6354	10.36
6	160	590	2.8	18.1	54.6	24.4	3.59	5272	8.93

NOTE.—See footnotes 1 and 2, page 551.

TABLE 21.—*Concluded*

Section	Acid phosphate (lbs. per 100 sq. ft.)	Production of flowers (per 48 plants) Total number	1st	2nd	3rd	4th	Average size of flowers	Stem length Total	Average
				Season II					
			percent	*percent*	*percent*	*percent*	*inches*	*inches*	*inches*
1	0	347	11.0	43.6	36.4	8.9	3.71	4326	12.46
2	10	375	10.4	46.5	37.8	5.3		4772	12.72
3	20	375	15.2	42.1	36.2	6.4		4828	12.87
4	40	402	8.7	48.2	35.0	7.9		4981	12.38
5	80	385	12.2	42.6	36.0	9.3		4740	12.31
6	160	360	6.1	36.3	44.1	13.3	3.71	3988	11.07
				Season III					
1	0	533	4.3	32.9	44.5	18.4	3.68	5451	10.22
2	10	615	8.5	36.3	42.0	12.8		7014	11.40
3	20	605	9.3	36.2	43.1	11.2		6935	11.46
4	40	656	8.1	36.1	41.5	13.2		7426	11.32
5	80	677	8.2	30.2	47.0	14.1		7486	11.06
6	160	638	4.6	28.2	46.0	21.9	3.76	6438	10.09
				Year					
1	0	1370	7.2	34.7	43.6	14.5	3.70	15055	10.98
2	10	1593	8.7	38.4	42.7	10.1		18545	11.64
3	20	1610	9.9	34.4	43.7	11.0		18546	11.51
4	40	1675	7.3	35.8	43.2	13.7		18665	11.74
5	80	1665	8.5	32.1	46.4	13.5		18581	11.16
6	160	1588	4.6	26.3	49.8	20.3	3.68	15699	9.88

NOTE.—See footnotes 1 and 2, page 551.

EFFECT OF ACID PHOSPHATE ON TOTAL YIELD OF FLOWERS

The data upon the effect of acid phosphate on the yield of flowers are arranged graphically in Figs. 30 and 31. The curves are consistent in showing an increased production as a result of the smallest application of acid phosphate, the tendency toward a rise being the least pronounced in the first season. With succeeding applications the results are more or less definite in showing a smaller proportional increase up to the largest application, when a decrease is shown, as a rule. Since the curves are of the same type for both own-root and grafted stock and for each variety, it is permissible to use the data for both years and all types of plants in describing a curve from which to draw conclusions applicable equally to own-root and grafted stock, and to Killarney and Richmond varieties. The data averaged thus are arranged in Table 22 (production per 48 plants) and the grand average is described in Fig. 31.

The excess in number of flowers produced in Section 3 over the yield from Section 1 (211 flowers per 48 plants) stands in the ratio of $\frac{211}{35.3}$ (=6) to the probable error obtained from the data given

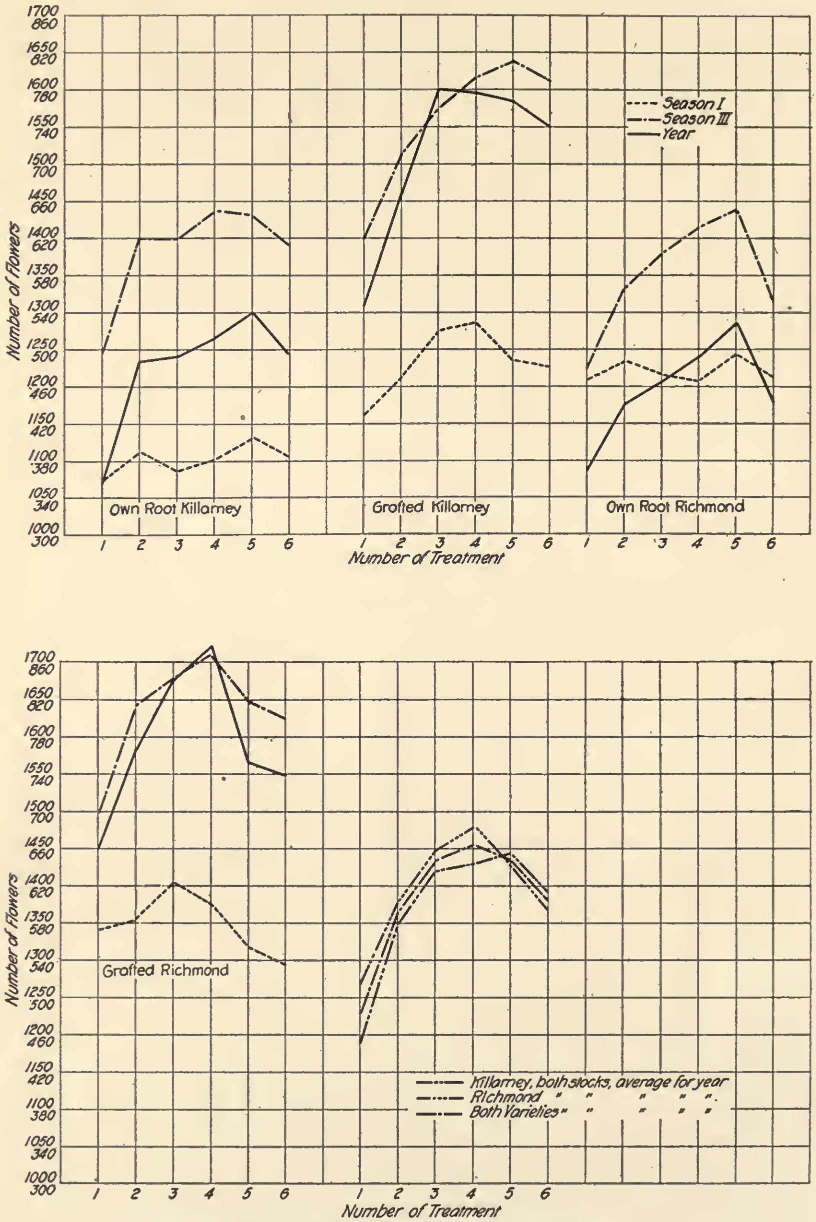

FIG. 30.—NUMBER OF ROSES PRODUCED, 1913-14

in Table 18. A difference in results six times the probable error corresponds to odds of 19,200 to 1[1] that it is due to the difference in treatment of the sections, hence, considerable reliance may be placed in the data after making allowance for the approximate value of the probable error.

TABLE 22.—AVERAGE YEARLY PRODUCTION OF FLOWERS, 1913-15

Section	Acid phosphate (lbs. per 100 sq. ft.)	Richmond			Killarney			Grand average
		1913-14	1914-15	Average	1913-14	1914-15	Average	
1	0	1267	1218	1242.5	1186	1489	1337.5	1290
2	10	1378	1348	1363.0	1346	1602	1474.0	1418
3	20	1446	1446	1446.0	1420	1693	1556.5	1501
4	40	1480	1446	1463.0	1429	1632	1530.5	1497
5	80	1425	1401	1413.0	1442	1718	1580.0	1496
6	160	1365	1419	1392.0	1396	1595	1495.5	1444

Two points are clear from the data. Applications of acid phosphate up to 20 pounds per 100 square feet of bench space (40 pounds per 100 cubic feet) cause an increase in the number of roses produced. Applications up to four times this amount cause neither further increase nor decrease in production, hence, there is a wide difference between the minimum quantity of acid phosphate that should be applied to produce the maximum crop, and that quantity which will cause injury from overfeeding. This is especially important since with most commercial fertilizers great care must be taken not to ruin the crop by excessive applications.

The significance of these results is perhaps not apparent at first glance. Calculated on the basis of 1,000 plants, an excess in production of 4,400 flowers is obtained by the use of 250 pounds of acid phosphate. This fertilizer costs at the present time about fifteen dollars per ton, while a conservative price for roses of the quality obtained (averaging about an 11-inch stem) is four dollars per hundred. The cost of fertilizer and of the labor to mix it with the soil are insignificant compared with the additional profit of $176 per 1,000 plants obtained by its use.

EFFECT OF ACID PHOSPHATE ON STEM LENGTH AND SIZE

The results of fertilization with acid phosphate upon total stem length are similar to those upon the number of flowers produced (see Table 21), that is, an increase with all applications excepting the heaviest, which caused a slight decrease. The relative increase and decrease of the two characters are not quite the same, however, as seen

[1]Ill. Agr. Exp. Sta. Bul. 119, p. 15.

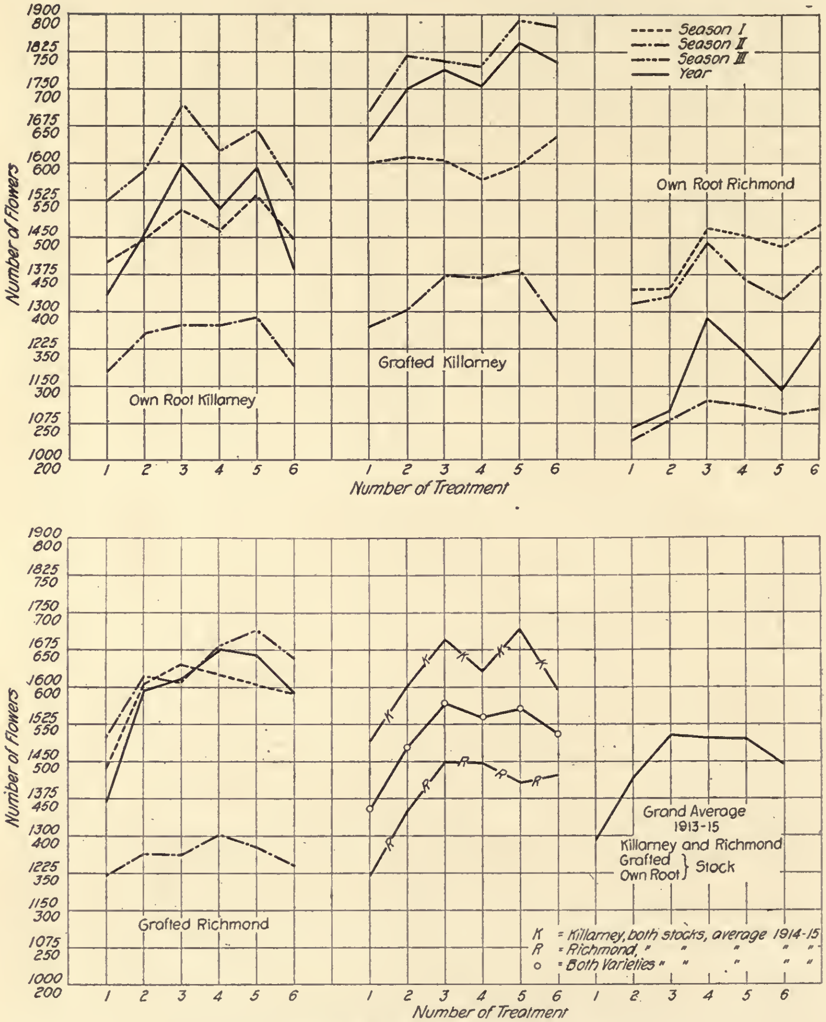

FIG. 31.—NUMBER OF ROSES PRODUCED, 1914-15

in the figures for average length of stem[1]. These bring out the fact that the average as well as total length of stem increases when acid phosphate is used as a fertilizer, unless in excessive amounts, so that quality as well as production is benefited.

No influence of fertilizing is seen upon the percentage of flowers in Classes 1, 2, 3, and 4, grouped according to the length of stem. While the average stem length may be increased slightly upon increas-

[1]The differences, while small, are well beyond the experimental error calculated in Table 19 and so are considered significant.

ing the production by the use of acid phosphate, no marked increase in the number of long-stemmed flowers is to be expected. Attention may be called, at this point, to the larger percentage of long-stemmed flowers in the Richmond variety than in Killarneys, particularly of own-root stock. It is worthy of mention that own-root stock, while producing fewer flowers, does yield as long-stemmed and as long-petaled roses as grafted stock.

No consistent relation is to be found between the difference in average size of the flowers from Sections 1 (no acid phosphate) and 6 (large amount of acid phosphate) and the difference in their fertilization. Since no figure for probable error has been obtained, it is impossible to attribute the existing differences to the treatment rather than difficulties of measurement and inaccuracy from insufficient number of flowers for comparison. It can only be said that no difference in size of roses great enough to be apparent in these records is obtained by fertilizing with acid phosphate.

RELATION OF INCREASE FROM THE USE OF ACID PHOSPHATE TO WEEKLY PRODUCTION

The relation of the increase in production obtained by the use of acid phosphate is shown in Figs. 32 to 35, in which the weekly production of flowers upon Section 1-1, to which no acid phosphate was applied, and upon that section of each variety and type of root stock giving the greatest return (Section 1-3, 1-4, or 1-5), was used in describing the graphs. The application of acid phosphate upon the sections chosen for comparison with Section 1-1 varied from 20 to 80 pounds per 100 square feet of bench space in different cases. In the figures, numbers of flowers are used as ordinates and weeks of the seasons as abscissæ. A curve representing the combined data of all types of plants used is shown in Fig. 36. It is unnecessary to comment in detail on these curves, since a glance at them shows that the advantage from the use of acid phosphate, while greatest in the spring as the soil is depleted of its original supply of phosphate, is evident thruout the year. Such evidence supports that found in the previous experiment (page 528) based on results from the use of smaller quantities of acid phosphate.

EFFECT OF LIMESTONE ON PRODUCTION OF FLOWERS

A comparison of the number of flowers produced from sections to which lime had been applied and those unlimed for the year 1914-15, is given in Table 23. During 1913-14, the limestone, applied as top-dressings, did not penetrate far enough beneath the surface to affect the condition of the soil materially, hence, no comparison is made for the production of that year.

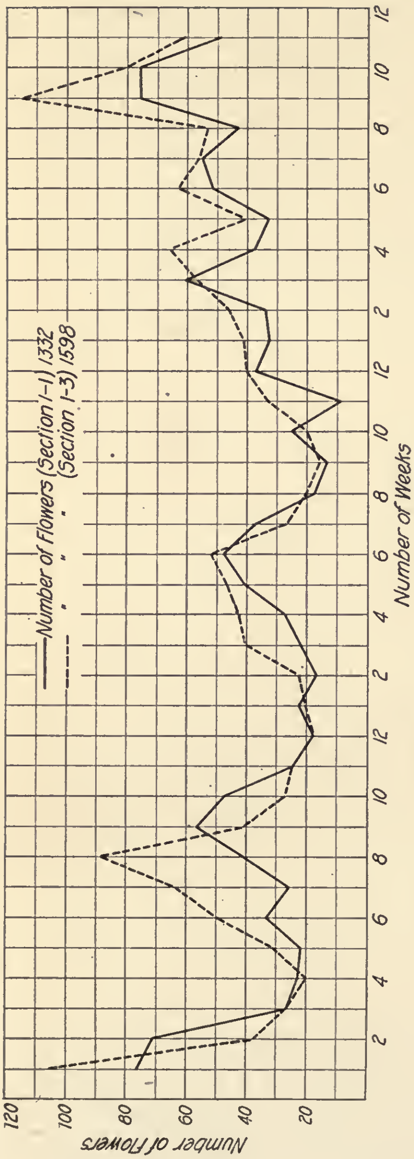

FIG. 32.—WEEKLY PRODUCTION, OWN-ROOT KILLARNEY, 1914-15

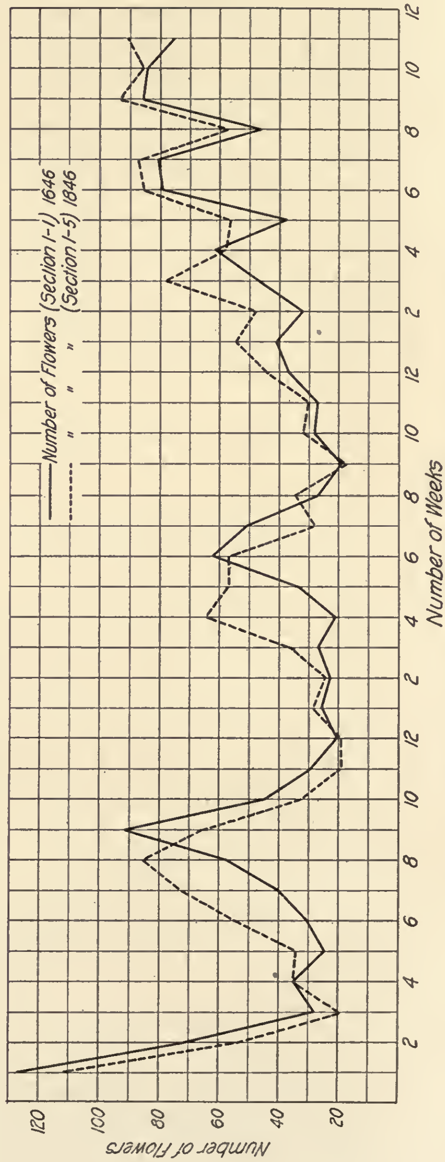

FIG. 33.—WEEKLY PRODUCTION, GRAFTED KILLARNEY, 1914-15

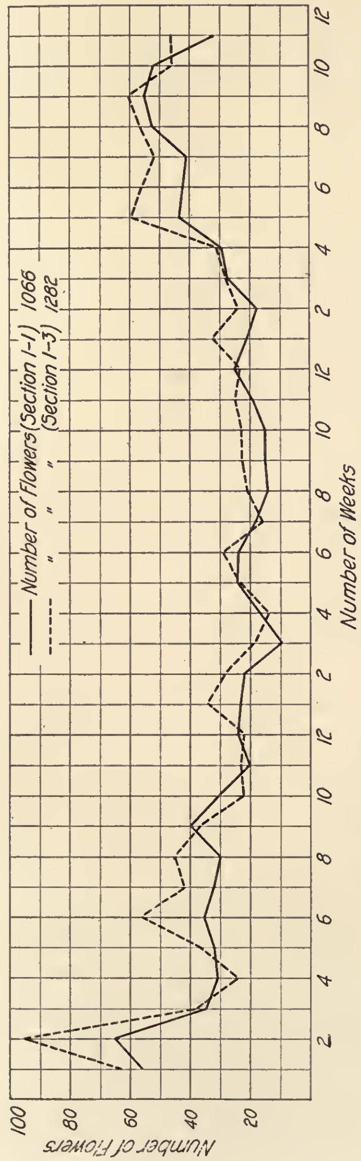

FIG. 34.—WEEKLY PRODUCTION, OWN-ROOT RICHMOND, 1914-15

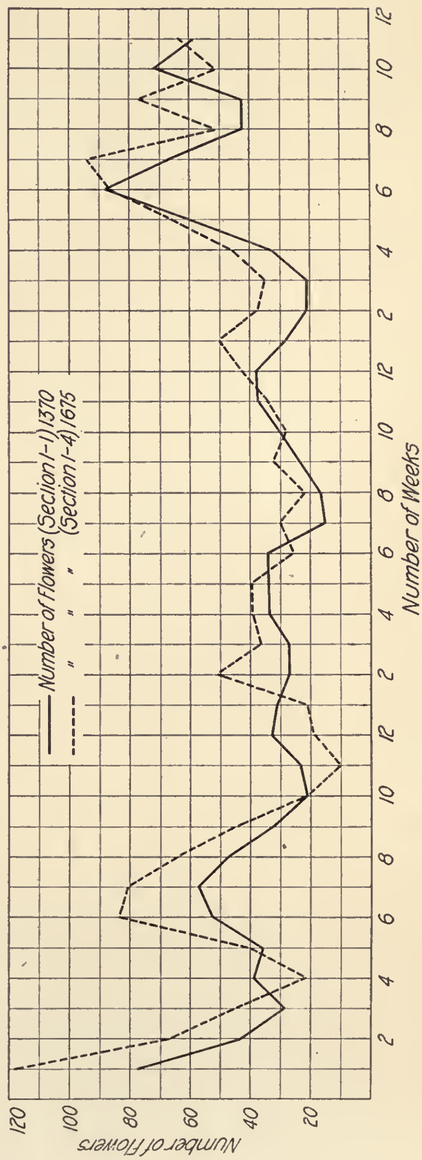

FIG. 35.—WEEKLY PRODUCTION, GRAFTED RICHMOND, 1914-15

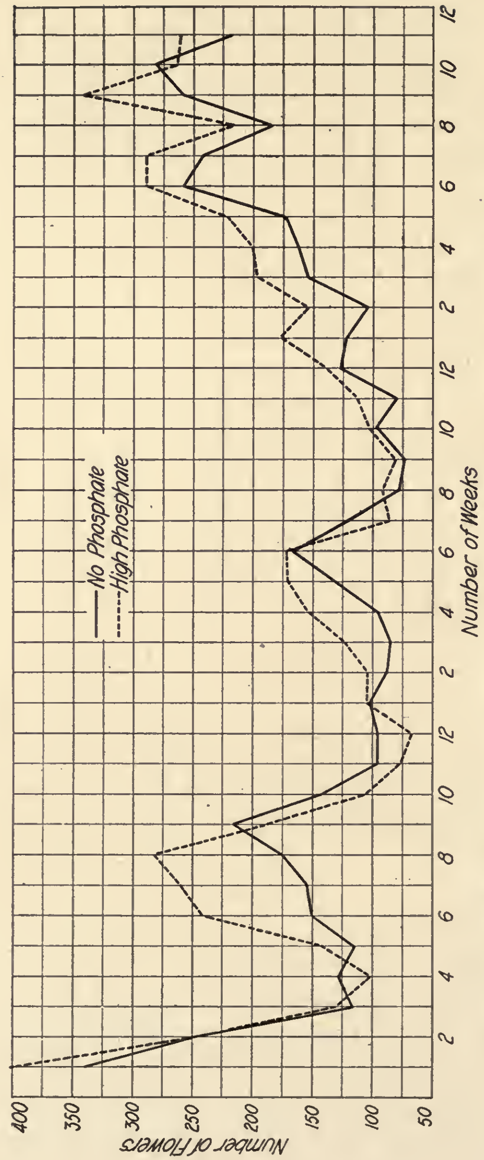

FIG. 36.—WEEKLY PRODUCTION, OWN-ROOT AND GRAFTED KILLARNEY AND RICHMOND, 1914-15

TABLE 23.—EFFECT OF LIMESTONE ON PRODUCTION OF ROSES, 1914-15
(Total number of flowers)

Lime				No Lime			
Killarney		Richmond		Killarney		Richmond	
Own-root	Grafted	Own-root	Grafted	Own-root	Grafted	Own-root	Grafted
4324	5293	3465	4532	4541	5303	3592	4969
9617		7997		9844		8561	
17614				18405			

It is evident from the data that those sections receiving no limestone produced more flowers. The results by section (representing a treatment with acid phosphate) for all types are given in Table 24 and arranged graphically in Fig. 37.

In comparison of yields per 96 plants, it would be necessary to have a difference exceeding 70 flowers (see page 548) in order to draw accurate conclusions. This difference is found with the first three

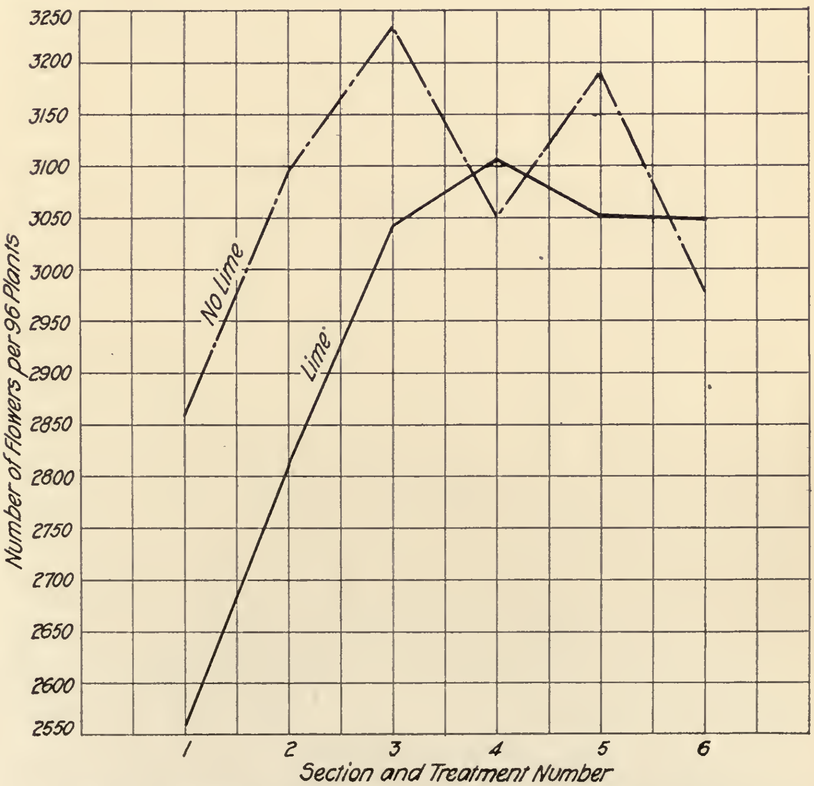

FIG. 37.—EFFECT OF LIMESTONE ON FLOWER PRODUCTION, 1914-15

TABLE 24.—EFFECT OF LIMESTONE ON PRODUCTION OF ROSES, 1914-15

Section	Acid phosphate (Pounds per 100 square feet)	Yield per 96 plants		
		Lime	No lime	Difference due to lime
1	0	2557	2857	−300
2	10	2809	3093	−284
3	20	3043	3235	−192
4	40	3106	3051	+ 55
5	80	3050	3189	−139
6	160	3049	2980	+ 69

treatments of the series. Beyond this, the results are not conclusive. The data are accurate, however, in showing a loss from the use of limestone with acid phosphate, up to the amounts which previous considerations have shown to be the maximum quantity it is advisable to apply.

CONCLUSIONS AND RECOMMENDATIONS

The soil used in the experiments described in the preceding pages was a brown silt loam. A description of the various soil types of Illinois, with their total content of the important fertilizing elements, is given in Bulletin 123 of this station, with the location of these types. Three facts are especially significant: The nitrogen content of the different soils suitable for rose growing varies from 1,870 to 8,900 pounds per acre (7 inches deep) and plans must be made by those florists who use soils of a type poorer in nitrogen than the brown silt loam to increase the content of nitrogen by use of green or barnyard manures in the field, by heavier applications of manure when mixing the soil for use in the greenhouse, and by more frequent applications of manure or commercial nitrogenous fertilizer than have been used in this experimental work. The phosphorus content not only of brown silt loam but of all the types of soil is low compared to that of the other elements, and the results from the experimental work here described are applicable to all. Peaty and sandy soils are low in potassium content and are benefited by applications of this kind of fertilizer. It is probable, however, that the necessity for having a compact soil for successful rose growing would prevent the use of such soils for that purpose.

KINDS OF FERTILIZER NEEDED

Applications of phosphatic fertilizer give the most pronounced increase in the production of roses. Nitrogenous fertilizer also is needed, but applications of potassium sulfate not only give no increase but decrease the yield.

(1) *Nitrogenous Fertilizer.*—The need for nitrogenous fertilizer is particularly urgent after the turn of the year and makes itself

apparent by the lightening of the color of the foliage that is associated by every rose grower with lack of plant food. This characteristic is a better guide to the time for applying nitrogenous fertilizer than any rule. The florist will largely do away with danger of nitrogen starvation by enriching the soil before filling the benches by the use of green manures or farmyard manure up to twenty tons per acre in the field, or by mixing manure with the soil as it is put in the benches. If the need for nitrogen is apparent, it may be supplied by liquid manuring, by mulching with rotted manure, or by applications of dried blood at the rate of 5 pounds per 100 square feet of bench space not oftener than six weeks apart. The nitrogen contained in such an application is equal to that in 130 pounds of average manure. Ammonium sulfate and sodium nitrate, while satisfactory sources of nitrogen, require too great care to prevent overfeeding to allow recommendation of them for general use. Applications of nitrogenous fertilizer should be lightest during periods of little sunshine and when the plants are off crop.

(2) *Phosphatic Fertilizer.*—Plants do not show marked signs of the need for phosphorus, and records of production alone can determine its need. Applications of acid phosphate up to 20 pounds per 100 square feet of bench space (40 pounds per 100 cubic feet of soil) have been found to give marked increases in production. The quantity of phosphorus contained in this application is equal to that contained in an application of 2,800 pounds of manure of average composition (50 percent moisture) to 100 square feet of bench space, or twice this amount mixed with 100 cubic feet of soil. Since manifestly it is impossible to use such a mixture, the need for phosphorus in the form of a commercial fertilizer is evident. Acid phosphate has proved to be a satisfactory source of phosphorus, but no comparison has been made in these experiments between acid phosphate and bone meal, basic slag, and other phosphate-containing fertilizers. Since the benefit from the use of acid phosphate is continuous thruout the year, it should be mixed with the soil before the benches are filled. Top-dressings with it are not so satisfactory, since surface root growth is stimulated in this way, resulting in the roots having contact with the soil particles in only an upper layer of the soil in the bench. There is no danger of overfeeding with acid phosphate, for four times the quantity here recommended has been applied without injury. In this respect acid phosphate possesses an advantage over bone, which cannot be mixed with soil or applied as top-dressings in excessive amounts without injuring the plants, as is true to a greater extent with high phosphate tankage, and blood and bone.

THE USE OF LIME

With such a need for phosphorus by rose plants, the use of lime or limestone in intimate contact with acid phosphate is to be discouraged, since the solubility of the phosphate would be decreased by its use. The production from plants in soil with which limestone has been mixed is lower than from those on untreated soil, whether or not acid phosphate has also been used, hence, mixing lime or limestone with the soil, tho quite a common practice among growers, cannot be recommended. In case an application of lime is needed to prevent the growth of algæ and moulds on the soil surface, finely ground limestone applied as a top-dressing at the rate of 10 pounds per 100 square feet of bench space and very lightly cultivated into the surface will accomplish this without being carried down into the soil further than an inch below the surface during the year.

Benefits of Fertilizing

The benefit from fertilizing is to be found in number of flowers produced and to a slight extent in the average stem length, tho not in percentage of long-stemmed flowers. No measureable change in length of petal follows fertilization with acid phosphate.

Kind of Stock to Plant

The experiments recorded in this bulletin with the varieties Killarney, Bride, and Richmond demonstrate the advisability of planting grafted stock, this conclusion being drawn from a record of production of grafted and own-root plants of first-year stock.

Recommendations

(1) Keep up the nitrogen content of the soil by turning under green or farm manure before use. If roses show signs of nitrogen starvation—a lightening of the color of the foliage—make up the need with applications of liquid manure, mulches of manure, or top-dressings of dried blood, the last in applications not exceeding 5 pounds per 100 square feet of bench space and applied not oftener than six weeks apart. Feed only during sunshiny weather and most generously during periods of heavy production.

(2) Use generous quantities of acid phosphate in the soil. It may be added (a) at the rate of 4 to 8 tons per acre in the field, (b) in a compost with soil at the rate of 40 to 80 pounds per 100 cubic feet of soil, or (c) by mixing it with the soil at the same rate just previous to filling the benches.

(3) Do not mix lime or limestone with the soil. If needed for sweetening the soil and for preventing the growth of algæ, make a top-dressing of finely ground limestone at the rate of 10 pounds per 100 square feet of bench space.