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THE EFFECTS OF PHOSPHORUS AND SULFUR FERTILIZERS ON FLOWER PRODUCTION OF ROSES AND CARNATIONS

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SUMMARY

Acid phosphate used with manure in greenhouse soil at the rate of 40 pounds to 100 square feet of bench increased the yields of Hoosier Beauty, Ophelia, Killarney, and White Killarney roses approximately 6 to 10 percent in a three-year test. The average increase was about 250 flowers from 100 plants. The fertilizer cost was about 65 cents.

In a one-year test on a smaller scale with Premier roses, the yield with acid phosphate (25 pounds to 100 square feet of bench) was 25 percent greater than from the control plot.

Steamed bone was not so effective in increasing flower production as was acid phosphate. This was true when equal money values of the two materials were applied (21.4 pounds of steamed bone to 40 pounds of acid phosphate), as well as when the two materials were applied at such rates as to carry approximately equivalent amounts of available phosphorus (31.5 pounds of steamed bone to 25 pounds of acid phosphate.)

The residual effects of steamed bone meal were more marked than those of acid phosphate. However, under ordinary conditions of fertilizer practice in the greenhouse the difference would be of slight practical importance.

Acid phosphate owes its effectiveness in a soil for roses to the phosphorus and not to the sulfur it carries. This is shown by the fact that the average yields of Premier roses for two years were about 12 percent higher with acid phosphate than with steamed bone meal and gypsum. Furthermore the yields with steamed bone meal and gypsum averaged about 5 percent higher than with gypsum alone.

In the first experiment with carnations acid phosphate used at the rate of 40 pounds to 100 square feet of bench with Champion and White Enchantress resulted in crop increases of about 6 percent, or one flower to a plant. In later experiments with Laddie carnations apparent increases as high as 7 percent were recorded for acid phosphate; the average difference noted over three seasons was about 3 percent. With steamed bone for the same period the average was no greater than from the control plants. This was also true of gypsum. Because of the relatively small numbers of plants used in the later series of experiments, it is impossible to say just what signficance these results have. A test with different varieties of carnations as to their responses to fertilizer treatment was unsatisfactory for the same reason.

No consistent relation was noted between fertilizer treatment and the occurrence of split calyces.

THE EFFECTS OF PHOSPHORUS AND SULFUR FERTILIZERS ON FLOWER PRODUCTION OF ROSES AND CARNATIONS

By F. F. WEINARD AND P. A. LEHENBAUER[a]

A loam soil from blue-grass sod, containing in mixture about one-fourth rotted cattle manure, is generally considered very suitable for filling greenhouse benches. The natural manure is particularly effective in improving the physical conditions of soil. Under present conditions, however, many growers have little choice as to soil, and manure of good quality is increasingly difficult to obtain.

In most cases the necessity of supplementing natural manures with commercial fertilizer is no longer a matter of question.

In the experiments described in this bulletin several commercial phosphate and sulfur fertilizers were used in the growing of roses and carnations. The results indicate that certain of these materials, particularly acid phosphate, may be used very effectively as a supplement for cattle manure.

Most cultivated soils contain a relatively small percentage of phosphorus. Field experiments have shown that the available phosphorus in such soils is seldom sufficient to meet the ordinary requirements of the growing crop. Sulfur occurs in soils in even smaller amounts, as a rule, than phosphorus, altho appreciable amounts of sulfur are added to field soils annually in rainfall. The amounts of the two elements taken up by plants are essentially similar. Field experiments have shown that sulfur also may in some cases be a factor limiting growth.

Natural manures are primarily nitrogenous, and contain a relatively small proportion of available phosphorus but considerable sulfur. Thus greenhouse soils are likely to be deficient in phosphorus even tho manures are mixed in.

Bone products have been generally used by florists as a supplementary source of phosphorus, but the supply is limited, and acid phosphate, of which there is a plentiful supply, is coming into wider use.

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[a]The first experiments described were begun by Dr. F. W. Muncie, formerly Associate in Floricultural Chemistry. From September, 1917, until September, 1922, the work was under the direction of Dr. P. A. Lehenbauer, formerly Assistant Chief in Plant Physiology. The later work was directed by Dr. Weinard, Assistant Chief in Plant Physiology.

Acid phosphate is made by treating ground rock phosphate with acid, thereby changing the phosphate into a more soluble form and insuring a more effective distribution in the soil. Commercial acid phosphate contains in addition to calcium phosphate an approximately equal amount of calcium sulfate (gypsum). Thus it is efficient as a carrier of either phosphorus or sulfur, depending on the needs of the soil.

While a great deal of information has been collected on the effects of phosphorus and sulfur fertilizers with field crops, it is impossible for the florist to apply this information directly to his problems, for conditions under glass differ widely from field conditions. Under glass it is possible to use to advantage a soil exceedingly rich in organic matter and mineral salts. Moreover, the values of the crop increases obtained by the use of fertilizer are such that cost places practically no limit on the amount that can be economically used.

Tests were therefore arranged in which a number of phosphate and sulfur-bearing materials, including acid phosphate, steamed bone meal, precipitated phosphate, gypsum, and sulfur, were used to supplement manure in greenhouse soils.

WORK OF OTHER INVESTIGATORS

Lumsden[1] increased the vigor of carnation plants with bone meal. Dorner, Muncie, and Nehrling[2] showed increases of 5 to 13 percent in flower production of carnations following the use of acid phosphate in comparatively large amounts. The time of cropping and the total yields for the season were not affected by varying the time of application of fertilizers, that is, weekly applications as compared with the same amounts applied at four intervals approximately eight weeks apart. No definite relation was established between fertilizer treatment and splitting of calyces, altho a tendency toward splitting was noted when the plants were underfed. Muncie,[3] working with roses, obtained beneficial effects with acid phosphate in amounts up to 20 pounds per 100 square feet of bench space, while four times this amount was used without injury to the plants. The increases in flower production averaged about 16 percent. No increases were noted with potassium sulfate under like conditions. Mixing ground limestone with the soil resulted in decreased production, regardless of whether acid phosphate was also used.

White[4] grew roses on soils treated with raw bone meal, and with a mixture of rock and acid phosphates, in comparison with untreated soil. During two years of the experiment the increases over the control plot were somewhat greater where acid phosphate was used. During the third season, when mineral phosphate was used on all plots, no great differences were to be seen.

Pember and Adams[5] concluded that the addition of acid phosphate at the rate of about 5 pounds per 100 square feet of bench would give good returns with carnations under most conditions, altho the material was used without injury in amounts up to 30 pounds per 100 square feet. Whether the total amounts were added to the soil at the beginning of the season, or at biweekly intervals thruout the season, did not seem to influence the results. A noticeable reduction in the percentage of split calyces occurred in those sections receiving nitrogen in comparatively large amounts.

Comprehensive reviews on sulfur in relation to soil fertility have been given by Olson and St. John[6] and by Crocker.[7] Further data from field experiments have been given by Powers.[8] In certain localities, notably on the basaltic soils of Oregon, sulfur fertilizers have given marked results with various field crops. Soils well supplied with organic matter are less likely to show the need of sulfur. Thus in Pennsylvania, Ohio, and Illinois, as pointed out by Stewart,[9, 10] little or no benefit has been derived from sulfur in various forms.

EXPERIMENTS WITH ROSES

Flower Production Stimulated by Acid Phosphate

Because of the very favorable results obtained in preliminary experiments[3] with relatively large amounts of acid phosphate, a new series of tests with roses was arranged on a larger scale. These and subsequent tests fully confirmed the results of the earlier work.

The four benches in the rose house, each 100 feet long, were divided into sections each four by five feet. The sections were separated by partitions consisting of two cross boards set about one inch apart to prevent leaching of soil and possible root growth from one section into the next.

The benches were filled with soil, and fertilizers were added July 13, 1916. One hundred pounds of well-rotted manure, containing about 50 percent moisture, and 3 pounds of dried blood were used to 100 square feet of bench. Acid phosphate containing about 16 percent available phosphoric acid was applied to all even-numbered sections at the rate of 40 pounds per 100 square feet. The odd-numbered sections received no acid phosphate.

The rose plants were set into the benches on July 14 and on September 28 all sections received a top dressing of pulverized limestone at the rate of 100 pounds per 100 square feet. On March 1 and May 1 following, all sections received an application of dried blood at the rate of 3 pounds per 100 square feet.

Manure, Dried Blood, and Acid Phosphate Added.—During the summer months of 1917 the plants were "dried off" by partially withholding water and then pruning back, following the usual practice of florists. After the plants had been pruned, the upper layer of soil was removed, leaving approximately three-fourths of the original soil. Fresh soil that had received rotted manure previously was then added to replace the soil taken out. After the required amount of new soil had been added to each section, dried blood was applied at the rate of 4 pounds to each 100 square feet. At the same time 2 pounds of acid phosphate was put on each section and, together with the dried blood, was worked into the surface of the soil by means of hand trowels.

A manure mulch was put on the soil of each section at the rate of 40 pounds a section on October 24. During the growing period of this season, as well as the next, the plants were fed with liquid manure[a] instead of dried blood, as had been done the season previous.

During the season of 1917-18 liquid manure was applied from January 28 to May 18, at intervals of approximately ten days. The amount applied averaged 4.5 gallons per section for each application. Of course the composition of liquid manure is variable.

Analyses at this laboratory[b] indicated that liquid manure made according to the process described contains on an average about .03 percent nitrogen, .027 percent phosphoric acid, and .008 percent potash. Thus the amount of phosphorus added in liquid manure would hardly be sufficient to influence the phosphorus requirements of the plants.

During the summer of 1918 the roses were again given a short period of rest by partially withholding water and were pruned back on July 10. Again about one-fourth of the soil was removed from the surface of each section and replaced with fresh soil which had been mixed with well-rotted manure in the proportion of 3 parts soil to 1 part manure. The new soil was put in the benches on July 13. Fertilizers were then applied to the surface of the soil of each section as follows: 5 pounds dried blood and 10 pounds acid phosphate to 100 square feet. No lime was applied during this season. On November 15 a manure mulch was applied at the rate of 2 bushels per section. During the growing season from October 28 to May 2 liquid manure was again applied at intervals of about 12 days at an average rate of 5 gallons to each section.

The varieties used were Hoosier Beauty, Ophelia, Killarney, and White Killarney. All the stock was one-year grafted. Hoosier Beauty

[a]The liquid manure was prepared as follows: 3 bushels of fresh cow manure, with sufficient water to cover well, were placed in a 325-gallon tank. The mixture was stirred and allowed to stand until fermentation took place, as was indicated by the rise of the manure to the surface of the liquid. This required from three to five days. Water was then added until the tank was filled, which caused the solid manure to sink to the bottom. The liquid was then drawn off into another tank. The process was repeated with the original manure and the second lot of liquid drawn off into the second tank. The liquid from the two treatments of the manure then was applied, by means of pipe connections and hose, to the soil. Equal amounts were applied, as nearly as possible, to each section.

[b]Englis, D. T. A study of liquid fertilizers. Thesis, University of Illinois, 1916.

and Ophelia occupied the two north benches and Killarney and White Killarney the two south benches. In the first season two varieties were planted to a bench in longitudinal rows. This arrangement proved unsatisfactory with the first two varieties named on account of their different moisture requirements. The plants were later reset in rows across the bench, so that the varieties occupied separate blocks in each plot.

In the first season 41 Ophelia plants showed crown-gall infection on the shoots. Galls were in evidence on this variety to some extent for the remainder of the experiment, but none of the plants were noticeably injured. The galled plants were distributed approximately equally on the treated and untreated plots, and when it was apparent that no appreciable error would result, the yields were included in the results from the fertilizer experiment. The other varieties were not affected.

Records of flower production by individual plants were kept during the three years from the beginning of September until the end of May. The flowers were cut so as to leave at least two good leaves above the previous break. Flowers with stems less than 4 inches in length were not counted.

Increases with Acid Phosphate.—Flower production was increased consistently each season, in each variety, where acid phosphate was used (Tables 1 and 4). Detailed analysis of the data[a] shows that the differences were due to the soil treatment and not to chance. Great variation in flower production by different plants was observed. With Ophelia plants in 1917-18, for example, the range was from 4 to 45 flowers to a plant. With Killarney in the same year the range was from 18 to 62 flowers a plant. These differences are due in part perhaps to actual differences in flowering capacity and in part also to location on the bench.

The average yearly crop increases in three varieties for the three-year period of the experiment were: Ophelia, 2.7 flowers a plant (9.8 percent); Killarney, 2.2 flowers a plant (6.0 percent); and White Killarney, 2.6 flowers a plant (7.9 percent). As has been previously pointed out, Hoosier Beauty was grown under unfavorable conditions in 1916-17, which no doubt accounts for the lack of response to the phosphate treatment in this season. During the two subsequent seasons definite increases averaging 1.9 flowers a plant (13.0 percent) were obtained in this variety with acid phosphate. In the test with Premier roses the increased yield with acid phosphate amounted to 4.7 flowers a plant (25 percent). The comparative rates of flower production of three varieties of roses, with and without acid phosphate, are shown graphically in Fig. 1.

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[a]Appendix, page 101.

The average length of flower stems where acid phosphate was used was equal to or greater than the average stem length from sections where no acid phosphate was applied. The benefit from acid phosphate was shown also in the grading of the flowers (Table 4). Closer analysis[a] showed further that plants which produced the most flowers did not give any undue proportion of short stems.

TABLE 1.—EFFECT OF ACID PHOSPHATE ON FLOWER PRODUCTION OF ROSES

Variety	Season	Treatment	Number of plants	Flowers per plant[1]	Increases	Average stem length
					perct.	*inches*
Hoosier Beauty..	1916-17	No phosphate...	144	18.10 ± .28		13.04
		Acid phosphate..	144	18.20 ± .33	0	13.08
	1917-18	No phosphate...	144	15.00 ± .25		13.32
		Acid phosphate..	144	17.01 ± .31	13.3	13.90
	1918-19	No phosphate...	144	13.94 ± .25		13.79
		Acid phosphate..	144	15.71 ± .33	12.7	13.95
Ophelia..........	1916-17	No phosphate...	144	32.12 ± .42		12.84
		Acid phosphate..	143	35.21 ± .47	9.6	13.07
	1917-18	No phosphate...	144	25.01 ± .36		13.44
		Acid phosphate..	143	27.68 ± .40	10.7	14.17
	1918-19	No phosphate...	144	25.57 ± .38		13.92
		Acid phosphate..	143	27.86 ± .41	9.0	14.17
Killarney........	1916-17	No phosphate...	144	36.56 ± .69		8.84
		Acid phosphate..	144	39.20 ± .60	7.2	9.08
	1917-18	No phosphate...	144	36.44 ± .44		9.67
		Acid phosphate..	144	39.08 ± .53	7.2	10.44
	1918-19	No phosphate...	144	35.53 ± .48		9.61
		Acid phosphate..	144	36.82 ± .60	3.6	10.17
White Killarney..	1916-17	No phosphate...	144	33.80 ± .41		...
		Acid phosphate..	144	35.90 ± .48	6.2	...
	1917-18	No phosphate...	144	32.89 ± .36		9.20
		Acid phosphate..	144	36.40 ± .49	10.7	9.92
	1918-19	No phosphate...	144	34.56 ± .43		9.48
		Acid phosphate..	144	36.87 ± .55	6.7	10.11

[1]The "probable errors" which are placed after the averages of flower production are of interest to those familiar with statistical methods. They indicate the reliability of the averages and are useful in determining the importance to be attached to differences in the results from different treatments.

It is clear that acid phosphate is very effective in soil used for growing greenhouse roses. Where acid phosphate was used as a supplement to manure, crop increases of 6 percent and higher were obtained consistently with several varieties of roses. The beneficial effects of the acid phosphate were not confined to any one season, but were evident during the entire period in which the plants were grown.

In these experiments the average increase in flower production with four varieties of roses was over 9 percent, or more than 250 flowers from 100 plants, as a result of using acid phosphate. Stem lengths averaged as long or longer than in the case of flowers from untreated soil.

The net profits from the crop increases were comparatively high, for with acid phosphate at $25 a ton the cost of the fertilizer for 100 plants was about 65 cents.

[a]Appendix, page 102.

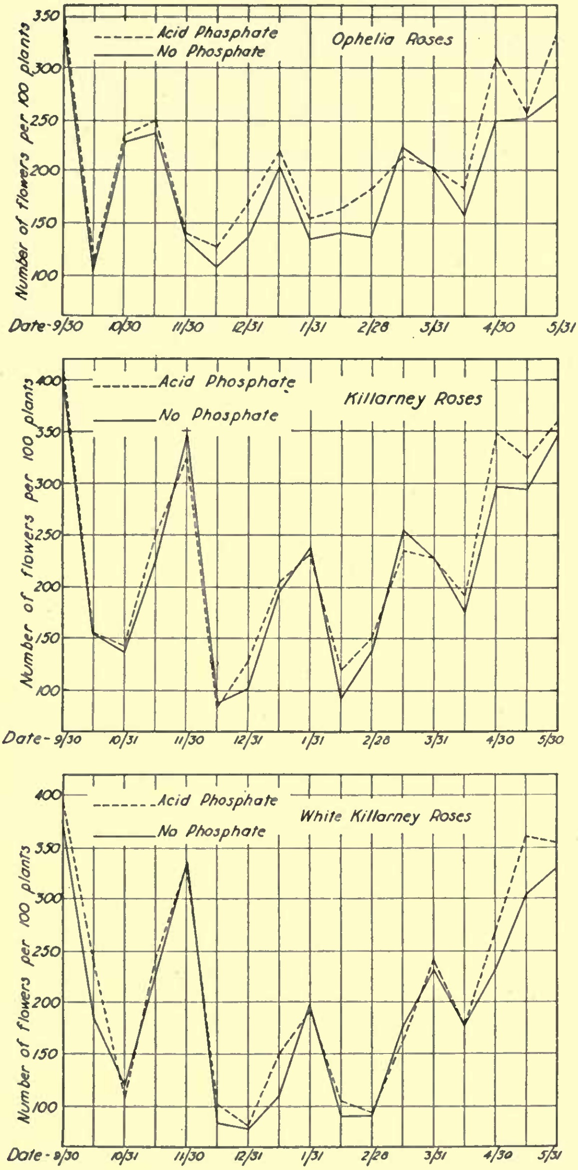

FIG. 1.—ACID PHOSPHATE INCREASED YIELDS OF ROSES

Flower production of all three varieties of roses was uniformly higher with acid phosphate. The differences were most marked during the winter months in each case. The relative increases in fall, winter, and spring were quite consistent in the three varieties, averaging 4 percent, 12 percent, and 8 percent respectively. The proportion of the crop obtained in each case during the months of December to February inclusive was little affected by the fertilizer treatment. About 27 percent of the season's cut from Ophelia, 23 percent from Killarney, and 20 percent from White Killarney was obtained during the winter. (Experiment 1916-1917)

Comparison of Phosphatic Fertilizers

Since steamed bone is classed with acid phosphate as a fertilizer supplying phosphorus, a comparative study was made of these two fertilizers in their effects on flower production. Steamed bone meal costs more per ton than acid phosphate, but as it contains nitrogen and about half again as much phosphorus, there is little difference in cost per pound of "plant food" in the two materials. The general opinion is, however, that the phosphorus as contained in acid phosphate is the more readily available to plants.

There are reasons why it is not wise to be content with applying the results of experiments with field crops to general greenhouse practice. Conditions of temperature and moisture in the greenhouse are more favorable to bacterial growth, and the accompanying decomposition of organic matter is so much more rapid that the tri-calcium phosphate of bone meal might possibly be made available as quickly as needed. The use of bone meal by florists has been so general and its favor so universal that nothing short of actual demonstration with the crop concerned would suffice to change floricultural practice.

Acid Phosphate and Steamed Bone Meal 1916-1917.—Soil was prepared by adding a liberal quantity of manure. After the benches were filled, the acid phosphate or steamed bone was added and worked into the soil. Acid phosphate was used at the rate of 40 pounds per 100 square feet of bench space 5 inches deep. The weight of the bone meal used was calculated from relative cost prices of the two fertilizers so as to obtain the same money value. For this purpose $15 a ton for acid phosphate and $28 a ton for steamed bone were chosen as representing fairly the stable pre-war prices. Thus bone meal was used at the rate of 21.4 pounds for each 100 square feet of bench space. Dried blood was applied uniformly over all sections whenever the appearance of the plants indicated a need of nitrogen.

One-year-old plants of Killarney and Richmond roses were grown in this experiment. They were dried off and rested from June 1 until July 14, then removed from the bench, their roots shaken clean of soil, and reset in the new soil containing the manure, dried blood, and the whole of the quantities of acid phosphate or bone meal required by the experiment. The Richmond occupied 18 five-foot sections of the two north benches and the Killarney 18 sections of the two south benches in the house, with 16 plants in each section.

An individual record was kept of each of the 576 plants, so that it is possible to know how many flowers each plant produced, the date of production, and the quality of the flowers as measured by length of stem (Table 2 and Fig. 2.) Records were taken each working day from September 15 to June 1. Flowers were cut so as to leave at least two good leaves above the previous break.

TABLE 2.—YIELDS OF ROSES WITH ACID PHOSPHATE AND STEAMED BONE, 1916-1917

Variety	Treatment	Flowers per plant	Increase	Average stem length
			perct.	*inches*
Killarney........	Acid phosphate.........	45.20 ± .60	29.5	10.53
	Steamed bone...........	34.90 ± .58		9.92
Richmond.......	Acid phosphate.........	35.45 ± .56	25.3	9.76
	Steamed bone..........	28.30 ± .39		9.63

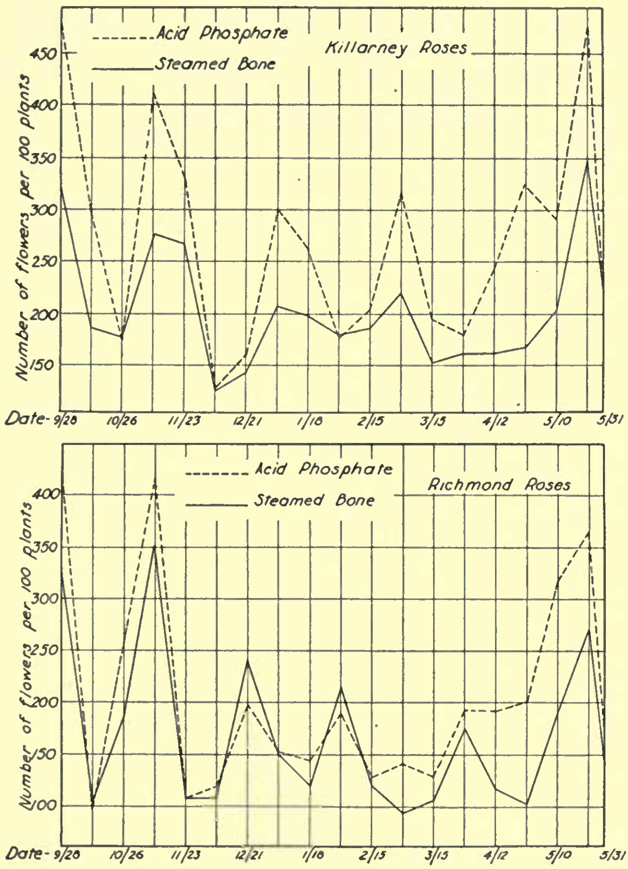

FIG. 2.—ACID PHOSPHATE MORE EFFECTIVE THAN STEAMED BONE

With both varieties of roses, the greatest differences in yields were noted during the fall and spring months, amounting to approximately 40 percent and 30 percent with Killarney and Richmond respectively. The differences during the winter months were about half the above figures. With acid phosphate, about 28 percent of the crop in each case was cut during the months of December to January inclusive; with steamed bone, about 32 percent of the entire crop was cut in the same period. (Experiment 1916-17)

Acid Phosphate, Steamed Bone Meal, and Precipitated Phosphate[a] *1921-1924.*—The differences in flower production obtained with acid phosphate and bone meal in the first test were so marked that the experiment was repeated. Precipitated phosphate, a finely divided material high in available phosphorus, was used also in this series of tests.

The plots were located on the second bench from the south in an east-and-west house. The bench was divided by cross partitions into 12 plots which were numbered consecutively from west to east. Each plot, with the exception of No. 6, was slightly over 8 feet long and contained 28 plants. Plot 6 was 9 feet long and contained 32 plants.

The soil used was a comparatively fertile brown silt loam. Rotted cow manure was thoroly worked into the soil in the field, approximately 1 part of manure being used to 4 parts of soil by volume. The first season the commercial fertilizers were worked into the soil on the bench before setting the plants. At the beginning of each subsequent season about an inch of the top soil was removed and new soil and fertilizers were added before the plants were started into growth.

Own-root rose plants of the variety Premier propagated the previous winter were benched in July, 1921, and allowed to remain undisturbed for three years. Each season beginning about the middle of June water was withheld sufficiently to stop growth without causing the leaves to fall. In the latter part of July the plants were pruned and started into growth. During the growing season the temperatures maintained were 58° F. at night and 68° F. by day. On bright days the temperature was allowed to rise to 73-78° F. Since there was sometimes a difference of several degrees in temperature between the two ends of the house, the fertilizer treatments were duplicated at both ends of the bench.

In an effort to keep conditions as uniform as possible on all plots pinching of shoots was avoided and all flowers were allowed to develop. This practice likewise insured a more accurate determination of the natural tendency toward long or short growth of stems under various treatments. Stems were cut at the second vigorous leaf above the previous break, except in the case of bottom shoots, which were cut considerably higher.

The seasons of record on roses were as follows: 1921-22, September 12 to May 29; 1922-23, September 18 to April 30; 1923-24, September 26 to May 10. With the exception of Sundays and holidays, flowers were cut and stem lengths measured daily. Data from the outside row at either end of the bench were not used in computing results.

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[a]Precipitated phosphates are now used chiefly in the manufacture of proprietary animal feeds.

Each season all rose plots received an initial application of nitrogen in the form of dried blood, at the rate of 5 pounds for each 100 square feet of bench surface. This was supplemented by a manure mulch in the fall and by feeding with liquid manure at biweekly intervals in the spring.

The kinds and amounts of the other fertilizers applied each season are given in Table 3. In 1921-22 the amount of acid phosphate used was near the optimum as shown by previous experiments. The precipitated phosphate used contained a similar amount of available phosphorus. The total phosphorus in the steamed bone, while almost

TABLE 3.—KINDS AND AMOUNTS OF PHOSPHORUS AND SULFUR FERTILIZERS USED WITH PREMIER ROSES, 1921-1924

Plot	Fertilizer (pounds per 100 square feet of bench)			
		1921-22	1922-23	1923-24
1	Steamed bone	31.5	9	31.5
2	Precipitated phosphate	15	8	15
3	Acid phosphate	25	14	25
4	Precipitated phosphate	15	8	15
	Gypsum	0	7	11
5	Steamed bone	31.5	9	31.5
	Gypsum	0	7	11
6	Gypsum	0	7	11
7	Acid phosphate	25	14	25
8	Steamed bone	31.5	0	0
9	Precipitated phosphate	15	0	0
10	Acid phosphate	25	0	0
11	Precipitated phosphate	15	8	15
12	Steamed bone	31.5	9	31.5

double that in the other materials, was present presumably in a less available form. In 1922-23 these amounts were varied and approximately equal amounts of phosphorus were applied in acid phosphate and in steamed bone. In 1923-24 the phosphatic fertilizers were used as in 1921-22.

Acid Phosphate More Effective Than Steamed Bone Meal.—Acid phosphate gave better results than did steamed bone meal or precipitated phosphate (Tables 2 and 4). In the one-season test flower production with acid phosphate exceeded that with steamed bone by 10.3 flowers a plant (29.5 percent) in the case of Killarney, and by 7.2 flowers a plant (25.3 percent) with Richmond roses.

From this it is clear that steamed bone meal proved less economical as a phosphorus fertilizer for roses than acid phosphate. When the two materials were applied at rates determined by equal money value, about 27 percent or over 850 more flowers were obtained from 100 plants where the acid phosphate was used.

In the later test, yields the first season were higher with both acid phosphate and precipitated phosphate, the increase being practically 2 flowers (9 percent) in each case. In the second season there

TABLE 4.—EFFECT OF PHOSPHORUS FERTILIZERS ON THE PRODUCTIVENESS OF ROSES, PREMIER, 1921-1924

Fertilizer	Season	Number of plants	Flowers per plant	Average stem length	Percentages in each grade				
					Under 6 inches	6 to 12 inches	12 to 18 inches	18 to 24 inches	24 inches and over
				inches					
No phosphate...	1921-22	32	18.49 ± .51	10.61 ± .10	4.7	59.7	30.7	4.7	.2
Acid phosphate....	1921-22	84	23.18 ± .31	11.14 ± .05	3.5	54.9	38.0	3.5	.1
	1922-23	56	23.46 ± .56	11.66 ± .06	3.0	43.2	51.0	2.4	.4
	1923-24	56	24.61 ± .53	11.28 ± .06	1.7	53.0	41.0	4.1	.2
Steamed bone...	1921-22	104	21.21 ± .28	11.06 ± .01	3.6	55.2	37.5	3.6	.1
	1922-23	48	23.44 ± .60	11.82 ± .06	3.2	39.1	54.9	2.5	.3
	1923-24	48	21.44 ± .44	10.81 ± .05	1.4	65.3	32.0	1.2	.1
Precipitated phosphate....	1921-22	112	23.06 ± .32	11.40 ± .04	2.4	52.1	41.4	3.9	.2
	1922-23	56	22.75 ± .67	11.62 ± .06	2.8	43.6	51.5	2.0	.1
	1923-24	56	21.41 ± .48	11.26 ± .06	1.8	54.2	41.5	2.2	.3

TABLE 5.—RESIDUAL EFFECTS OF PHOSPHORUS FERTILIZERS ON THE PRODUCTIVENESS OF ROSES, PREMIER, 1921-1924

Fertilizer	Season	Number of plants	Flowers per plant	Average stem length	Percentages in each grade				
					Under 6 inches	6 to 12 inches	12 to 18 inches	18 to 24 inches	24 inches and over
				inches					
Acid phosphate.... (1921 only)	1921-22	28	22.54 ± .52	11.28 ± .09	2.7	53.0	41.1	3.2	...
	1922-23	28	21.54 ± .87	11.09 ± .08	5.6	48.5	44.6	1.3	...
	1923-24	28	20.68 ± .50	10.82 ± .09	1.7	56.2	39.6	2.3	.2
Steamed bone... (1921 only)	1921-22	28	21.25 ± .49	10.97 ± .09	4.3	54.7	36.3	4.7	...
	1922-23	28	20.96 ± .62	11.60 ± .09	3.4	45.2	49.5	1.9	...
	1923-24	28	21.21 ± .47	11.32 ± .08	1.4	54.8	41.1	2.7	...
Precipitated phosphate.... (1921 only)	1921-22	28	24.21 ± .63	11.48 ± .08	2.5	49.5	44.0	3.9	.1
	1922-23	28	21.43 ± .76	11.50 ± .08	4.5	41.8	52.7	1.0	...
	1923-24	28	19.64 ± .55	10.62 ± .08	.7	69.9	26.9	2.5	...

were no significant differences between the yields on the several phosphate plots. In the third season production with acid phosphate exceeded that with either of the other substances by 3.2 flowers a plant (15 percent).

The stem lengths with acid phosphate and precipitated phosphate were slightly longer on the average than with steamed bone. This difference in stem lengths was also evident in the grading of the flowers (Table 4).

The 16 percent of phosphoric acid in acid phosphate is considered relatively available for use by plants, while perhaps half of the 27 percent of phosphoric acid in steamed bone meal is available over a growing season. With this fact in mind twice as much phosphoric acid in the form of steamed bone meal was used with Premier roses as was applied in the form of acid phosphate. With acid phosphate at $25 a ton and steamed bone meal at $40, the costs of the fertilizer for 100 plants were about 40 cents for the acid phosphate and twice as much for the steamed bone. Yet about 9 percent more flowers were obtained with the acid phosphate in the first season, an increase of about 190 flowers from 100 plants.

In the second season, when smaller amounts of fertilizers were used, there were no differences between yields. Comparatively large amounts of acid phosphate seem to be necessary to produce heavy cropping of roses, and on the other hand, the residual effects of the steamed bone may have been partly responsible for this result.

In the third season, with fertilizer applications similar to those of the first season, an even greater difference in yields was obtained than in the first season. With acid phosphate the crop of flowers was about 15 percent larger. This meant an increase of about 300 flowers from 100 plants.

Acid Phosphate Most Effective When Applied Annually.—A second application of phosphate fertilizers in 1922-23 gave no increase in yield, with the possible exception of acid phosphate, in comparison with plants which received phosphate the first season only (Table 5). In the third season, however, the increase in flower production by the plants receiving annual applications of acid phosphate amounted to 3.9 flowers a plant (19 percent). In the case of steamed bone and precipated phosphate there were no differences in yield on the different plots. Presumably this was a result of the residual effects from a single application of these materials.

With acid phosphate there was evidently a distinct advantage in annual applications of the fertilizer. With steamed bone or precipitated phosphate, however, a single application in the three-year period proved about as effective as repeated treatments. Stem lengths were practically uniform with each fertilizer.

TABLE 6.—COMPARATIVE EFFECTS OF PHOSPHORUS AND SULFUR FERTILIZERS ON THE PRODUCTIVENESS OF PREMIER ROSES

Fertilizer	Season	Number of plants	Flowers per plant	Average stem length	Percentages in each grade				
					Under 6 inches	6 to 12 inches	12 to 18 inches	18 to 24 inches	24 inches and over
				inches					
Acid phosphate...	1922-24	56	47.77±1.09	11.46±.04	2.3	48.2	45.9	3.3	.3
Steamed bone....	1922-24	48	44.88± .90	11.33±.04	2.3	51.7	43.9	1.9	.2
Precipitated phosphate...	1922-24	56	44.18±1.01	11.45±.04	2.4	48.7	46.6	2.1	.2
Gypsum........	1922-23	32	19.69± .56	11.58±.08	3.8	42.1	52.7	1.2	.2
	1923-24	32	20.69± .59	10.89±.08	3.5	61.6	31.7	3.2	...
Steamed bone and gypsum	1922-23	28	21.18± .61	11.51±.08	2.3	45.4	51.6	.7	...
	1923-24	28	21.22± .59	11.02±.08	2.5	62.2	32.8	2.5	...
Precip. phos. and gypsum	1922-23	28	23.39± .76	11.65±.08	3.5	40.2	54.6	1.5	.2
	1923-24	28	21.50± .62	10.55±.08	2.6	67.4	29.4	.6	...

Altho the residual effects of acid phosphate proved to be less marked than in the case of steamed bone, the value of the crop increases from annual applications of acid phosphate was such as to repay the cost many times over.

More frequent applications of acid phosphate than once each season were not tried. Surface applications of acid phosphate, however, encourage the growth of roots near the surface, where they are subject to drying, and the practice is therefore not recommended. On the other hand, any attempt to turn the material into the soil during the growing season would result in the destruction of active roots.

Gypsum Not Effective for Increasing Flower Production

Gypsum was used on certain plots of Premier roses in 1922-24, in amounts approximately equivalent to the gypsum applied on other plots in acid phosphate (Tables 3 and 6).

The average number of flowers cut in 1922-23 where acid phosphate or steamed bone was used was 3.8 flowers (19 percent) more than with gypsum. The average with precipitated phosphate was higher by 3.1 flowers (16 percent) than with gypsum. Neither steamed bone and gypsum, nor precipitated phosphate and gypsum, gave better results than steamed bone or precipitated phosphate alone. Again in the following season more flowers were obtained with acid phosphate than with gypsum, the difference amounting to 3.9 flowers a plant (19 percent). Stem lengths were uniform thruout.

The fact that no benefit was obtained from the use of gypsum in the rose soil under the conditions of the experiment indicates that the beneficial effects of acid phosphate were due to the phosphoric-acid content rather than to the sulfate added to the soil at the same time. Large amounts of cattle manure, usually one part by volume to three or four of soil, are used in the preparation of the soil for growing greenhouse roses. Natural manures are also used for mulches. Thus the supply of sulfur in the original loam, supplemented by heavy applications of organic matter, was evidently sufficient for maximum growth of roses. As it is everywhere the custom to use natural manures freely in the preparation of such soils, this result is likely to be generally applicable as far as greenhouse rose soils are concerned.

EXPERIMENTS WITH CARNATIONS

Profitable Increases Secured From Use of Acid Phosphate in 1916-1917

Tests with carnations were arranged on a fairly large scale in order to check the results obtained with acid phosphate in earlier work.[2] In 1916-17, with a comparatively large number of plants, profitable increases in yields of carnations were again obtained where acid phosphate was used. In later experiments with fewer plants of each variety the results were not conclusive.

For this experiment with carnations 720 plants of the variety Champion were set in the two south benches of the greenhouse, and 720 plants of the variety White Enchantress were set in the two north benches. Each bench was divided into 18 five-foot sections and each section contained 20 plants. At the two ends of each of the four benches sections were reserved as checks, and no records were taken of the plants growing in this soil. The sections were separated by two cross boards set about one inch apart.

TABLE 7.—INFLUENCE OF ACID PHOSPHATE ON FLOWER PRODUCTION OF CARNATIONS, 1916-1917

Variety	Treatment	Number of plants	Flowers per plant	Average flower diameter	Average stem length
				inches	*inches*
Champion.......	No phosphate......	354	20.62 ± .16	2.86	17.33
	Acid phosphate.....	350	21.66 ± .17	2.84	17.53
White Enchantress......	No phosphate......	345	19.27 ± .13	3.58	17.72
	Acid phosphate.....	356	20.65 ± .14	3.56	17.84

Brown silt loam soil 5 inches deep was used in the benches. Rotted stable manure was added to the soil of all sections at the rate of 100 pounds per 100 square feet of bench space, and dried blood at the rate of 3 pounds per 100 square feet before the plants were set in the bench. Later in the year manure mulches and applications of dried blood at the same rate were made in uniform amounts for all sections as often as was necessary. Acid phosphate was applied to all even-numbered sections at the rate of 40 pounds per 100 square feet. This was applied after the manure and dried blood had been thoroly incorporated in the soil. No acid phosphate was added to the soil in the odd-numbered sections.

The plants were fairly uniform and apparently free from disease when set into the soil on August 4. During the growing period in the greenhouse, however, a number of plants were lost as the result of stem rot, so that there remained at the end of the season a total of 704 plants of the variety Champion and 701 of White Enchantress. The flowers were picked each working day from September 15 to June 1. Records were made of the number of flowers from each plant, flower diameter, quality of flower, and stem length.

An increase in the number of flowers was obtained, under the conditions of the experiment, by supplementing manure with acid phosphate (Table 7, Fig. 3). The differences in yield amounted to 1.0 flower a plant (5 percent) with Champion and 1.4 flowers a plant

(7.2 percent) with White Enchantress. There were no differences in quality of the flowers as measured by diameter and stem length.

FIG. 3.—EFFECT OF ACID PHOSPHATE ON CARNATION YIELDS

The differences in favor of acid phosphate were about 5 percent and 7 percent with Champion and White Enchantress respectively. About 35 percent of the crop of Champion was picked during December to February inclusive, and about 40 percent of the crop of White Enchantress was picked in the same period.

As White Enchantress is very susceptible to splitting, a record was kept of the number of split calyces in the different treatments. The number of flowers with split calyces from plants in the sections treated with acid phosphate was 12.3 percent, and the number from the sections not receiving acid phosphate was 11.2 percent of the total cut from the respective treatments. This is too small a difference to be considered significant.

Later Experiments with Phosphorus Not Conclusive

Fertilizer work with carnations was resumed in 1921. For three seasons soil plots were arranged which contained phosphates and sulfur fertilizers in varying amounts. No definite conclusions in favor of any of the treatments could be drawn from these tests.

The experiments were conducted on two benches adjacent to the south bench in an east-and-west house. Sixteen 6-foot plots, each

TABLE 8.—KINDS AND AMOUNTS OF PHOSPHORUS AND SULFUR FERTILIZERS USED WITH CARNATIONS, 1921-1924

Plot	Fertilizer	Pounds per 100 square feet of bench
	1921-22	
1	Steamed bone	23.5
2	Acid phosphate	12.5
3	Ammonium sulfate	12
4	Control	...
5	Gypsum	18.5
6	Potassium sulfate	16.5
7	Acid phosphate	18.5
8	Steamed bone	23.5
9	Precipitated phosphate	23.5
10	Gypsum	18.5
11	Potassium sulfate	16.5
12	Acid phosphate	25
13	Sulfur	25
14	Ammonium sulfate	12
15	Precipitated phosphate	11.5
16	Gypsum	23
	1922-23	
1	Steamed bone	5
2	Acid phosphate	10
3	Gypsum	10
4	Control	...
5	Gypsum	20
6[a]	Precipitated phosphate	4
9	Precipitated phosphate	4
10	Gypsum	10
11	Steamed bone	5
12	Acid phosphate	10
13	Gypsum	18
14	Control	...
	1923-24	
1	Control	0
2	Steamed bone	21
3	Precipitated phosphate	10
4	Acid phosphate	17
5	Gypsum	8
6	Sulfur	2
7[a]	Acid phosphate	34
10	Acid phosphate	34
11	Sulfur	2
12	Gypsum	8
13	Acid phosphate	17
14	Precipitated phosphate	10
15	Steamed bone	21
16	Control	...

[a]In 1922-23 Plots 7, 8, 15, and 16 and in 1923-24 Plots 8 and 9 were not used in this experiment.

containing 24 plants, were set off by cross partitions. The plots were numbered consecutively, beginning at the east end of the south bench. The initial steps in preparing the soil were similar to those with roses. Fresh soil was used each season, the commercial fertilizers being incorporated just before setting the plants.

Laddie carnations were transplanted from the field about the first week in August. During the growing season temperatures were maintained as follows: night, 52° F., day, 58° F., except on bright days, when the temperature rose to 63-68°. The seasons of record were as follows: 1921-1922, September 28 to March 16; 1922-23, October 3 to March 26; 1923-24, September 26 to April 16. Thruout the experiments note was made of split calyces in order to determine their relation, if any, to fertilizer treatment. Measurement of stem lengths and flower diameters began about the first of November.

The first season all carnation plots received, in addition to manure, dried blood at the rate of 1.5 pounds per 100 square feet, except where ammonium sulfate was used. The second season 2 pounds and the third season 8 pounds of dried blood were used per 100 square feet of bench. The kinds and rates of application of other materials used each year are shown in Table 8. These fertilizers were usually worked into the soil just before benching the plants. In 1923 this plan was varied in that half the plots (Nos. 10 to 16) received fertilizer when the plants were benched July 29, and duplicate treatments were applied to the remaining plots (Nos. 1 to 7) September 21, after the plants were well established.

The increases in number of flowers obtained with the phosphate fertilizers were not large enough to be considered with certainty as resulting from the fertilizer treatment (Table 9). The low yields with ammonium sulfate and potassium sulfate in 1921-22 were doubtless the results of the use of excess amounts of fertilizer. In 1923-24 the time of application of the fertilizers made no differences in the yields. The average yield a plant on plots receiving fertilizers in July was 6.21±.10, and on plots receiving similar applications in September the yield averaged 6.27±.10 flowers a plant.

TABLE 9.—EFFECT OF PHOSPHORUS AND SULFUR FERTILIZERS ON PRODUCTIVENESS OF LADDIE CARNATIONS

Fertilizer	Season	Number of plants	Flowers per plant	Average flower diameter	Average stem length
				inches	*inches*
Control	1921-22	26	7.08±.25	3.53	19.99
	1922-23	48	6.46±.19	3.38	19.26
	1923-24	48	6.29±.19	3.44	21.73
Acid phosphate	1921-22	73	7.60±.18	3.48	19.54
	1922-23	48	6.83±.19	3.38	19.03
	1923-24	91	6.12±.14	3.50	21.43
Steamed bone	1921-22	47	6.66±.17	3.46	19.88
	1922-23	48	6.52±.20	3.32	19.23
	1923-24	48	6.62±.17	3.30	20.82
Precipitated phosphate	1921-22	48	6.73±.19	3.52	20.35
	1922-23	47	6.81±.20	3.33	18.94
	1923-24	48	6.02±.18	3.29	21.58
Gypsum	1921-22	72	7.04±.16	3.53	19.94
	1922-23	96	6.62±.14	3.37	19.04
	1923-24	48	6.52±.19	3.54	21.23
Ammonium sulfate	1921-22	34	3.00±.36	3.26	13.95
Potassium sulfate	1921-22	37	4.83±.29	3.31	16.58
Sulfur	1923-24	47	5.94±.18	3.54	21.30

Steamed bone was no more efficient than acid phosphate, and at the rates used the cost of bone meal was as high or higher.

The actual yields on the plots where gypsum was used were slightly higher on the average than on the check plots. They were lower, however, than with acid phosphate, and no definite conclusions can be drawn with such results as a basis. In the case of the other sulfur-bearing materials, excess amounts were no doubt responsible for decreased yields.

No consistent relation between fertilizer treatment and the occurrence of split calyces was noted in these experiments (Table 10).

TABLE 10.—PERCENTAGES OF FLOWERS WITH SPLIT CALYCES ON LADDIE CARNATION PLOTS

Fertilizer	1921-22		1922-23		1923-24	
	Total flowers	Split flowers	Total flowers	Split flowers	Total flowers	Split flowers
		perct.		*perct.*		*perct.*
Control	147	12.2	280	12.1	273	9.5
Acid phosphate	446	13.7	258	27.1	527	10.6
Steamed bone	286	11.5	281	13.2	608	5.3
Precipitated phosphate	255	19.6	268	17.2	594	5.2
Gypsum	435	17.2	562	16.5	273	8.8
Ammonium sulfate	62	32.2	...	...	...	...
Potassium sulfate	148	19.6	...	...	...	...
Sulfur	...	...	...	...	257	6.9

In 1925-26 an attempt was made to determine whether there are any differences in the response of different varieties of carnations to phosphatic fertilizers. Twelve varieties were planted and various fertilizers applied. Records of flower production were kept from October 15 to April 15. The results were so irregular that no definite comparisons were possible (Table 11). As a test of the effect of different fertilizers on flower production, the results of this test have little or no value. The yields obtained from the check plots were as good as or better than those from the heavily fertilized plots. It is quite likely that the concentration of salts in the soil was too high.

TABLE 11.—EFFECTS OF COMMERCIAL FERTILIZERS ON CARNATIONS, 1925-1926

Variety	No fertilizer				Fertilizer			
	Number of plants	Flowers per plant	Average flower diameter	Average stem length	Number of plants	Flowers per plant	Average flower diameter	Average stem length
			inches	*inches*			*inches*	*inches*
Betty Jane	20	9.70± .42	3.1	24.5	19	9.53±.25	3.1	23.2
Edna	20	5.45± .24	2.9	20.8	20	5.30±.23	2.9	19.0
Eldora	19	14.20± .43	2.9	21.7	18	9.72±.42	2.8	16.3
Laddie	20	4.50±1.53	3.3	28.5	20	5.90±.95	3.3	23.7
Maine Sunshine	20	5.50± .29	2.8	19.1	19	5.47±.18	2.8	19.3
Olivette	20	9.85± .21	3.1	22.8	20	9.50±.42	3.0	19.1
Rosalind	19	6.63± .34	3.0	19.6	19	5.26±.28	2.9	16.2
Spectrum	20	7.30± .30	3.1	25.5	20	8.25±.31	3.0	23.3
Surprise	24	4.00± .31	2.9	25.3	23	4.65±.26	2.7	21.6
White Enchantress	20	8.85± .40	3.4	21.7	20	8.35±.29	3.3	21.1
White Perfection	20	5.40± .42	3.0	22.0	19	5.79±.41	3.0	18.7
Winsome	20	7.50± .22	3.1	25.0	20	6.00±.27	3.1	22.1

Description of Experiment.—The soil was prepared in the field by adding cattle manure, approximately 1 part being used to 4 parts of soil by volume. This soil was used for planting in one of the center benches of the east-and-west house. The soil in the opposite bench received in addition heavy applications of commercial fertilizers as follows: dried blood, 16 pounds to 100 square feet of bench; acid phosphate, 40 pounds; and sulfate of potash, 5 pounds. The fertilizers were stirred into the soil before benching the plants on July 23, 1925.

CONCLUSIONS AND RECOMMENDATIONS

Acid phosphate, used to supplement manure and dried blood, is particularly effective in increasing the productiveness of greenhouse roses. It may also prove effective with carnations, tho increases in yield are likely to be less marked.

Increases in the number of roses or carnations resulting from the use of acid phosphate are not accompanied by decreased length of stem or size of flower.

Acid phosphate is much more effective and more economical for greenhouse use than is steamed bone meal.

Annual applications of about 25 pounds of acid phosphate to 100 square feet of bench are recommended as being probably near the optimum, at least for roses, in most greenhouse soils. As much as 40 pounds may be used without danger of overfeeding.

No beneficial effects on flower production are likely to result ordinarily from the use of sulfur-bearing commercial fertilizers in greenhouse soils.

LITERATURE CITED

1. Lumsden, David. Fertilizers for carnations. N. H. Agr. Exp. Sta. Bul. 159. 1912.
2. Dorner, H. B., Muncie, F. W., and Nehrling, A. H. The use of commercial fertilizers in growing carnations. Ill. Agr. Exp. Sta. Bul. 176. 1914.
3. Muncie, F. W. The use of commercial fertilizers in growing roses. Ill. Agr. Exp. Sta. Bul. 196. 1917.
4. White, Thomas H. Experiments with fertilizers on greenhouse crops. Md. Agr. Exp. Sta. Bul. 222. 1918.
5. Pember, F. R., and Adams, G. E. A study of the influence of physical soil factors and of various fertilizer chemicals on the growth of the carnation plant. R. I. Agr. Exp. Sta. Bul. 187. 1921.
6. Olson, Geo. A., and St. John, J. L. An investigation of sulfur as a plant food. Wash. Agr. Exp. Sta. Bul. 165. 1921.
7. Crocker, Wm. The necessity of sulfur carriers in artificial fertilizers. Jour Am. Soc. Agron. 15, 129-141. 1923.
8. Powers, W. L. Sulfur in relation to soil fertility. Ore. Agr. Exp. Sta. Bul. 199. 1923.
9. Stewart, Robert. Sulfur in relation to soil fertility. Ill. Agr. Exp. Sta. Bul. 227. 1920.
10. ————. Sulfur and soil fertility. Florists' Rev. 56, no. 1431, 35. 1925.
11. Babcock, E. B., and Clausen, R. E. Genetics in relation to agriculture. McGraw-Hill. 1918.

APPENDIX

In fertilizer experiments factors other than those under investigation exert an important influence on the observed results. The inherent variability of the plants and differences in soil and other environmental conditions between plots all have their effects. Under such conditions the "probable error" of the mean is a useful aid in drawing conclusions.

TABLE 12.—MEANS, STANDARD DEVIATIONS, COEFFICIENTS OF VARIABILITY, AND COEFFICIENTS OF CORRELATIONS DERIVED FROM THE DATA ON FLOWER PRODUCTION OF ROSES, TABLES 15 TO 19

Variety	Treatment	Year	Mean	Standard deviation	Coefficient of variability
Hoosier Beauty......	No phosphate......	1916-17	18.10±.28	5.05±.20	27.90
		1917-18	15.00±.25	4.46±.26	29.73
		1918-19	13.94±.25	4.40±.17	31.50
	Acid phosphate.....	1916-17	18.20±.33	5.75±.23	31.60
		1917-18	17.01±.31	5.70±.23	33.50
		1918-19	15.71±.33	5.80±.23	36.90
Ophelia.............	No phosphate......	1916-17	32.12±.42	7.46±.30	23.10
		1917-18	25.01±.36	6.41±.25	25.62
		1918-19	25.57±.38	6.80±.27	26.60
	Acid phosphate.....	1916-17	35.21±.47	8.35±.33	23.55
		1917-18	27.68±.40	7.15±.28	25.83
		1918-19	27.86±.41	7.30±.29	26.20
Killarney............	No phosphate......	1916-17	36.56±.69	8.28±.33	22.65
		1917-18	36.44±.44	7.90±.31	21.67
		1918-19	35.53±.48	8.50±.34	23.90
	Acid phosphate.....	1916-17	39.20±.60	7.20±.28	18.38
		1917-18	39.08±.53	9.52±.38	24.36
		1918-19	36.82±.60	10.70±.43	29.10
White Killarney......	No phosphate......	1916-17	33.80±.41	7.24±.86	21.40
		1917-18	32.89±.36	6.41±.25	19.48
		1918-19	34.56±.43	7.60±.30	21.90
	Acid phosphate.....	1916-17	35.90±.48	8.54±.34	23.80
		1917-18	36.40±.49	8.96±.36	24.61
		1918-19	36.87±.55	9.80±.39	26.50
Killarney............	Steamed bone......	1916-17	34.90±.58	10.35±.41	29.65
	Acid phosphate.....		45.20±.60	10.70±.42	23.00
Richmond...........	Steamed bone......	1916-17	28.30±.39	6.87±.27	24.25
	Acid phosphate.....		35.45±.56	9.89±.39	27.90

In the experiments described in this bulletin the yields of flower crops were highly variable, altho environmental conditions were maintained as uniform as is possible under ordinary greenhouse conditions. It is important, therefore, that ample allowance be made for variability in drawing conclusions. Detailed data on flower production by roses and carnation plants are given in the frequency tables (Tables 15 to 20). The means, standard deviations, and coefficients of variability computed from these data are shown in Tables 12 and 13.

It was thought that there might be a correlation between the number of flowers produced by the plant and length of flower stems, and

TABLE 13.—MEANS, STANDARD DEVIATIONS, AND COEFFICIENTS OF CORRELATION DERIVED FROM THE DATA ON FLOWER PRODUCTION OF CARNATIONS, TABLE 20

Variety	Treatment	Mean	Standard deviation	Coefficient of variability
Champion	No phosphate	20.62 ± .16	4.57 ± .12	22.21
	Acid phosphate	21.66 ± .17	4.78 ± .12	22.06
White Enchantress	No phosphate	19.27 ± .13	3.64 ± .09	18.89
	Acid phosphate	20.65 ± .14	3.96 ± .10	19.17

also that there might exist a greater correlation of this sort in the acid-phosphate series than in the no-phosphate. Thus the excess of production in the first series might simply represent a larger number of short-stemmed flowers. This obviously would not be desirable from the standpoint of the florist. The relation between yield and stem length, as indicated by the correlation coefficient, r, is shown for three varieties of roses in Table 14.

The correlation coefficients are very small, in many cases too small in relation to the probable error to be considered at all significant. From these data it appears that there was little or no relation between the number of flowers produced by a plant and the stem lengths. The two characters varied practically independently. Stem lengths did not decrease consistently with increased yields by the plants. Since this was true regardless of fertilizer treatment, there was no error from this source to impair the value of the data on flower production with and without acid phosphate.

TABLE 14.—CORRELATION BETWEEN NUMBER OF FLOWERS AND STEM LENGTH IN ROSES

Variety	Treatment	Year	Coefficient of Correlation
			r
Hoosier Beauty	No phosphate	1916-17	−.112 ± .013
		1917-18	−.079 ± .014
		1918-19	−.064 ± .015
	Acid phosphate	1916-17	−.045 ± .013
		1917-18	−.030 ± .014
		1918-19	−.010 ± .014
Ophelia	No phosphate	1916-17	−.092 ± .011
		1917-18	.006 ± .011
		1918-19	−.036 ± .011
	Acid phosphate	1916-17	−.060 ± .010
		1917-18	−.007 ± .011
		1918-19	−.045 ± .011
Killarney	No phosphate	1916-17	−.062 ± .009
		1917-18	−.012 ± .009
		1918-19	−.061 ± .010
	Acid phosphate	1916-17	−.096 ± .009
		1917-18	−.048 ± .009
		1918-19	−.065 ± .009
White Killarney	No phosphate	1916-17	−.021 ± .010
	Acid phosphate	1916-17	−.042 ± .009
Killarney	Steamed bone	1916-17	−.081 ± .009
	Acid phosphate	1916-17	−.057 ± .008
Richmond	Steamed bone	1916-17	−.052 ± .010
	Acid phosphate	1916-17	−.010 ± .009

TABLE 15.—FREQUENCY TABLES SHOWING VARIABILITY IN FLOWER PRODUCTION BY OPHELIA ROSES

Flowers per plant	Number of plants					
	No phosphate			Acid phosphate		
	1916-17	1917-18	1918-19	1916-17	1917-18	1918-19
1-5	...	...	1	...	...	1
6-10	...	1	...	...	1	...
11-15	...	5	9	...	5	3
16-20	5	29	19	2	12	18
21-25	21	47	43	12	41	35
26-30	36	35	40	23	38	34
31-35	36	18	23	36	26	29
36-40	29	7	7	36	14	21
41-45	12	2	2	16	7	2
46-50	5	...	...	12	...	1
51-55	...	...	...	4	...	...
56-60	...	...	...	1	...	...
61-65	...	...	...	1	...	...

TABLE 16.—FREQUENCY TABLES SHOWING VARIABILITY IN FLOWER PRODUCTION BY KILLARNEY ROSES

Flowers per plant	Number of plants					
	No phosphate			Acid phosphate		
	1916-17	1917-18	1918-19	1916-17	1917-18	1918-19
16-20	1	...	1	...	2	...
21-25	7	10	13	2	7	15
26-30	22	26	27	17	22	16
31-35	34	36	38	25	24	26
36-40	31	28	33	43	25	30
41-45	24	26	15	28	23	25
46-50	16	8	8	21	22	12
51-55	6	9	5	8	14	8
56-60	2	1	2	...	4	8
61-65	1	...	2	...	1	1
66-70	...	...	...	...	...	2
71-75	...	...	...	...	...	1

TABLE 17.—FREQUENCY TABLES SHOWING VARIABILITY IN FLOWER PRODUCTION BY KILLARNEY AND RICHMOND ROSES, 1916-1917

Flowers per plant	Number of plants			
	Killarney		Richmond	
	Steamed bone	Acid phosphate	Steamed bone	Acid phosphate
13-17	8	1	4	5
18-22	5	3	30	9
23-27	22	2	30	15
28-32	26	12	43	24
33-37	30	15	25	37
38-42	22	25	9	19
43-47	13	28	1	20
48-52	10	18	2	10
53-57	5	23	...	2
58-62	2	11	...	1
63-67	1	5	...	2
68-72	...	...	...	...
73-77	...	...	...	...
78-82	...	1	...	...

TABLE 18.—FREQUENCY TABLES SHOWING VARIABILITY IN FLOWER PRODUCTION BY HOOSIER BEAUTY ROSES

Flowers per plant	Number of plants					
	No phosphate			Acid phosphate		
	1916-17	1917-18	1918-19	1916-17	1917-18	1918-19
1-5	1	2	1	...	3	2
6-10	7	17	17	13	17	26
11-15	29	62	72	33	37	46
16-20	66	48	40	45	45	40
21-25	31	14	12	39	34	24
26-30	8	1	2	7	6	4
31-35	2	...	...	3	2	2
36-40				1	...	...

TABLE 19.—FREQUENCY TABLES SHOWING VARIABILITY IN FLOWER PRODUCTION BY WHITE KILLARNEY ROSES

Flowers per plant	Number of plants					
	No phosphate			Acid phosphate		
	1916-17	1917-18	1918-19	1916-17	1917-18	1918-19
11-15	2	...	...	1	...	...
16-20	8	3	3	7	6	1
21-25	15	13	9	12	8	8
26-30	28	40	34	24	22	16
31-35	35	34	36	26	30	25
36-40	33	39	31	40	31	31
41-45	15	13	19	18	26	18
46-50	8	1	11	11	14	17
51-55	...	1	1	5	6	8
56-60	...	...	...	...	1	6
61-65	...	...	...	...	...	4

TABLE 20.—FREQUENCY TABLES SHOWING VARIABILITY IN FLOWER PRODUCTION BY CARNATIONS

Flowers per plant	Number of plants			
	Champion		White Enchantress	
	No phosphate	Acid phosphate	No phosphate	Acid phosphate
10	1	...	...	...
11	2	3	3	...
12	5	4	3	1
13	9	3	6	...
14	10	13	14	8
15	20	10	23	12
16	25	13	31	28
17	17	22	46	22
18	31	29	31	37
19	36	24	35	50
20	28	34	39	49
21	27	19	19	25
22	29	29	19	30
23	21	28	34	20
24	18	23	15	17
25	24	24	5	12
26	12	13	11	13
27	15	19	3	6
28	7	11	5	7
29	5	9	2	5
30	3	7	...	6
31	4	4	...	3
32	1	3	1	3
33	2	2	...	2
34	1	1	...	...
35	1	2	...	...
36	...	1	...	...