March, 1951

COTTON FERTILIZATION

AGRICULTURAL EXPERIMENT STATION

ORGANIZATION

BOARD OF REGENTS

HOWARD PYLE (ex officio) ..... Governor of Arizona
MARION L. BROOKS, M.A. (ex officio)
State Superintendent of Public Instruction

CLEON T. KNAPP, LL.B., President ..... Term Expires Jan., 1953
WILLIAM R. MATHEWS, A.B. ..... Term Expires Jan., 1953
WALTER R. BIMSON, Treasurer ..... Term Expires Jan., 1955
LYNN M. LANEY, B.S., J.D., Secretary ..... Term Expires Jan., 1955
JOHN G. BABBITT, B.S. ..... Term Expires Jan., 1957
MICHAEL B. HODGES ..... Term Expires Jan., 1957
JOHN M. JACOBS ..... Term Expires Jan., 1959
EVELYN JONES KIRMSE, A.M. ..... Term Expires Jan., 1959

JAMES BYRON MCCORMICK, S.J.D., LL.D. ..... President of the University
ROBERT L. NUGENT, Ph.D. ..... Vice-President of the University

EXPERIMENT STATION STAFF

PAUL S. BURGESS, Ph.D. ..... Director
RALPH S. HAWKINS, Ph.D. ..... Vice-Director

DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOILS

WILLIAM T. MCGEORGE, M.S. ..... Agricultural Chemist
THEOPHIL F. BUEHRER, Ph.D. ..... Physical Chemist
WALLACE H. FULLER, Ph.D. ..... Associate Biochemist
HOWARD V. SMITH, M.S. ..... Associate Agricultural Chemist
EDWARD L. BREAZEALE, M.S. ..... Assistant Agricultural Chemist
LOGAN L. BRIMHALL, B.S. ..... Assistant Agricultural Chemist (Phoenix)
GEORGE E. DRAPER, M.S. ..... Assistant Agricultural Chemist (Phoenix)

TABLE OF CONTENTS

PAGE

INTRODUCTION 3

COTTON FERTILIZATION 4

COTTON FERTILIZATION PROJECT 7

RANDOMIZED EXPERIMENT — SMALL PLOTS 8

1949 Experiments 10

1950 Experiments 13

SUMMARY 18

ILLUSTRATIONS

PLATE 1.—CUB TRACTOR AND FAIRBANKS APPLICATOR USED IN FERTILIZER EXPERIMENTS. 11

FIGURE 1.—COMPARATIVE FERTILIZER RESPONSE ON FIELDS JUST OUT OF COTTON AND FIELDS JUST OUT OF ALFALFA 9

FIGURE 2.—TYPICAL PLAN OF PLOTS AND TREATMENTS USED IN COTTON EXPERIMENTS, 1950 10

COTTON FERTILIZATION

By Logan L. Brimhall and W. T. McGeorge*

INTRODUCTION

At the present time cotton ranks first in acreage of all the crops grown in Arizona. Until a few years ago comparatively little commercial fertilizer was used in cotton production. Some fertilizer experiments had been conducted in the state but the results were not clearly conclusive and this was attributed largely to inability to control cotton insects. With better insect control interest in fertilization has increased and estimates have been made that 90 per cent of the cotton acreage will be fertilized in 1951.

While better control of insects has reduced this factor as a major cause of variable yields there are still a number of variables to consider in fertilizer use on cotton. Most of these involve the chemical, physical, and biological properties of the soil as they affect soil structure, soil moisture relations, and plant food availability. There is considerable evidence that fertilizer response varies with soil texture—that is, response is more often observed on light soils. There is also evidence that cotton in a rotation program gives better yields than continuous cotton; this is significantly true when cotton follows alfalfa in the rotation.

While many different chemical elements are needed to grow crops the three most frequently mentioned are nitrogen, phosphorus, and potassium. In fertilizer terms these are stated as nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O).

One way to estimate the amount of fertilizer needed to grow a crop is to determine how much plant food is sold off the land when the crop is harvested—in other words, how much is taken out of the soil by growing crops. Of course, in this connection it is advisable to know how much is present in the soil, for all soils contain a certain reserve supply of practically all the mineral elements needed by plants.

An approximate estimate for cotton is that in producing a bale of cotton (500 lb.) 65 lb. of nitrogen (N), 25 lb. of phosphate (P_2O_5), and 50 lb. of potash (K_2O) are needed. Cotton lint is practically pure cellulose and therefore contains little or no mineral matter. The only plant food sold off the land is that in the cottonseed. Some may be lost in the stalks and leaves which may not be returned to the soil. On the basis of seed production 1,000 lb. of seed is equivalent in terms of nitrogen, phosphate, and potash to:

	Nitrogen (N)	Phos. Acid (P_2O_5)	Potash (K_2O)
In the seed	38 lb.	18 lb.	14 lb.
In the leaves and stalk	27 lb.	7 lb.	36 lb.

*Some of the field experiments conducted in 1949 and 1950 were in cooperation with County Agricultural Agents; K.K. Henness, Pinal County, G.E. Blackledge, Pima County, A.R. Face, Yuma County, and S.L. Owens, Graham County.

In terms of fertilizer materials an approximate estimate of the fertilizer needed for growing a bale of cotton per acre would be as follows:

65 lb. nitrogen (N) from either	80 lb. ammonia gas 150 lb. uramon 200 lb. ammonium nitrate 310 lb. ammonium sulfate 400 lb. sodium nitrate 400 lb. calcium nitrate 310 lb. cyanamid
25 lb. phosphoric acid (P_2O_5) from either	40 lb. calcium metaphosphate 47 lb. liquid phosphoric acid 57 lb. treble superphosphate 122 lb. single superphosphate
50 lb. potash (K_2O) from either	100 lb. potash sulfate 84 lb. potash muriate

Now to consider the reserve supply of these in Arizona soils. On the basis of many chemical analyses of Arizona soils most of them contain, on an average, 1,600 to 3,000 lb. nitrogen (N), 8,000 to 16,000 lb. phosphoric acid (P_2O_5), and 80,000 lb. potash (K_2O) per acre-foot. This supply is sufficient to maintain plant growth for many years *provided* it is present in a readily available form —that is, a form that the roots can extract from the soil. Actually they are present in organic and mineral forms of widely variable availability. By means of chemical tests on the soil an attempt is made to determine the availability and, while chemical tests can be used as a guide to fertilization, the only completely reliable test is a fertilizer field test using different amounts and different combinations of fertilizer materials.

COTTON FERTILIZATION

With the increase in use of commercial fertilizer for growing cotton in the state there arose a need for experimental data for guidance. This report is a survey of fertilizer experiments on cotton which have been conducted in past years and of experiments now being conducted on this crop.

The earliest fertilizer experiments on record were conducted during the years 1920 to 1928 at the Mesa Experiment Farm and on ranches in the Salt River Valley. Reports on these are to be found in Annual Reports of the Experiment Station and in Experiment Station Bulletin No. 129.

The first experiments which were conducted on the Mesa Experiment Farm, 1920 to 1922, were not very encouraging from a fertilizer use standpoint. The following comparisons were made.

5 and 10 tons manure per acre
10 tons manure plus 300 lb. superphosphate
300 lb. treble superphosphate

500 lb. treble superphosphate plus 200 lb. sodium nitrate
500 lb. treble superphosphate plus 400 lb. cottonseed meal
200 lb. sodium nitrate
600 lb. sodium nitrate
700 lb. cottonseed meal
200 lb. 8-8-2 commercial fertilizer

No profitable response was obtained from any of these fertilizer applications.

In 1926 experiments were conducted on three ranches in the Salt River Valley and the following yields were obtained.

	lb. lint per acre		
	Creed ranch	Mesa farm	Traush ranch
10 tons manure per acre	527	304	295
10 tons manure plus 1,000 lb. treble superphos.	551	308	303
1,000 lb. ammonium sulfate	561	334	265
600 lb. ammonium sulfate plus 750 lb. treble super.	642	358	265
1,000 lb. treble superphosphate	347	354	228
Check, no fertilizer	459	310	288

On the Creed ranch nitrogen alone and nitrogen with phosphate gave response but there was no response to phosphate when applied without nitrogen. At the Mesa Experiment Farm there is only a small increase in yield from either nitrogen or phosphate. On the Traush ranch there is no evidence of fertilizer response even though the lint yields were the lowest of the three. Some potash tests were made in these experiments but the results are omitted as they did not show any effect on yield.

In 1927 fertilizer experiments were conducted on three additional ranches in the Salt River Valley with the following comparative yields.

	lb. lint per acre		
	Osborne Peoria	Smith Glendale	Litch-field
Check, no fertilizer	440	249	290
10 tons manure per acre	490	302	260
10 tons manure plus 500 lb. treble superphosphate	509	320	304
500 lb. ammonium sulfate	567	381	251
500 lb. ammonium sulfate plus 500 lb. treble super.	569	439	234
500 lb. treble superphosphate	424	278	259

On the Osborne and Smith ranches the soil is classed as light textured and on the Litchfield ranch the soil is heavy textured. On the light-textured soil the yields show a nitrogen response at both ranches and on the Smith ranch an additional response when phosphate was applied with the nitrogen. On the heavy soil there was no response to either nitrogen or phosphate even though the yields were low.

In 1928 two experiments were conducted on ranches in the Salt River Valley using smaller applications than had been used in previous experiments. The following comparative yields were obtained from these experiments.

	lb. lint per acre	
	Smith ranch	Lassen ranch
Check, no fertilizer	256	244
150 lb. ammonium sulfate per acre plus 142 lb. treble.	239	300
250 lb. ammonium sulfate plus 142 lb. treble super.	230	311
450 lb. ammonium sulfate plus 142 lb. treble super.	311	296
150 lb. ammonium sulfate	314	266
250 lb. ammonium sulfate	327	256
450 lb. ammonium sulfate	311	323

On the Smith ranch there was no response to phosphate — the best yields were obtained with nitrogen alone. On the Lassen ranch the data are not consistent for the lighter applications of nitrogen but additional yield was obtained when applied with phosphate. When 450 lb. per acre of ammonium sulfate was applied the yield from nitrogen alone is greater than when supplemented with phosphate.

In the *Fifty-ninth Annual Report of the Experiment Station* there is a report on an experiment with upland cotton at the Mesa Experiment Farm which gave the following comparative yields.

	lb. seed cotton per acre
Check, no fertilizer	1,300
300 lb. ammonium nitrate per acre	1,800
500 lb. ammonium nitrate	1,800
300 lb. treble superphosphate	1,450
300 lb. treble super. plus 300 lb. ammonium nitrate	2,200
300 lb. treble super. plus 500 lb. ammonium nitrate	2,200

The phosphate response in this experiment is small—possibly enough to pay for the fertilizer. Nitrogen plus phosphate gave a good response. This experiment indicates no additional response above 100 lb. nitrogen and 100 lb. P_2O_5.

In 1947 an experiment was conducted at the Mesa Experiment Farm, by the Agronomy Department, to compare fertilizer applications on land where cotton followed cotton and where cotton followed alfalfa. In this experiment the phosphate was applied at a depth of 10 inches, in bands, and the nitrogen was applied as a side dress. The following comparative yields were obtained.

	lb. seed cotton per acre	
	after cotton	after alfalfa
Check, no fertilizer	1,614	2,240
600 lb. treble superphosphate per acre	1,657	2,302
300 lb. treble super. plus 150 lb. sodium nitrate	1,835	2,260
300 lb. sodium nitrate	1,727	2,122

150 lb. sodium nitrate plus 600 lb. treble super.	1,806	2,382
150 lb. ammonium sulfate	1,753	2,192

This experiment presents some quantitative data on the value of alfalfa in a rotation which includes cotton. In both cases there was response to both nitrogen and phosphate although the response was not great. Yield of cotton on the fertilizer plots of land just out of cotton was not as great as the yield of unfertilized plots just out of alfalfa. In the *Fifty-eighth Annual Report of the Experiment Station* there is a report very similar to the above. In this case no profitable response was obtained with fertilizer on land just out of alfalfa but positive response was obtained on other lands of the Experiment farms.

In 1948 an experiment was conducted at the Mesa Experiment Farm on land that had a previous history of six continuous years in cotton. The soil analysis showed 8 ppm PO_4. The following comparative yields were obtained from this experiment.

	lb. seed cotton per acre
Check, no fertilizer	1,546
200 lb. 16-20 ammonium phosphate per acre	2,209
400 lb. 10-20 commercial fertilizer mix	2,203
200 lb. single superphosphate plus 200 lb. ammonium nitrate	2,045
400 lb. 10-10 commercial fertilizer mix	2,015
286 lb. 14- 6 commercial fertilizer mix	2,003
400 lb. 10-20 commercial fertilizer mix	1,934
100 lb. single super. plus 200 lb. ammonium nitrate	1,796
400 lb. single super. plus 200 lb. ammonium nitrate	1,796

Best response was obtained in this experiment from 16-20 and 10-20 nitrogen-phosphate combinations.

The fertilizer experiments on cotton which have just been presented are field experiments which have been previously reported in Experiment Station Bulletin 129 and in Annual Reports of the Experiment Station. These field trials show a wide variation in yield. Differences in soil type, in soil fertility, and other growth-limiting factors may have been involved. It is of interest that early experiments at the Mesa Experiment Farm did not show a profitable response to commercial fertilizer while in recent years definite response has been obtained. A number of field tests have been conducted by the extension service and, in general, the results obtained have been in harmony with other observations. These are no increase in yield from potash but frequent response to nitrogen and to nitrogen supplemented by phosphate.

COTTON FERTILIZER PROJECT

In 1947 a project was initiated to conduct an extensive study on the fertilization of field crops of which cotton is, of course, of major importance. It was planned to conduct these fertilizer experiments on private farms rather than on the farms of the Experiment Station. The first two years' work on this project was

more or less exploratory—primarily to make a survey of the existing fertilizer program from which a suitable experimental design could be developed for irrigated farms. In general these exploratory tests were located on large blocks of land. Due to "split" harvesting and other difficulties, reliable yield data proved difficult to obtain. On the whole these experiments were in most part observation experiments but were nevertheless worth the effort. A number of these large-scale field experiments were located on the Goodyear ranch, Litchfield. They involved phosphate and nitrogen applications, in which the nitrogen was applied in single and in split applications. Split applications, which meant that some of the nitrogen was applied late in the summer, delayed maturity and opening of the bolls. Such effects however would depend upon the length of the growing season and especially upon date of the first frost in the fall.

The exploratory experiments did show definite response to both nitrogen and phosphate in some cases but not in all the experiments. One of these large-scale experiments for which yield data are accurate is presented.*

This experiment was conducted on the Hodges ranch, Perryville, on land a part of which was just out of alfalfa and the rest just out of continuous cotton. The experiment covered an entire 42-acre field of which 21 acres had been in cotton continuously for six years and 21 acres had been in alfalfa the preceding four years.

Treble superphosphate was applied at rates of 300 and 600 pounds per acre in a band 10 inches deep and under the plant line. Nitrogen was applied as a side dress. The soil analysis showed a low available phosphate content. There was no consistent difference between the various fertilized plots so all were averaged for each of the 21 acres and compared with the average of all the unfertilized plots. The comparative yields are given in pounds seed cotton per acre in Figure 1.

While there was both nitrogen and phosphate response in both blocks of land the unfertilized land just out of alfalfa outyielded the fertilized land which had been in continuous cotton.

RANDOMIZED EXPERIMENTS — SMALL PLOTS

In conducting fertilizer experiments on private farms one is usually confronted with the desire of the farmer for large experimental blocks and few replications. This is what prompted the type of experiments to which reference has just been made. The experience gained during these two years showed that the use of large areas for fertilizer blocks is not advisable. Wide variations in soil conditions within large experimental areas, variations in depth of water penetration caused by variable slope and length of water run, inability to obtain accurate harvest data,

*For the first two years experiments were conducted by John Gray, Assistant Chemist.

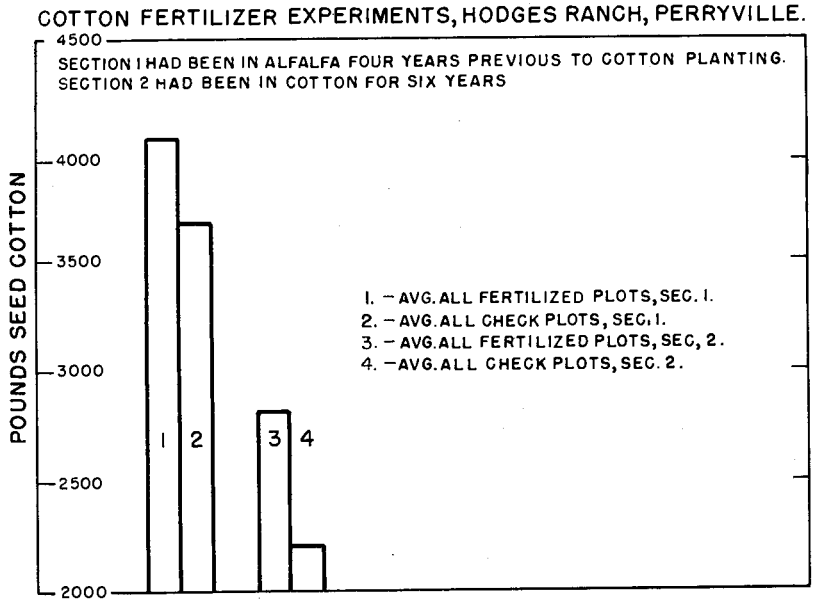

Figure 1.—Comparative fertilizer response on fields just out of cotton and fields just out of alfalfa.

and cost of fertilizer for large plots presented problems that could not be met with limited funds and personnel. In 1949 a small replicated plot plan was designed for use in future experiments. A typical example of such design is given. This plan was employed in conducting cotton fertilizer experiments in 1949 and 1950. Four replications of each treatment were made on plots four rows wide and 100 feet long. Various farms were selected with the help of the County Agricultural Agents in the cotton-growing counties. All the experiments were placed in fields with the regular cotton crop. All the fertilizer applications were made when the plants were 4 to 8 inches high—at thinning. The farmer irrigated and cultivated the experimental area just as for the rest of the field but the Experiment Station staff took care of fertilization and harvesting of the experimental plots. Even though the plots were small the harvesting data was quite accurate and therefore the yields are reported on an acre basis.

All applications of fertilizer were made with the experimental Fairbanks fertilizer applicator. Bands were placed on both sides of the plant row and as close as possible without disturbing the plants—namely 8 to 10 inches to the side and 4 to 6 inches deep. In most of the experiments conducted in 1949 ammonium nitrate was used as a source of nitrogen and treble superphosphate as a source of phosphate. In some of the 1950 experiments both ammonium nitrate and uramon were used as a source of nitrogen. Potash, as potassium sulfate, was used in a number of experiments.

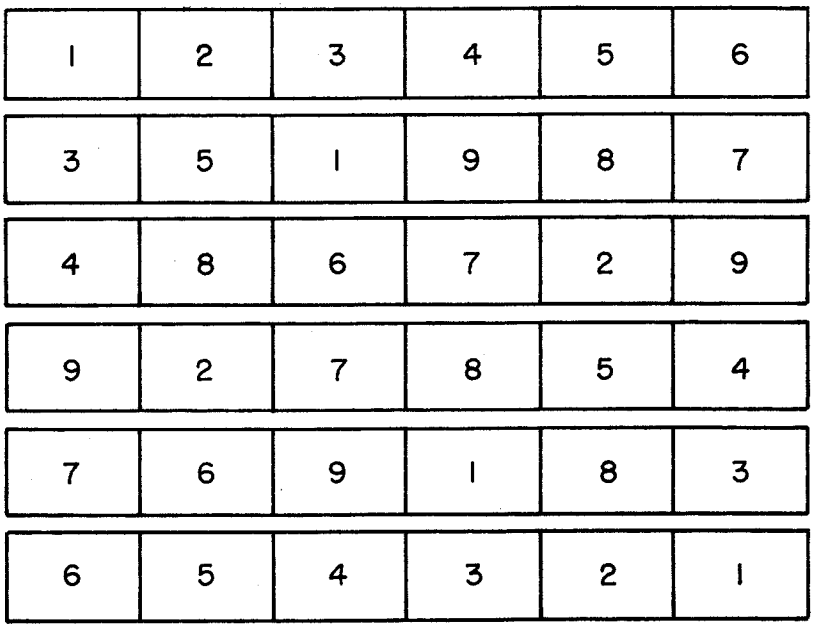

Figure 2.—Typical plan of plots and treatments used in cotton experiments 1950. In this plan the plots are four rows 100 feet long, each treatment replicated four times. N_1 represents 50 lb. N, N_2 100 lb. N., P_1 50 lb. P, and P_2 100 lb. P.

Plots no.	Treatment	Plot no.	Treatment
1	N_1	5	N_1P_1
2	N_2	6	N_1P_2
3	P_1	7	N_2P_1
4	P_2	8	N_2P_2

9 Check plot, no fertilizer

1949 EXPERIMENTS

Co-operator, Verl Brown, Litchfield, NE¼NW¼ Sec. 7 T2N R1W.

Before planting cotton in 1949 this field had been double cropped with hegari and barley and the land had been in alfalfa for three years preceding this. The soil is typical of the area, being rather light—loam or fine sandy loam. For the experiment the upper part of thirty-five rows near the center of the field was selected for uniformity of slope and soil texture.

The irrigation water used on this land contained 19 ppm nitrate nitrogen. The soil samples taken November 2, 1949, showed 500 ppm soluble salts, 9 ppm PO_4, and 7 ppm nitrate. As the experiment progressed it was evident that the plots fertilized with nitrogen were making better vegetative growth but at harvest time there was no apparent difference in appearance. The following comparative yields were obtained.

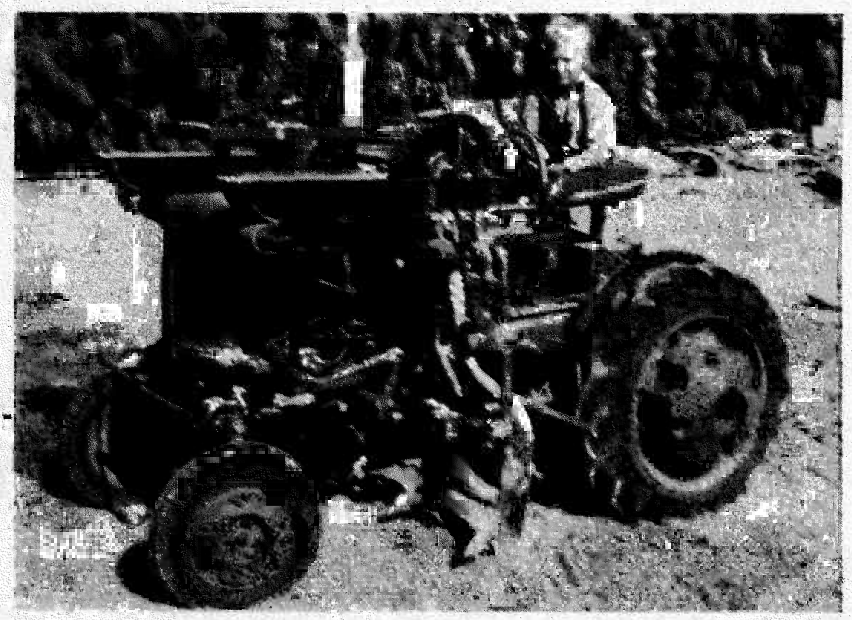

Plate I.—Cub tractor and Fairbanks applicator used in fertilizer experiments.

	lb. seed cotton per acre		
	first pick.	second pick.	total
20 lb. nitrogen	2,060	950	3,010
20 lb. nitrogen plus 25 lb. phosphate (P_2O_5)	2,355	550	2,905
Check, no fertilizer	2,200	635	2,835
70 lb. nitrogen plus 75 lb. P_2O_5	2,155	655	2,810
75 lb. P_2O_5	2,160	650	2,810
70 lb. nitrogen	1,980	915	2,885
70 lb. nitrogen plus 25 lb. P_2O_5	2,160	520	2,680
20 lb. nitrogen plus 75 lb. P_2O_5	2,045	530	2,575
25 lb. P_2O_5	2,040	500	2,540

There is no significant response to either nitrogen or phosphate in this experiment, and the nitrate content of the irrigation water and cropping history of the land may have been factors as the land was recently out of alfalfa.

Co-operator, A. W. Austin, Sec. 35 T2N R4E, Pima 32 long staple cotton.

The cropping history of this field was continuous cotton for eight years. The soil was rather light but had enough clay to become hard when dry. It is classified as a Mohave sandy loam. The seed was planted for a thin stand without chopping. Fertilizer was applied when the plants were 6 inches high. The stand was quite uniform.

Soil samples taken May 16, 1949, showed only 1 ppm PO_4 and 1 ppm nitrate which is of course extremely low. The nitrogen-fertilized plots showed a definite plant response and this was more evident in the plots at the upper end, nearest the irrigation ditch, where water penetration is usually deep. The experiment was located at the center of the field and extended from 50 feet from the ditch to about 300 feet from the lower end of the field. The following comparative yields were obtained from this experiment.

	lb. seed cotton per acre		
	first pick.	second pick.	total
70 lb. nitrogen plus 75 lb. phosphate (P_2O_5)	338	1,142	1,480
70 lb. nitrogen plus 20 lb. P_2O_5	333	1,020	1,353
70 lb. nitrogen	327	738	1,065
20 lb. nitrogen plus 75 lb. P_2O_5	384	661	1,045
25 lb. P_2O_5	405	569	974
75 lb. P_2O_5	344	641	985
Check, no fertilizer	369	556	925
20 lb. nitrogen plus 25 lb. P_2O_5	345	595	940
20 lb. nitrogen	317	580	897

The yield data for this experiment show response to both nitrogen and phosphate. Since the highest yield was obtained from the heaviest application of nitrogen and phosphate there is an indication that heavier applications of fertilizer might have increased the yield further. Further indication of this is evident in the soil analysis. Also chemical analyses were made of leaves taken from plants in this experiment and these showed that fertilization had increased the percentage of nitrogen, phosphate, and potash in the plant.

Co-operator, Allen Hutchins, Stanfield

This field had been in cotton continuously since it was taken out of the desert eight years previous to the installation of the experiment. The soil is medium textured. The soil analyses, samples taken June 9, 1949, showed 10 ppm PO_4 and 3 ppm nitrate. The comparative yields obtained from this experiment are given as follows.

	lb. seed cotton per acre
70 lb. nitrogen plus 75 lb. phosphate (P_2O_5)	1,676
70 lb. nitrogen plus 25 lb. P_2O_5	1,469
70 lb. nitrogen	1,458
20 lb. nitrogen plus 75 lb. P_2O_5	1,164
20 lb. nitrogen	1,077
20 lb. nitrogen plus 25 lb. P_2O_5	1,045
75 lb. P_2O_5	870
25 lb. P_2O_5	859
Check, no fertilizer	859

The fertilizer response in this experiment is in most part a nitrogen response. No response was obtained with phosphate alone but the phosphate-nitrogen combination gave the highest response.

Co-operator, Dale Gladden, Marana

The soil on which this experiment was conducted is typical of the large area of land cropped to cotton in the Marana district—a medium heavy soil which would probably be classed as silty clay loam. The experimental plots were located in an area which extended 150 feet from the head ditch to about the same distance from the lower end of the field. There was considerable difference in yield obtained from the several replications of different treatments in this experiment. The highest yields were from the plots nearest the irrigation ditch, and this indicates that the differences noted were due to difference in depth of water penetration. This is based on other observations which have shown that fertilizer response will be reduced or will be completely absent if water is allowed to become a limiting factor. The comparative yields obtained from this experiment were as follows.

	lb. seed cotton per acre		
	first pick.	second pick.	total
70 lb. nitrogen plus 75 lb. phosphate (P_2O_5)	2,388	47	2,434
20 lb. nitrogen plus 75 lb. P_2O_5	2,209	79	2,288
75 lb. P_2O_5	2,209	47	2,256
70 lb. nitrogen plus 25 lb. P_2O_5	2,097	156	2,253
70 lb. nitrogen	2,128	63	2,191
20 lb. nitrogen plus 25 lb. P_2O_5	2,129	47	2,176
20 lb. nitrogen	2,081	47	2,128
25 lb. P_2O_5	2,048	78	2,126
Check, no fertilizer	2,072	23	2,095

There is response to both nitrogen and phosphate in this experiment and the heaviest applications gave the highest yields. As already mentioned there was some variation in plot yields which was related to the distance from the head ditch. While response was noted in all the fertilized plots the yield increases were greatest for the plots where deeper penetration of water was obtained.

1950 EXPERIMENTS

Co-operator, Verl Brown, Litchfield

This experiment was located in the same field as the one conducted in 1949 but in a different section of the field. The rates of fertilizer applications were increased over those of the previous year. The following comparative yields were obtained.

	lb. seed cotton per acre
100 lb. nitrogen plus 50 lb. phosphate (P_2O_5)	4,220
100 lb. nitrogen	4,120
100 lb. nitrogen plus 100 lb. P_2O_5	3,890
50 lb. nitrogen	3,580
50 lb. nitrogen plus 100 lb. P_2O_5	3,545
50 lb. nitrogen plus 50 lb. P_2O_5	3,620
100 lb. P_2O_5	3,170
50 lb. P_2O_5	3,020
Check, no fertilizer	2,900

The yields for the check, no fertilizer, plots was about the same for both 1949 and 1950 but slightly higher for the latter. The fertilized plots were all higher in 1950 and show a definite response to nitrogen and a slight additional response to nitrogen supplemented by phosphate. It may be significant that the growing season was longer in 1950.

Co-operator, A. W. Austin, Scottsdale, long staple cotton.

This experiment is a continuation of the 1949 experiment conducted on this ranch and was repeated because of the very low soil analysis for this land and the fact that in 1949 the highest yield was obtained from the heaviest fertilizer application. The cotton was again planted thinly in order to eliminate thinning. The 10th consecutive year in cotton for this land was 1950 and, in view of this, the test was modified to include some tests with potash. The following comparative yields were obtained from this experiment.

	lb. seed cotton per acre
100 lb. nitrogen plus 100 lb. phosphate (P_2O_5)	1,810
100 lb. nitrogen plus 100 lb. P_2O_5, plus 100 lb. potash (K_2O)	1,730
100 lb. nitrogen (uramon)	1,640
100 lb. nitrogen (ammonium nitrate)	1,525
100 lb. nitrogen plus 100 lb. K_2O	1,365
Check, no fertilizer	1,210
100 lb. K_2O	1,170
100 lb. P_2O_5	1,145
100 lb. P_2O_5 plus 100 lb. K_2O	1,030

The comparative yields in this table show response to both nitrogen and phosphate and all, checks included, are higher than in 1950. There was no response to potash either alone or in combination with nitrogen and phosphate. Phosphate shows no response when nitrogen is a limiting factor.

Co-operator, Bob Palmer, Casa Grande, SW¼ Sec. 30 T6S R7E.

The soil in this experiment was a silt loam of the Casa Grande series; and the area is about 5 miles east of Casa Grande. The land had been in cotton three years. Soil analyses of samples taken February 24, 1950, showed 3 ppm PO_4 and 6 ppm nitrate. The comparative yields from this experiment are given as follows.

	lb. seed cotton per acre
100 lb. nitrogen plus 100 lb. phosphate (P_2O_5)	3,780
100 lb. nitrogen plus 100 lb. P_2O_5 plus 100 lb. potash (K_2O)	3,750
100 lb. nitrogen plus 100 lb. K_2O	3,430
100 lb. nitrogen (ammonium nitrate)	3,370
100 lb. nitrogen (uramon)	3,230
100 lb. P_2O_5 plus 100 lb. K_2O	2,595
100 lb. P_2O_5	2,465
100 lb. K_2O	2,640
Check, no fertilizer	2,460

All the nitrogen fertilized plots had a much greener color and were about a foot and a half taller than the no-nitrogen plots. The yield data show a nitrogen response and an additional response when phosphate was applied with the nitrogen. There was no yield response for potash.

Co-operator, Cecil Montgomery, Casa Grande

This experiment was located on a medium light textured soil which had been continuously in cotton for several years. The ranch joins the Hutchins ranch, on the east, where a fertilizer experiment was conducted in 1949. The analysis of soil samples taken May 10, 1950, showed 11 ppm PO_4 and 2 ppm nitrate. The comparative yields obtained from this experiment were as follows.

	lb. seed cotton per acre
100 lb. nitrogen	2,190
100 lb. nitrogen plus 50 lb. phosphate (P_2O_5)	2,145
100 lb. nitrogen plus 100 lb. P_2O_5	2,075
50 lb. nitrogen plus 100 lb. P_2O_5	1,675
50 lb. nitrogen plus 50 lb. P_2O_5	1,600
50 lb. nitrogen	1,645
100 lb. P_2O_5	990
Check, no fertilizer	965
50 lb. P_2O_5	930

There was a significant fertilizer response in this experiment. In the plots where greatest response was obtained the plants were about twice the height of the unfertilized plants. The response however is to nitrogen only. A comparison of the yields obtained in this experiment with the yields obtained on the Hutchins ranch in 1949 show a greater yield for 1950, which was a longer growing season.

Co-operator, R. D. Brittian, Magma, NE¼ NW¼ Sec. 3 T4S R9E.

This experiment was located on a moderately heavy soil and the crop was the fourth consecutive year in cotton. Previous to this the field had been in alfalfa. The analysis of soil sample taken May 4, 1950 showed 3 ppm PO_4 and 5 ppm nitrate. Following are the comparative yields from this experiment.

	lb. seed cotton per acre
100 lb. nitrogen plus 100 lb. phosphate (P_2O_5)	3,775
100 lb. nitrogen plus 50 lb. P_2O_5	3,745
100 lb. nitrogen	3,710
50 lb. nitrogen plus 50 lb. P_2O_5	3,475
50 lb. nitrogen	3,350
50 lb. nitrogen plus 100 lb. P_2O_5	3,340
100 lb. P_2O_5	2,850
Check, no fertilizer	2,775
50 lb. P_2O_5	2,765

The major response in this experiment is to nitrogen even though the soil analysis indicated a deficiency of available phosphate. This may be due to the fact that this is a heavy soil.

Co-operator E. I. Palmer, Thatcher

This experiment was located in the Safford Valley on a medium heavy soil which has been continuously in cotton for several years. The analysis of the soil sample showed 8 ppm PO_4 and 12 ppm nitrate. The following comparative yields were obtained from this experiment.

	lb. seed cotton per acre
50 lb. nitrogen	2,695
50 lb. nitrogen plus 100 lb. phosphate (P_2O_5)	2,475
50 lb. P_2O_5	2,460
Check, no fertilizer	2,430
100 lb. nitrogen plus 50 lb. P_2O_5	2,400
50 lb. nitrogen plus 50 lb. P_2O_5	2,375
100 lb. nitrogen plus 100 lb. P_2O_5	2,355
100 lb. P_2O_5	2,310
100 lb. nitrogen	2,285

This experiment shows no response to either nitrogen or phosphate. The same experiment was conducted on four other ranches: namely, Lee Johns, Lone Star; Otto Mack, Safford; Angel Escabedo, Safford; and Silas Jarvis, Geronimo. Only the Palmer experiment was harvested, as none showed any apparent response. In general the comparison of yields shows some inconsistency and further experiments are needed in this valley before definite conclusions can be drawn. The yields are not as great as in the preceding experiment on the Brittian ranch which was also located on a heavy soil.

Co-operator, Wayne Wright, Roll.

This experiment was located in the Roll Valley on a silty clay loam soil. The analysis of a soil sample taken May 24, 1950, show 4 ppm PO_4 and 6 ppm nitrate. The following comparative yields were obtained from this experiment.

	lb. seed cotton per acre
100 lb. nitrogen (ammonium nitrate)	3,840
100 lb. nitrogen (uramon)	3,720
100 lb. nitrogen; 100 lb. P_2O_5; 100 lb. K_2O	3,650
100 lb. nitrogen; 50 lb. P_2O_5	3,600
50 lb. nitrogen (ammonium nitrate)	3,515
100 lb. nitrogen; 50 lb. P_2O_5	3,380
100 lb. nitrogen; 100 lb. P_2O_5	3,345
50 lb. nitrogen; 100 lb. P_2O_5	3,270
50 lb. nitrogen; 50 lb. P_2O_5	3,150
50 lb. P_2O_5	2,890
Check, no fertilizer	2,820
100 lb. P_2O_5	2,725

The response in this experiment is entirely to nitrogen, no response to either phosphate or potash.

Co-operator, Dale Gladden, Marana.

This experiment was located in a field about 2 miles from the

experiment conducted on this ranch in 1949. The soil is a silt loam and representative of the type of soil existing in this extensive cotton area. The following comparative yields were obtained from this experiment.

	lb. seed cotton per acre
100 lb. nitrogen plus 50 lb. phosphate (P_2O_5)	3,740
100 lb. nitrogen plus 100 lb. P_2O_5	3,610
100 lb. nitrogen	3,610
Check, no fertilizer	2,630

As in the 1949 experiment the major response is to nitrogen with little evidence that phosphate fertilization will be profitable on this soil. Yields for the 1950 experiment were greater than for 1949 and the response to nitrogen is greater.

Co-operator, Earl Horton, Marana.

This experiment was located on land about 1 mile north of the Dale Gladden experiment. The soil type is very similar on both ranches. The experimental plots extended almost the entire length of the quarter-mile-long rows and it is believed that difference in water penetration, quite often a condition to be found in long irrigation runs, had some influence on the uniformity of yields. The highest yields among the replicated plots were at the lower end of the rows. The slope of the field was such as to give more water at the lower end. However all plots are averaged and the comparative yields obtained were as follows.

	lb. seed cotton per acre
100 lb. nitrogen plus 100 lb. phosphate (P_2O_5)	4,070
100 lb. nitrogen plus 100 lb. potash (K_2O)	3,900
100 lb. nitrogen plus 100 lb. P_2O_5 plus 100 lb. K_2O	3,630
100 lb. nitrogen	3,500
Check, no fertilizer	2,990
100 lb. P_2O_5 plus 100 lb. K_2O	2,870

Here again the major response is to nitrogen with an additional increase in yield when nitrogen is supplemented by phosphate. There is no response to phosphate or potash when nitrogen is a limiting factor.

Co-operator U.S. Field Station, Sacaton.

This experiment was located on the long staple cotton block at the U.S. Field Station. The field had been leveled before planting and this leveling operation created a fertility gradient from north to south and this influenced the plot yields somewhat. An analysis of the irrigation water used on this field showed a nitrate content equivalent to 37 pounds nitrate nitrogen per acre-foot which should take care of the nitrogen requirement of the crop. The soil was quite sandy and very low in organic matter. In view of this an additional treatment was included in the experiment: namely a side dressing of manure. These plots produced plants that were definitely better than those in all the other plots.

The response to manure was greater at the south end of the field where the leveling operation had cut deeper than at the north end where the leveling was less severe. The following comparative yields were obtained from this experiment (long staple cotton).

	lb. cotton lint per acre
Manure side dress, 4½ tons per acre	658
100 lb. nitrogen; 100 lb. P_2O_5; 100 lb. K_2O	626
100 lb. P_2O_5	605
100 lb. nitrogen; 100 lb. P_2O_5	588
Check, no fertilizer	570
100 lb. nitrogen	501

It is somewhat difficult to interpret the yields in this experiment as 4.5 tons of manure would not contain enough plant food to give a greater response than the chemical fertilizers. Since water is such an important factor in growth of cotton it is possible that this method of manure application may have improved the water-holding capacity of the soil. At all events the manure produced the highest lint yield.

SUMMARY

Reliable harvesting data were obtained for four cotton fertilizer experiments in 1949 and ten in 1950. These experiments were located in widely scattered sections of the state. In general, the major fertilizer response is for nitrogen. Phosphate fertilizers have given lesser response and no response when nitrogen is deficient and a growth-limiting factor. On the other hand, nitrogen gives a response on nitrogen deficient soils when phosphate is deficient. When both nitrogen and phosphate are deficient in the soil the major response is to nitrogen but an additional increase in yield is obtained when phosphate is applied with the nitrogen. In the experiments thus far conducted there has been no increase in yield from potash either alone or in combination with nitrogen and phosphate except possibly in the experiment at Sacaton on long staple cotton. The results obtained in this experiment are not conclusive. In other words, for the soils on which these experiments were located, fertility is largely an adjustment of the N: P_2O_5 balance in the soil and, since it takes twice as much nitrogen as phosphate to produce a crop of cotton, the response and the limiting effect of nitrogen are greater.

To date the experiments indicate that 100 lb. nitrogen and 50-100 lb. P_2O_5 per acre are desirable and reasonable amounts to apply in fertilizing this crop. Nitrogen alone gives the more profitable yield in proportion to pounds per acre applied, but if phosphate is deficient nitrogen plus phosphate will give the highest yield. Phosphate is considered a less efficient fertilizer than nitrogen because of its lesser mobility in the soil and so it must be applied in proportionately larger amount than nitrogen. On the basis of pounds applied to pounds which the crop actually uses

nitrogen fertilizers are more efficient. The adjustment of the $N:P_2O_5$ balance is one that must be attained in the soil and is not necessarily the same as that in the fertilizer applied to the soil.

The fourteen experiments for which reliable data were obtained in 1949 and 1950 are summarized in Table 1. In this table the yields of seed cotton in pounds per acre is given in Column 2 for the unfertilized plots and for the highest yielding fertilized plots in Column 3. The difference, or increase, is given in Column 4. In the last two columns the pounds N and P_2O_5 which gave the highest yields are given. For comparison where the highest yield was obtained with nitrogen plus phosphate the yield for nitrogen alone is given and where the highest yield was obtained with nitrogen alone the yield for nitrogen plus phosphate is given.

In four of the eleven experiments with short staple cotton the highest yield was obtained with nitrogen alone. For the other seven experiments in which the highest yields were obtained with nitrogen plus phosphate the increase in yield over nitrogen alone was less than 150 pounds seed cotton per acre.

The comparative yields on the different ranches, both for the fertilized and unfertilized plots, is of interest. The yields on the unfertilized plots in 1949 varied from 859 to 2,835 pounds per acre and on the fertilized plots from 1,676 to 3,010 pounds. In 1950 the yields varied from 965 to 3,520 pounds on the unfertilized plots and from 2,190 to 4,200 on the fertilized plots. These figures are presented to illustrate the variation in productive capacity of lands being cropped to cotton in the state. The yields for the two years are given separately because a late fall and longer growing season undoubtedly contributed to the higher yields in 1950. This is shown by the yields obtained on two ranches where experiments were conducted both years. The wide range in productive capacity for this group of soils is shown by the range in yields, and increase in yields, obtained by fertilization with nitrogen and/or phosphate. On six ranches the yields were increased 800 pounds seed cotton or more per acre and the total yields varied between 1,676 and 4,220.

While many cotton lands in Arizona can be profitably fertilized there are other factors than plant food deficiency which must be in harmony for maximum production. Some of these are as follows:

Soil
- Soil fertility—plant food supply
- Soil moisture—holding capacity and availability
- Soil structure and texture
- Cultural practices

Climate
- Length of growing season
- Air and soil texture

Insects and plant diseases.

A striking example of limiting productive capacity is illustrated by experiments conducted on two ranches at Ocatillo in co-opera-

TABLE 1.—POUNDS PER ACRE OF SEED COTTON ON UNFERTILIZED PLOTS, HIGHEST YIELDS ON FERTILIZED PLOTS, HIGHEST INCREASE FROM FERTILIZATION, AND POUNDS N AND P_2O_5 WHICH GAVE THE HIGHEST YIELDS.

Co-operator	Unfert. plot	Highest fertilized plots	Increase yield	lb. N	lb. P_2O_5
Short staple cotton — 1949					
Brown	2,835	2,905		20	25
Brown	2,835	3,010	175	20	0
Hutchins	859	1,458		70	0
Hutchins	859	1,676	817	70	75
Gladden	2,095	2,191		70	0
Gladden	2,095	2,434	339	70	75
Short staple cotton — 1950					
Brown	2,900	4,120		100	0
Brown	2,900	4,220	1,320	100	50
Gladden	3,620	3,610		100	0
Gladden	3,620	3,740	120	100	50
Bob Palmer	2,460	3,300		100	0
Bob Palmer	2,460	3,780	1,320	100	100
Montgomery	965	2,145		100	50
Montgomery	965	2,190	1,225	100	0
Brittian	2,775	3,710		100	0
Brittian	2,775	3,775	1,000	100	100
E. I. Palmer	2,430	2,475		50	100
E. I. Palmer	2,430	2,695	265	50	0
Wright	2,820	3,600		100	50
Wright	2,820	3,840	1,020	100	0
Horton	2,990	3,500		100	0
Horton	2,990	4,070	1,080	100	100
Long staple cotton — 1949					
Austin	925	1,065		70	0
Austin	925	1,480	555	70	75
Long staple cotton — 1950					
Austin	1,210	1,580		100	0
Austin	1,210	1,810	600	100	100
Sacaton	570	626	56	100	100

tion with the Fertilizer Division of the Tovrea Land & Cattle Co. The two farmers reported low yields and no fertilizer response. The soil analysis showed a good supply of available phosphate. The soil is a sandy type and there is some evidence that its pro-

ductivity capacity may be limited by factors other than fertility —possibly the water-holding capacity of the soil is the limiting factor. The fertilizer comparisons made on these two ranches were nitrogen, phosphate, nitrogen plus phosphate, and a manure mixture to which iron sulfate had been added. There was no response to any of these treatments at any time during the growing period and the yields were not increased. Growth was quite uniform. Further experiments will be necessary to determine the growth-limiting factor.

The influence of moisture relationships was clearly evident in several of our field experiments. That is, better response to fertilizer was obtained in some of the plots which were nearest to the irrigation ditch. More water was stored in the soil at this point at each irrigation. The ability of the soil to store water depends upon the rate of penetration during the irrigation, the length of time the water is on the land, and the water-holding capacity of the soil. The water is on the land for a longer period at the head of the irrigation run and at the lower end where the water is held back by the end of the furrow. The evidence gained from our experiments showed that poor water penetration, or moisture stress, affects phosphate response more than nitrogen response.

This report is in the nature of a progress report on cotton fertilization and the experiments are being continued.