EFFECT OF CERTAIN INORGANIC FERTILIZERS ON YIELD AND FIBER PROPERTIES OF COTTON

by

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CHAPTER I

INTRODUCTION

During the last few years there has been a decided increase in the use of inorganic fertilizers on Arizona soils. The total tonnage of fertilizers sold in Arizona increased from a little over 8,000 tons in 1938 to almost 31,000 tons during the year 1946.[1] Part of this increase in fertilizer usage has been due to a necessity for increasing or maintaining yields in order to compensate for higher production costs. Also, the farmers of this state are beginning to realize that the soil fertility is rapidly being depleted where recommended cultural practices are not followed. The cotton grower is especially concerned with the problem of maintaining a satisfactory level of plant nutrients in the soil, because much of the cotton land has been cropped almost continuously to cotton for many years.

A large majority of the cotton farmers in this state have erroneously believed that the productive capacity of the soil can be maintained through crop rotation alone. It was thought that if the land were planted to alfalfa for two

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1. McGeorge, W.T. Fertilizer Handbook for Arizona Farmers, p. 27.

or three years out of every ten, the high yields of cotton which they were obtaining could be realized indefinitely. However, a glance at a table showing the amounts of nitrogen, phosphorus, and potash used by the plants in the production of what are considered good yields will completely explode this concept.[2] Six tons of alfalfa hay remove 280 pounds of nitrogen, 70 pounds of phosphorus, and 270 pounds of potash. Table I shows the amount of plant nutrients removed from the soil in the production of a bale of cotton. It is apparent that a bale of cotton removes, through the seed and lint, only 39.48 pounds of nitrogen, 15.71 pounds of phosphoric acid, and 15.27 pounds of potash. It is conceded, of course, that there is a nitrogen response of two or more years' duration resulting from the alfalfa having grown in symbiotic relationship with the soil bacteria.

One of the most important problems facing the cotton grower in Arizona today has to do with the profitable returns which might be expected from the application of various combinations of inorganic fertilizers. They want to know what fertilizers to apply, how much to apply, when to apply, and the best method of application. Obviously, no "blanket" recommendations can be made to fit all situations. An intelligent appraisal of the previous cropping history, however, together with a laboratory or field analysis of

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2. McGeorge, W.T. op. cit., p. 28.

TABLE I

WEIGHT OF PLANTS AND PLANT NUTRIENTS IN PLANTS THAT PRODUCE A BALE OF COTTON[3]

Part	Per cent of weight	Weight in lbs.	Pounds nitrogen	Lbs. phosphoric acid	Pounds potash
Roots	8.80	417	2.00	1.08	3.75
Stems	23.15	1,096	7.01	2.30	9.35
Leaves	20.25	959	21.58	4.60	10.45
Burs	14.21	673	5.52	3.23	20.79
Seed	25.03	1,090	38.58	15.26	12.32
Lint	10.56	500	0.90	0.45	2.95
Total	100.00	4,735	75.59	26.92	59.59

3. Brown, H.P. Cotton, p. 231.

the soil fertility will materially aid in answering some of these questions.

In order to have fertilizers serve most efficiently when used in the growth of cotton, several factors must be looked after carefully by the growers. A suitable soil must be selected and properly prepared. The crop must be cultivated efficiently, harvested, and marketed. The method and time of application of the fertilizer usually exert a tremendous influence on the efficiency with which the fertilizers act. The kind and amount of fertilizers per acre, availability of the nutrient materials, and the proportioning of the plant food constituents in the fertilizers to fit best the needs of the soil and crop are highly essential. Also, an understanding of the amount of each nutrient actually assimilated by the plants in the production of a good yield of seed cotton materially aids in completion of an understanding of the fertilizer needs of the soil.

The value of a cotton crop is not determined solely by the amount of seed cotton harvested per acre. Other factors such as lint percentage, staple length, grade, strength index, and boll size are very important in an evaluation of the crop of cotton. Numerous experiments have shown that various fertilizers may affect some of these properties, including yield, under varied soil conditions and in different localities.

The study reported herewith was instituted for the

express purpose of testing the effect of certain inorganic fertilizers upon the yield and fiber properties of cotton grown on Arizona soils. It also attempts to throw light upon the limited knowledge available to cotton growers in Arizona, with particular reference to the returns per acre which may be expected through the use of these fertilizers.

CHAPTER II

REVIEW OF LITERATURE

Cotton plants usually respond readily to proper fertilizers, a fact which is borne out by the results of numerous experiments conducted in several states. The increase in yield has been as high as 500 pounds of seed cotton per acre on soils which were producing an average yield and were thought to have sufficient plant nutrients.

Staten and Hinkle[1] of New Mexico recently obtained very good results with a series of fertilizer tests on a number of different soil types. Weighted averages for all tests indicated an increase in yield of .396 pounds of lint cotton per pound of available phosphorus applied alone, .694 pounds of lint cotton per pound of available nitrogen applied alone, 1.134 pounds of lint cotton per pound of combined available nitrogen and phosphorus, and 1.838 pounds of lint cotton for each pound of available nitrogen and phosphorus contained in barnyard manure. From this work it might be concluded that the plant nutrients in manure are more effective than those contained in commercial

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1. Staten, G. and Hinkle, D.A. Maintaining Cotton Yields Through Fertilizer and Crop Rotation.

fertilizers. A large percentage of the increase due to manure, however, was attributed to the fact that one of the tests was conducted on a poor, sandy soil.

In 1928, Bartholomew and Jannsen[2] published a report on the effect of fertilizers on the size of cotton bolls, and found that in many instances an increased yield resulted in four different ways: (1) an increase in size of bolls and a decrease in number of bolls, (2) an increase in the number of bolls, (3) an increase in number and size of bolls, and (4) an increase in boll size and lint percentage. They found that profitable increases in yield were obtained where the proper fertilizers were used relative to the soil fertility. In general, the increase in yield was due mainly to the increase in the number of bolls, as the average increase was approximately 40 per cent more bolls. The size of the bolls was increased approximately 5 per cent by all fertilizer treatments.

The results of an investigation by Turner[3] of Georgia show that significant increases in boll size were found when potash was increased. Significant increases in yield of seed cotton per acre also were shown between 20-, 40-, and

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2. Bartholomew, R.P. and Jannsen, G. "Effect of Fertilizers on the Size of Cotton Bolls." Am. Soc. Agron. J.; 20:1048-1054 (1928).
3. Turner, J.H., Jr. "The Effect of Potash Level on Several Characters in Four Strains of Upland Cotton which Differ in Foliage Growth." Ibid.; 36:688-698 (1944).

80-pound levels of potash. The soils of the Coastal Plain of Georgia are commonly deficient in potash, as evidenced by the prevalence of Cotton Rust, a disease which is attributed to this deficiency.

The importance of maintaining proper nutrient levels for the control of various diseases and insects has been emphasized by a large number of workers. Recent work by Tisdale and Dick[4] in Alabama showed conclusively that a normal supply of available potassium in the soil will materially reduce the effect of Cotton Wilt (Fusarium vasinfectum). Various plots were treated with a 6-8-0[5] fertilizer while others received an application with a composition of 6-8-4. The cotton growing on plots receiving no potash was seriously infected by the fungus, while potash-treated plots showed very little infection and almost doubled the yields of the "no potash" plots. Practically the same results were obtained by Rast[6] in which the application of 500 pounds of kainit, containing 12.5 per cent potash, resulted in yields of 1,127 pounds of seed cotton. The unfertilized cotton produced only 525 pounds, and the same

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4. Tisdale, H.B. and Dick, J.B. "Cotton Wilt in Alabama as Affected by Potash Supplements and as Related to Varietal Behavior and Other Important Agronomic Problems." Am. Soc. Agron. J.; 34:405-426 (1942).
5. "6-8-0" means 6 per cent nitrogen, 8 per cent phosphoric acid, and 0 per cent of potash.
6. Rast, L.E. "Control of Cotton Wilt (Fusarium) by Use of Potash Fertilizers." Am. Soc. Agron. J.; 14:222-224 (1922).

relationship existed between the two treatments with respect to the degree of infection.

A more recent investigation was conducted in which stable manure, applied at the rate of 4 tons per acre, outyielded all applications of commercial fertilizers on soil affected by the Fusarium-heterodera Complex. This investigation, reported by Pinckard and Leonard[7] in 1944, showed that the manure outyielded the check plots by 850 pounds of seed cotton per acre.

Further evidence of the role of fertilizers in the control of diseases was presented by Blank[8] in 1944 in his studies of the effect of fertilizers on Root Rot. The application of 600 pounds of a 12-0-0 fertilizer decreased the occurrence of Root Rot by a significant or highly significant margin in every replicate during two of the three years tested. Highly significant increases in yield were obtained every year by the same fertilizer usage. The same results with respect to yields were manifested by 600 pounds per acre of a 12-8-0 fertilizer mixture, although the phosphorus tended to increase the Root Rot development.

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7. Pinckard, J.A. and Leonard, O.A. "Influence of Certain Soil Amendments on the Yield of Cotton Affected by the Fusarium-heterodera Complex." Am. Soc. Agron. J.; 36:829-843 (1944).
8. Blank, L.M. "Effect of Nitrogen and Phosphorus on the Yield and Root Rot Responses of Early and Late Varieties of Cotton." Ibid.; 36:875-888 (1944).

Hastening of maturity, or "earliness," is another factor which may be influenced by the maintenance of a proper nutrient balance in the soil. When associated with cotton production it becomes of paramount importance, since almost always a number of bolls fail to mature before frost. Another phase of earliness concerns the difference in grade of the seed cotton harvested at the first picking and that obtained from later pickings. Probably the most important nutrient element associated with hastening of maturity is phosphorus. One of its physiological functions in all plants seems to be a stimulation of production of reproductive organs relatively early in the plant's life.

This function of phosphorus has been demonstrated by the results of a large number of experiments with cotton. In 1926, Warner[9] reported that a complete fertilizer caused early fruiting and three weeks of rapid fruiting, while no fertilizer delayed fruiting with no period of rapid fruiting. He determined that earliness may be measured in a number of ways: early squaring, rapidity of squaring, early blooming, percentage of blooms developing into bolls early in the season, short boll period, and other factors which determine the earliness of the cotton crop. Potash has also been known to affect the maturity or

9. Warner, J.D. "Effect of Fertilizers on the Fruiting Activities of Cotton Plants." Am. Soc. Agron. J.; 18:1045-1050 (1926).

percentage of seed cotton harvested at the first picking. A gain of 39 per cent at the first picking was secured by Williams[10] of North Carolina from the use of 600 pounds of a complete fertilizer containing 21 per cent potash. Increasing the potash from 7 per cent to 21 per cent in the same fertilizer resulted in a 19 per cent increase at the first picking.

Numerous investigations have been undertaken to determine the effect of different nitrogen sources on yield and other properties of cotton. In the seedling stage, ammonia fertilizers should not be applied in close proximity to the plants, due to the toxic effect of ammonia on tender plant tissue. Tidmore[11] reported a loss of most of the plants at seedling stage on application of ammonium hydroxide, although calcium nitrate applied at the same rate of nitrogen in pounds per acre caused no visible detrimental effect.

Bledsoe[12] obtained the highest yields from quick-acting inorganic fertilizers such as sodium nitrate, which gave an increase in yield varying from 167 to 233 pounds of seed cotton per acre. A mixture of sodium nitrate and ammonium sulfate produced the most economical results. He

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10. Williams, C.B. "Wise Use of Fertilizers on Cotton--Their Effect upon Yield and Maturity for Different Soils in North Carolina." Am. Soc. Agron. J.; 18: 1036-1043 (1944).
11. Tidmore, J.W. "Ammonium Hydroxide Versus Calcium Nitrate for Cotton Seedlings," Ibid.; 25:619-622 (1933).
12. Bledsoe, R.P. "Cotton Fertilizers and Cultural Methods."

found that a fertilizer containing 80 per cent inorganic and 20 per cent organic fertilizer materials as the source of nitrogen, in general, was best adapted to the growth of cotton plants. The same results were shown in the Fifty-fifth Annual Report of the North Carolina Agricultural Experiment Station, in which a study was made of the effect of varying the ratio of inorganic to organic sources of nitrogen in a complete fertilizer upon the yield and quality of cotton.[13]

In an attempt to determine the best type of fertilizer to use for cotton, Skinner, et al[14] of North Carolina obtained the highest yields with a concentrated fertilizer containing acid-forming ammonium salts, or with soluble nitrogen fertilizers applied in conjunction with limestone. He concluded that organic sources of nitrogen are just as effective as inorganic sources of nitrogen as a fertilizer for cotton.

Another important aspect of fertilizers for cotton deals with their effect on stand and germination. As has already been stated, the direct application of ammonium

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13. _____. "A Study of the Effects of Varying the Ratio of Inorganic to Organic Sources of Nitrogen in a Complete Fertilizer upon Yield and Quality of Cotton." Fifty-fifth Annual Report of the North Carolina Agricultural Experiment Station.

14. Skinner, J.J., et al. "Adapting High Analysis and Concentrated Fertilizers to Cotton Soils." Soil Science; 44:1-22 (1937).

hydroxide to cotton seedlings caused the death of a large majority of them. Musgrove and Coe[15] determined that the application of any fertilizer at time of planting and in close proximity to the seed is apt to cause poor seed germination and consequent reduction in stand of cotton. They achieved much better results by applying the fertilizer previous to, instead of at, planting time. The work of Collins, et al[16] showed that on flat prepared seed beds, fertilizer placed at the time of planting in a narrow band at each side of the row in a zone ranging from 1.5 to 3.5 inches laterally from the seed and from one to 3 inches below the seed level resulted in the most rapid germination and seedling growth, as well as the highest yields of seed cotton. A band of fertilizer at only one side of the row gave similar results. An application of fertilizer adjacent to the seed at planting time, therefore, can not be recommended, especially if it is a highly-concentrated inorganic fertilizer. The application of fertilizers in side bands, as a general rule, has given excellent results relative to germination and stand, and also as to availability.

The effect of fertilizers on length and strength of cotton fibers has been the object of a great deal of

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15. Musgrove, G.W. and Coe, D.G. "Influence of Fertilizer Treatments on Stand or Germination of Cotton." Am. Soc. Agron. J.; 19:171-180 (1927).
16. Collins, E.R., et al. Placement of Fertilizers for Cotton.

experimentation and investigation, but the results have shown that fertilizers have very little effect on these properties. Reynolds and Stansel[17] in 1933 could not increase the fiber length by the application of nitrogen, phosphorus, or potassium, nor by varying the rates of application. In 1935, Pope[18] stated that the use of fertilizers failed to affect the length or strength of the staple.

Skinner, et al[19] proved that varying the particle size of granulated fertilizers had no appreciable effect on emergence, stand, or yield of cotton. In a decision as to which type or form to apply, therefore, the more finely-divided fertilizers should not be given preference on the basis of their effect on the growth of cotton.

Serviss and Hawkins[20] conducted a series of experiments on the use of fertilizers for cotton in the Salt River Valley, the results of which were published in 1929. They applied nitrate, phosphate, and potash fertilizers to a number of different soils which varied widely in type and fertility. On the heavier soils, none of the fertilizer

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17. Reynolds, E.B. and Stansel, R.H. "Effect of Fertilizers on the Length of Cotton Fibers." Am. Soc. Agron. J.; 27:408-411 (1935).
18. Pope, O.A. Effects of Fertilizer Treatments on Length and Strength of Fiber.
19. Skinner, J.J., et al. "Effectiveness on Cotton Soils of Granulated Mixed Fertilizers of Different Particle Size." Am. Soc. Agron. J.; 33:314-324 (1941).
20. Serviss, G.H. and Hawkins, R.S. Cotton Fertilizer Experiments in the Salt River Valley.

treatments were profitable, and in very few cases was there any increase in yield over the check. The addition of potash was unprofitable in all cases, suggesting that there was sufficient potash in the soil for obtaining maximum yields. Applications of phosphorus increased yields in a few instances, but generally were not profitable. Ammonium sulfate on light, sandy soils yielded a net profit of more than $30 per acre in a few cases, and almost consistently increased the yields.

CHAPTER III

EXPERIMENTAL PROCEDURE

In this experiment, cotton of the Acala variety was tested because it is well adapted to Arizona conditions and is grown exclusively throughout the cotton-producing areas of the state. The experiment was conducted on Laveen clay loam soil at the Mesa Experiment Farm in the Salt River Valley near Mesa, Arizona. Three borders of approximately .4 of an acre each, were planted to cotton on April 3, 1947, after a proper seed bed was prepared. Each border was divided into half borders, and the entire three borders were arranged in a 6 x 6 Latin square design by the following fertilizer treatments:

1. Check (no treatment).
2. Treble superphosphate at the rate of 600 pounds per acre.
3. Treble superphosphate--300 pounds per acre plus 150 pounds of nitrate of soda.
4. Nitrate of soda--150 pounds.
5. Treble superphosphate--600 pounds and 150 pounds of ammonium sulfate per acre.
6. 150 pounds of ammonium sulfate.

The treble superphosphate was applied in deep bands, 18 inches in depth, prior to bedding up and planting and 10 inches to one side of the row. The nitrogen fertilizers

were applied in 2-inch furrows, prior to planting and after bedding up, near the seed row. The borders were then irrigated and planted when the soil was at the optimum moisture content.

The 6 x 6 Latin square design resulted in a replication of each treatment in each half border and also eliminated, as far as possible, the effect of differences in soil type and fertility on the various factors to be studied. The "end" effect was eliminated by leaving approximately 15 feet at each end of the borders untreated, although planted to cotton.

The cropping history afforded us a means of determining the effect of rotation on yield and character of lint. The east half of border E-28 and all of E-29 had been planted to alfalfa for the three previous years, while the west half of border E-28 and all of E-27 had been cropped continuously with cotton for several years. In designing the fertilizer experiment, however, no difference in rate or method of application of the various fertilizers was made between previously cropped alfalfa borders and previously cropped cotton borders.

During its growth all of the cotton received the same cultural practices of hoeing, thinning, cultivating, dusting, and irrigating. The harvesting dates were September 1, October 2, and November 10, 1947. No unusual weather conditions prevailed throughout the length of the

experiment, and the first killing frost occurred on November 7, 1947.

The yield figures obtained from each replication were computed on the basis of the pounds of seed cotton per acre produced.

A 10-boll sample, picked at random from each plot, was analyzed in the laboratory for a determination of lint percentage, lint index, boll size, staple length, Pressley index or strength index, uniformity of length of fiber, and percentage waste.

The lint percentage was calculated on the weight basis of the lint ginned from the seed cotton harvested.

The lint index is the weight in grams of the lint from 100 seeds.

Boll size refers to the number of bolls required to make a pound of seed cotton, and was calculated from the known weight of the 10-boll sample taken from each plot.

Staple length was determined by measuring the halo length of combed samples of lint on the seed. The mean distance between the raphe and the end of the dense fibers was used.

Pressley index or strength index is a comparison of the relative breaking strength of small samples of fibers. It is calculated by dividing the weight in pounds required to break the sample on the Pressley breaking machine by the weight in milligrams of the sample tested.

Uniformity of length of fiber was determined by sorting on the Pressley sorting machine and calculating the percentage by weight of the three modal groups.

Percentage waste figures were obtained from the Pressley sorter on the basis of the percentage by weight of the fibers less than one-half inch in length.

Data in each case were analyzed statistically by the Analysis of Variance method.

CHAPTER IV

EXPERIMENTAL RESULTS AND DISCUSSION

Total Yields

Of all the factors in the determination of the economic returns from a crop of cotton, yield is of paramount importance. No other factor shows as much response to tillage operations, soil fertility, moisture conditions, and all of the other methods by which the farmer is able to affect the growth of the cotton plant as does the total pounds of seed cotton produced per acre. The cotton obtained from the three pickings was grouped together, and the total yields analyzed statistically for the effect of the various fertilizer treatments on the seed cotton per acre produced. The results are given in Table II, page 21.

Discussion: With the exception of the nitrate of soda, all of the fertilizer treatments were responsible for increased total yields of seed cotton per acre. The use of treble superphosphate plus ammonium sulfate resulted in the largest increase, which was statistically significant at the .05 level of significance. None of the other treatments increased the yield enough to be significant at either the .01 or .05 level. The application of 150 pounds of nitrate of soda depressed the yield by 3.9 pounds, although in combination with treble superphosphate it tended to

TABLE II

EFFECT OF THE FERTILIZER TREATMENTS ON TOTAL YIELDS IN POUNDS OF SEED COTTON, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	Yield per acre
1. Check (no treatment)	1,928.0
2. 600 lbs. treble superphosphate	1,978.6
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	2,047.7
4. 150 lbs. nitrate of soda	1,924.1
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	2,093.8
6. 150 lbs. ammonium sulfate	1,972.2
Critical difference required for significance at .01	221.7
at .05	165.7

Analysis of Variance of Total Yield of Seed Cotton per Acre

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	3,898,495.7	111,385.6
Borders	5	2,739,212.5	547,842.5
Series	5	619,385.9	123,877.2
Treatments	5	136,460.4	27,292.1
Error	20	403,436.9	20,171.8

result in increased yields over treble superphosphate applied alone.

The average yields of each treatment on the soil previously cropped to cotton and on the soil previously planted to alfalfa were calculated to determine the effect of cropping history on yield. The results are given in Table III, page 23.

Table III shows that the cropping history had a much greater effect on yield than did the application of any of the commercial fertilizers. From Table II it may be determined that the greatest yield increase resulting from any fertilizer treatment was 165.8 pounds, while the average increase on the land previously cropped to alfalfa amounted to 517.9 pounds of seed cotton per acre. This further substantiates the conclusions of many investigators that crop rotation with legumes is basic if maximum yields of cotton are to be maintained.

First Picking Yields

Farmers are vitally interested in harvesting as much of the cotton crop as possible prior to the advent of damp, cold weather, since unfavorable weather may be responsible for lowering the quality of the lint as much as three grades. For lint harvested in September, Arizona growers generally receive several cents more per pound than for lint harvested in January. Usually they are obliged to pay

TABLE III

EFFECT OF CROPPING HISTORY ON YIELD IN POUNDS OF SEED COTTON PER ACRE

Treatment	After cotton	After alfalfa	Increase in yield
1. Check (no treatment)	1,613.9	2,242.3	628.4
2. 600 lbs. treble superphosphate	1,657.8	2,303.3	644.5
3. 300 lbs. treble superphosplate plus 150 lbs. nitrate of soda	1,835.0	2,260.5	425.5
4. 150 lbs. nitrate of soda	1,726.6	2,121.6	395.0
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	1,806.3	2,381.8	575.5
6. 150 lbs. ammonium sulfate	1,752.1	2,191.6	438.8
Average	1,732.1	2,250.0	517.9

more to get the later pickings harvested than is required for the first picking. Therefore, a study of the effects of fertilizers on the amount of seed cotton harvested at the first picking, a direct measure of their effect on hastening of maturity or earliness, is economically important. Table IV, page 25, shows the effect of the fertilizers used in this experiment on the amount of seed cotton obtained from the first picking.

Discussion: All of the treatments resulted in a greater percentage of the total crop being harvested at the first picking. A highly significant increase resulted from the use of treble superphosphate in combination with ammonium sulfate. The application of treble superphosphate in conjunction with nitrate of soda caused a significant increase in first picking yield. A comparison of the effects of the two nitrogen fertilizers applied singly and in combination with treble superphosphate indicates that ammonium sulfate resulted in a greater increase in first picking yields than did nitrate of soda; whereas treble superphosphate apparently had a greater effect than did either of the nitrogen fertilizers. None of the three fertilizers alone affected the first picking yields enough to be statistically significant.

Table IV also shows the percentages of the total yields which were harvested at the first picking. The use of

TABLE IV

EFFECT OF THE FERTILIZER TREATMENTS ON FIRST PICKING YIELDS IN POUNDS OF SEED COTTON, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	Total yield per acre	First picking	
		Yield per acre	Per cent of total
1. Check (no treatment)	1,928.0	856	44.40
2. 600 lbs. treble superphosphate	1,978.6	918	46.40
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	2,047.7	966	47.14
4. 150 lbs. nitrate of soda	1,924.1	870	45.22
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	2,093.8	1,007	48.09
6. 150 lbs. ammonium sulfate	1,972.2	905	45.89
Critical difference required for significance at .01		135	
at .05		101	

Analysis of Variance of First Picking Yields of Seed Cotton per Acre

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	431,828	12,338
Borders	5	139,930	27,986
Series	5	44,740	8,948
Treatments	5	98,590	19,718
Error	20	148,568	7,428

fertilizers increased the percentage of seed cotton gathered at the first picking in every case, with the largest increase due to treble superphosphate plus ammonium sulfate. The three treatments containing phosphate fertilizer resulted in a greater increase in the percentage of seed cotton harvested at the first picking than did the nitrogen fertilizers alone. Therefore, the fertilizers were directly responsible for hastening the maturity of the cotton plants, with the greatest effect on earliness due to the phosphate. These results further substantiate the fact that phosphorus tends to promote the fruiting activities of cotton early in the life of the plant.

Lint Percentage

Another very important aspect of cotton production deals with the ginning percentage or lint percentage. If the producer is able to increase the amount of lint ginned from a given amount of seed cotton, the money return per acre is increased correspondingly. This increase in lint may be the result of a number of things, such as an increase in the average length of fiber, an increased density of fibers on the seed, a reduction in size of seeds, or a combination of any of these methods. The effect of these inorganic fertilizers on the lint percentage is presented in Table V, page 27.

Discussion: The highest lint percentage was obtained

TABLE V

EFFECT OF CERTAIN INORGANIC FERTILIZERS ON LINT PERCENTAGE, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	Lint percentage
1. Check (no treatment)	37.3
2. 600 lbs. treble superphosphate	37.0
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	36.9
4. 150 lbs. nitrate of soda	36.4
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	36.4
6. 150 lbs. ammonium sulfate	37.0
Critical difference required for significance at .01	2.2
at .05	1.7

Analysis of Variance of Lint Percentage

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	52.7	1.5
Borders	5	5.4	1.1
Series	5	4.3	.9
Treatments	5	3.5	.7
Error	20	39.5	2.0

from the check plots, with all the fertilizer treatments resulting in insignificant decreases. Nitrate of soda, and treble superphosphate plus ammonium sulfate each depressed the ginning percentage by 0.9 per cent, the greatest reduction effected; but this was not enough to be statistically significant even at the 5 per cent level. The other three treatments caused a slight lowering of the lint percentage when compared with the check. No definite trends were indicated by any of the fertilizers applied. From the results of this work the conclusion is reached that an increase in inorganic soil fertility had very little effect on the lint percentage or ginning outturn.

Lint Index

As previously stated, lint index refers to the weight in grams of the lint from 100 seeds. One can readily see that there is a high degree of correlation between lint percentage and lint index, a fact which is further borne out by the results of this experiment. In order to be accurate in the determination of the effect of fertilizers on the character of the lint and to check the results of the lint percentage calculations, the lint index of the various plots was derived and analyzed statistically by the Analysis of Variance method. Results are submitted in Table VI, page 29.

Discussion: The analysis of variance and table of data

TABLE VI

EFFECT OF CERTAIN INORGANIC FERTILIZERS ON LINT INDEX, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	Lint index
1. Check (no treatment)	7.0
2. 600 lbs. treble superphosphate	7.2
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	7.0
4. 150 lbs. nitrate of soda	6.9
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	6.8
6. 150 lbs. ammonium sulfate	7.0
Critical difference required for significance at .01	.7
at .05	.5

Analysis of Variance of Lint Index

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	9.0	.3
Borders	5	1.6	.3
Series	5	2.5	.5
Treatments	5	.7	.1
Error	20	4.2	.2

show that the application of treble superphosphate at the rate of 600 pounds per acre plus 150 pounds of ammonium sulfate caused the greatest reduction in lint index. Practically identical results were obtained from the use of nitrate of soda alone. Neither of these reductions was of sufficient magnitude to be significant when analyzed statistically. Treble superphosphate, applied singly, increased the lint index slightly when compared with the check, while the other treatments did not affect the lint index of the cotton studied. These results correspond very closely with those obtained in the lint percentage study. It may be concluded, therefore, that the lint index is not influenced by additions of these inorganic fertilizers.

Boll Size

The producer is aware of the desirability of obtaining larger bolls in order to reduce the cost of harvesting and to increase the amount of seed cotton produced by each plant. As previously reported, Bartholomew and Jannsen in 1928 found that one of the best methods of increasing yield is to increase the size of the bolls without decreasing the number of bolls.

Discussion: In the present experiment, the number of bolls per pound of seed cotton, which is an accurate measure of boll size, was significantly affected by treble superphosphate plus ammonium sulfate. The next largest bolls

were found in the plots receiving 600 pounds of treble superphosphate alone, but the increase in size was not enough to be significant statistically. Both of the nitrogen fertilizers reduced the size of the bolls. One may conclude, therefore, that the nitrogen decreased boll size and the phosphate tended to increase the size of the cotton bolls. The results are presented in Table VII, page 32.

Staple Length

The average length of the cotton fibers is one of the main factors in the determination of the price the farmer receives for his cotton. In most markets, premiums are paid for the longer-stapled cottons because of easier spinning due to reduction in breaks during the spinning process. On the other hand, lint cotton on the Arizona market which has a staple length of less than 15/16 inches sells at a discount. Any increase in staple length, therefore, is very desirable from the point of view of the farmer as well as the manufacturer. The effect of the various fertilizer treatments on the staple length and the statistical analysis are reported in Table VIII, page 33. The staple lengths are given in thirty-seconds of an inch.

Discussion: Highly significant increases in staple length resulted from the use of treble superphosphate, singly and in combination with ammonium sulfate. All other treatments caused increases in length of staple, although

TABLE VII

EFFECT OF CERTAIN INORGANIC FERTILIZERS ON BOLL SIZE, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	No. bolls per lb. seed cotton
1. Check (no treatment)	75.2
2. 600 lbs. treble superphosphate	73.1
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	76.6
4. 150 lbs. nitrate of soda	75.6
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	68.8
6. 150 lbs. ammonium sulfate	77.0
Critical difference required for significance at .01	8.1
at .05	6.0

Analysis of Variance of Boll Size

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	1,223.4	34.9
Borders	5	288.5	57.7
Series	5	113.9	22.8
Treatments	5	284.0	56.8
Error	20	537.0	26.8

TABLE VIII

EFFECT OF CERTAIN INORGANIC FERTILIZERS ON LENGTH OF STAPLE, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	In thirty-seconds of an inch
1. Check (no treatment)	32.9
2. 600 lbs. treble superphosphate	34.8
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	33.7
4. 150 lbs. nitrate of soda	33.9
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	34.5
6. 150 lbs. ammonium sulfate	33.3
Critical difference required for significance at .01	1.5
at .05	1.1

Analysis of Variance of Staple Length

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	40.9	1.2
Borders	5	5.4	1.1
Series	5	1.0	.2
Treatments	5	15.9	3.2
Error	20	18.6	.9

not enough to be significant even at the 5 per cent level. The increases in length over the check due to treble superphosphate plus nitrate of soda and to nitrate of soda alone approached significance at the 5 per cent level. In view of the results, therefore, treble superphosphate was responsible for a larger increase in staple length than was either of the nitrogen fertilizers. The cotton from the unfertilized plots yielded lint approximately one inch in length, while the application of treble superphosphate resulted in a staple length of over 1 1/16 inches. On the basis of the market quotations for the 1947 season, the longer lint would have sold for approximately 2 cents more per pound than the lint from the unfertilized plots.

Strength of the Fiber

Another very important factor in the determination of the quality of fiber is its strength index or breaking strength. It is measured by obtaining the weight in pounds required to break a small sample of cotton fibers divided by the weight of the sample in milligrams. In the textile industry, strength index is very important in the manufacture of certain special fabrics such as the cord in tires, belting, and so forth. A sample of fibers from each plot was tested for relative breaking strength on the Pressley breaking machine, and subjected to a statistical analysis. The results are shown in Table IX, page 35.

TABLE IX

EFFECT OF CERTAIN INORGANIC FERTILIZERS ON THE STRENGTH INDEX OF COTTON FIBERS, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	Strength index
1. Check (no treatment)	7.86
2. 600 lbs. treble superphosphate	7.75
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	7.97
4. 150 lbs. nitrate of soda	7.58
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	7.77
6. 150 lbs. ammonium sulfate	7.59
Critical difference required for significance at .01	.50
at .05	.37

Analysis of Variance of Strength Index

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	3.26	.93
Borders	5	.22	.04
Series	5	.36	.07
Treatments	5	.69	.14
Error	20	1.99	.10

Discussion: The table and analysis of variance show that both of the nitrogen fertilizers, when applied alone, caused an appreciable reduction in the strength of the fiber, but there was not enough difference to be significant even at the .05 level. The application of treble superphosphate plus nitrate of soda increased the strength index by .11 points. This was the only treatment which resulted in fibers stronger than the check. Treble superphosphate alone and in combination with ammonium sulfate reduced the breaking point of the fibers slightly. Neither the treble superphosphate nor either of the nitrogen fertilizers resulted in any clear-cut tendency to influence strength index. These results agree with those obtained by other investigators, which show that soil fertility has very little effect on the strength of cotton fibers.

Uniformity of Staple Length

The uniformity of length of fibers is a property which probably is just as important as length of staple. The ideal would be attained if all of the fibers were relatively strong and uniformly long. As previously stated, the uniformity of staple length refers to the percentage by weight of the three modal groups. In order to find out the effect of certain inorganic fertilizers on this fiber property, the samples from each plot were sorted according to length on the Pressley sorting machine and were analyzed

statistically. The results are reported in Table X, page 38.

Discussion: As can be readily observed from the data, four of the treatments increased the uniformity, while the other treatment resulted in a decrease. Treble superphosphate at the rate of 600 pounds per acre caused an increase of 3.7 per cent by weight of the three modal groups; 150 pounds of ammonium sulfate gave 1.8 per cent more uniform staple lengths; treble superphosphate plus nitrate of soda resulted in 1.3 per cent more lint in the three modal groups; and nitrate of soda alone increased the uniformity by 0.9 per cent. None of the increases, however, was of a sufficient magnitude to be statistically significant. Because treble superphosphate in combination with ammonium sulfate depressed staple uniformity, no definite conclusions as to beneficial or undesirable results can be stated. In other words, the fertilizers used in this experiment had very little effect on uniformity of staple length.

Percentage Waste

In the textile industry, all lint one-half inch or shorter in length is considered as waste and can not be used in the manufacture of most materials. Therefore, an analysis of the effect of fertilizers on percentage waste is of considerable importance. The fibers one-half inch

TABLE X

EFFECT OF CERTAIN INORGANIC FERTILIZERS ON THE UNIFORMITY OF STAPLE LENGTH, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	Per cent in three modal groups
1. Check (no treatment)	71.0
2. 600 lbs. treble superphosphate	74.7
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	72.3
4. 150 lbs. nitrate of soda	71.9
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	68.8
6. 150 lbs. ammonium sulfate	72.8
Critical difference required for significance at .01	6.2
at .05	4.7

Analysis of Variance of Uniformity of Staple Length

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	621.7	17.8
Borders	5	127.9	25.6
Series	5	59.3	11.9
Treatments	5	114.5	22.9
Error	20	320.0	16.0

or less in length, sorted by the Pressley sorting machine, were weighed and the percentage by weight figures obtained for each treatment. Table XI, page 40, shows the results.

Discussion: The application of treble superphosphate alone significantly lowered the percentage waste figures as compared with the check. The use of treble superphosphate with nitrate of soda actually increased the waste fibers by 0.3 per cent, while it resulted in 0.2 per cent more waste when applied with ammonium sulfate. The decrease in percentage waste due to treble superphosphate, therefore, appears to be inconclusive because it did not cause a similar result when applied in combination with the nitrogen fertilizers. Nitrate of soda alone reduced the waste by 0.4 per cent, which was not enough to be significant, while ammonium sulfate applied alone had no effect. More experimentation must be carried out before a definite statement can be made as to the effect on waste percentage to be expected from the use of these fertilizers.

Economic Returns from Use of Fertilizers

In a discussion of any soil-improving practice, such as the use of fertilizers, there is but one sound basis upon which the value of the practices can be measured, and that is profit. This is well demonstrated by the fact that only those practices which have proved profitable to the farmer have persisted and now have widespread application.

TABLE XI

EFFECT OF CERTAIN INORGANIC FERTILIZERS ON PERCENTAGE WASTE OF COTTON FIBER, WITH THE ACCOMPANYING STATISTICAL ANALYSIS

Treatment	Percentage waste
1. Check (no treatment)	11.6
2. 600 lbs. treble superphosphate	9.6
3. 300 lbs. treble superphosphate plus 150 lbs. nitrate of soda	11.9
4. 150 lbs. nitrate of soda	11.2
5. 600 lbs. treble superphosphate plus 150 lbs. ammonium sulfate	11.8
6. 150 lbs. ammonium sulfate	11.6
Critical difference required for significance at .01	1.6
at .05	1.2

Analysis of Variance of Percentage Waste

Treatment	Degrees Freedom	Sum Squares	Mean Squares
Total	35	76.0	2.2
Borders	5	17.9	3.6
Series	5	13.7	2.7
Treatments	5	22.5	4.5
Error	20	21.9	1.1

In order to determine money returns from the use of the fertilizers tested in this experiment, the cost of the fertilizers applied, the value of the increased lint, the net returns per acre, and the effect of cropping history on the net profit were calculated. The cost of the fertilizer materials appears in Table XII, page 42.

The calculation of the net returns per acre from the use of the fertilizers involved the determination of the value of the increase in lint, the increase in miscellaneous costs, and the total increase in cost. The increase in pounds of lint per acre was calculated from the yield of seed cotton and the computed lint percentage from each treatment. The value of the lint was derived from the average market quotations for cotton of the Middling grade and an average staple length of 1 1/16 inches. This average price was found to be 31.17 cents per pound during the 1947 season. The increase in miscellaneous costs refers to the cost of picking, hauling, ginning, storing, baling, and so forth of the increase in seed cotton resulting from the use of the fertilizers and in excess of the value of the increased yield of seed. The total increase in cost is the cost of the fertilizers plus the increase in miscellaneous costs. The net returns from the use of the fertilizers are reported in Table XIII, page 43.

Discussion: On the basis of the net returns per acre

TABLE XII

COST OF FERTILIZERS APPLIED

Treatment no.	Cost of fertilizer*	Delivery cost**	Cost of application+	Total cost
1	$-----	$-----	$-----	$-----
2	21.30	.60	3.50	25.40
3	14.93	.45	5.50	20.88
4	4.28	.15	2.00	6.43
5	25.37	.75	5.50	31.62
6	4.07	.15	2.00	6.22

*Based on market price per ton as of January 31, 1947.
**Based on a flat rate of $2.00 per ton.
+Based on the cost of sub-soiling at the rate of $3.50 per acre and drilling the fertilizer at $2.00 per acre.

TABLE XIII

NET RETURNS PER ACRE FROM USE OF FERTILIZERS

Treatment No.	Increased lint		Cost of fertilizers	Increased misc. costs	Total inc. in cost	Net return per acre
	Pounds	Value				
1	----	$----	$----	$----	$----	$ ----
2	18.7	5.83	25.40	.71	26.11	-20.28
3	44.2	13.78	20.88	1.69	22.57	- 8.79
4	- 1.4	- .44	6.43	- .06	6.37	- 6.81
5	60.4	18.83	31.62	2.33	33.93	-15.10
6	16.4	5.11	6.22	.62	6.84	- 1.73

it is apparent that the nitrogen fertilizers produced more pounds of lint per dollar invested in fertilizers than did the phosphate, although all of the treatments actually resulted in a money loss on the basis of the first-year returns. It must be realized, however, that the entire cost of the fertilizers was charged up to the first-year returns; and it is a well-known fact that in our Arizona soils there may be a residual effect carried over for a number of years after phosphates have been applied.

In a recent work by Volk[1] this residual effect of phosphorus was demonstrated very conclusively. He grew cotton continuously on the same plots for fourteen years and added 30, 60, 90, and 120 pounds of phosphoric acid to various plots the first seven of the fourteen years. At the end of seven years the application of phosphate was discontinued. The first or second year after discontinuing, all of the plots which had received the phosphorus dropped in yield by approximately 200 pounds of seed cotton per acre. In the fourth year after discontinuing the phosphate applications, those plots which had received only 210 pounds of phosphoric acid in seven years produced yields lower than those obtained from the check plots at the beginning of the

1. Volk, G.W. "Response to Residual Phosphorus of Cotton in Continuous Culture." Am. Soc. Agron. J.; 37:330-340 (1945).

test. The 60-pound plots maintained yields above the check for seven years after the treatments were stopped, while the 90- and 120-pound plots outyielded the check plots for a number of years after the seven-year period. Twenty-five per cent of the phosphorus was lost by erosion, which was two and one-half times as much as was assimilated by the plants.

As the work of Volk was carried out in Alabama on soils with an average pH of 5.5, one can expect a much greater residual effect on our alkaline soils in comparison with his results. It is inaccurate, therefore, to apply the cost of the fertilizer applications to the first year's profit and loss statement. Cotton will be grown on these same plots in 1948, and perhaps subsequent years, with no further phosphate applications in an effort to determine the residual effect, if any.

The effect of cropping history on the net returns from the use of the fertilizers is submitted in Table XIV, page 46. The increase in lint in each case was calculated from the average yields of each treatment in the three half borders previously cropped to cotton and in the three half borders previously cropped to alfalfa. A comparison of the results shows that there was a much greater return per dollar invested when the fertilizers were added to the "worn-out" land than was realized from the soil recently cropped to alfalfa. Table XIV also shows that the addition

TABLE XIV

EFFECT OF CROPPING HISTORY ON NET RETURNS PER ACRE FROM USE OF FERTILIZERS

Treatment no.	Increased lint		Cost of fertilizers	Increased misc. costs	Total inc. in cost	Net return per acre
	Pounds	Value				
			After Cotton			
1	-----	$ ----	$-----	$-----	$-----	$-----
2	16.2	5.05	25.40	.62	26.02	-20.97
3	78.9	24.59	20.88	3.11	23.99	.60
4	40.7	12.69	6.43	1.59	8.02	4.67
5	71.0	22.13	31.62	2.71	34.33	-12.20
6	51.0	15.90	6.22	1.96	8.18	7.72
			After Alfalfa			
1	-----	-----	-----	-----	-----	-----
2	22.1	6.89	25.40	.84	26.24	-19.35
3	7.0	2.18	20.88	.26	21.14	-18.96
4	-44.4	-13.84	6.43	-----	6.43	-20.27
5	50.1	15.62	31.62	1.96	33.58	-17.96
6	-18.9	- 5.89	6.22	-----	6.22	-12.11

of the nitrogen fertilizers alone to cotton after alfalfa caused quite a reduction in yield of lint per acre, with the greater reduction occurring after the nitrate of soda. This suggests a toxic effect of the sodium form of nitrogen and perhaps unbalanced nitrogen nutrition, since all plots receiving nitrogen alone were more vegetative. From these results one may conclude that the use of fertilizers immediately following alfalfa on heavy soils should be limited to phosphates.

CHAPTER V

SUMMARY AND CONCLUSIONS

Various inorganic fertilizers were applied to Upland cotton grown on Laveen clay loam soil at the Mesa Experiment Farm in the Salt River Valley near Mesa, Arizona, to study their effect on yield and fiber properties. The experiment was set up in a 6 x 6 Latin square design with treble superphosphate, nitrate of soda, and ammonium sulfate being used individually and in different combinations. Half of the plots used had grown cotton continuously for several years, while the others had grown alfalfa. First picking and total yields, lint percentage, lint index, boll size, staple length, strength index, and percentage waste were determined for each treatment. All of the data were analyzed statistically by the Analysis of Variance method. The economic returns per acre were calculated for each fertilizer treatment, and the results used as a criterion for determining the advisability of applying various types of fertilizers under the existing conditions. The effect of cropping history on yield and net returns also was calculated.

Except for the application of 150 pounds of nitrate of soda, all of the treatments resulted in increased

yields. The fertilizer materials were found to act much more efficiently on soil which had been planted to cotton for a number of years than when applied to land which had been previously cropped to alfalfa. Cropping history had a much greater effect on yield than did any of the various inorganic fertilizers.

Every treatment tended to hasten the maturity of the cotton crop, as evidenced by a greater percentage of the seed cotton being harvested at the first picking. Treble superphosphate had a greater effect on "earliness" than did either of the nitrogen fertilizers.

There was very little effect on lint percentage resulting from the use of the fertilizers.

Lint index was not materially influenced by the addition of these inorganic fertilizers.

Size of the bolls was not significantly affected by the various fertilizer treatments.

The cotton fibers were lengthened a sixteenth of an inch by the application of treble superphosphate. Smaller increases in staple length resulted from the nitrogen fertilizers, although the increases were not great enough to prove conclusively that the nitrogen was primarily responsible for the increase. The results of this study show that a proper phosphate balance is necessary for the maximum elongation of cotton fibers.

The strength of the cotton fibers was not affected significantly by the fertilizers used in this experiment.

No clear-cut tendency was shown on the part of any of these inorganic fertilizers to influence the uniformity of the staple length.

The fertilizers used in this experiment failed to influence, conclusively, the per cent of waste fibers.

From the standpoint of the first-year returns, none of the treatments resulted in a net profit when the returns from all of the plots were considered. When the cropping history was considered, the fertilizer applications returned a net profit in three of the five treatments on soil which had been planted to cotton for several years. Net losses occurred from every treatment on the soil previously cropped to alfalfa.

Nitrogen fertilizers alone should not be applied to a heavy soil which has been cropped to alfalfa for a number of years. On "worn-out" soil of the type used in this study, a fertilizer program involving the application of a small amount of phosphate (40 to 50 pounds of phosphoric acid) along with a heavier application of nitrogen (50 to 60 pounds) may be followed economically. More experimentation must be carried out, however, before widely applicable recommendations can be made. The importance of rotating cotton with alfalfa on heavy soils in Arizona must not be overlooked.

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