THE EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON THE YIELD AND CAROTENE CONTENT OF SWEETPOTATOES

by

AFTAN ZGHEIR AL-RAWI

B. S., Kansas State College of Agriculture and Applied Science, 1953

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1953

CONTENTS

INTRODUCTION

Sweetpotatoes are considered an important vegetable crop both in Kansas and in the United States. Climatic conditions in Kansas are favorable, and a considerable area in the state is suitable for the production of the crop. The area in sweetpotato production in Kansas for the ten year period of 1940 through 1949 averaged 2,000 acres annually. The average production of sweetpotatoes in the state during the same ten year period was 236,000 bushels annually. The major producing areas which are suitable for sweetpotatoes in Kansas are located in the valleys of the Kansas and Arkansas Rivers. The flood of 1951 covered most of these areas. Sweetpotato growers in these areas are interested in learning to manage this flooded soil and this has been one of the main objectives of this study.

The outstanding value of sweetpotatoes as a food is not generally appreciated. Pound for pound, they contain about 50 percent more food value (calories) than the Irish potato. Varieties with deep orange-colored flesh are among the richest sources of carotene; and the sweetpotato compares favorably with the tomato as a source of vitamin C. The carbohydrate and protein content of sweetpotatoes are similar to those of polished rice, but the sweetpotato has the marked advantages of having, in addition, a high content of vitamins A and C.

Many people believe that sweetpotatoes are a poor land crop. There is probably no such crop. Sweetpotatoes can produce profitable yields only on soils of good fertility, either natural or added in the form of manures and commercial fertilizers. Many cultivated lands in Kansas do not have sufficient nutrients for maximum yield of sweetpotatoes. This has encouraged the sweetpotato growers in the state to use commercial fertilizers to increase their yields.

Much of this cultivated sweetpotato land was covered with a sandy soil material by the flood of 1951. The growers have now become increasingly interested in learning what fertilizers, if any, should be used on this type of soil tp produce maximum yields of sweetpotatoes.

OBJECTIVES OF THE EXPERIMENT

The objectives of this study were to determine: (1) the yield of sweetpotatoes on a flooded soil, (2) the optimum levels of nitrogen, phosphorus, and potassium for the maximum yield of sweetpotatoes on a flooded soil, and (3) to determine whether fertilizer has any effect on carotene content of sweetpotatoes.

REVIEW OF LITERATURE

Voorhees (1898) in New Jersey, stated that 200 bushels of sweetpotato roots contain on the average 30 pounds of nitrogen, 10 pounds of phosphorus, and 45 pounds of potassium.

Kiett (1912) in South Carolina, has shown in several analyses that the Yellow Jersey sweetpotatoes yield of 214 bushels per acre removed 0.213 percent of nitrogen, 0.0519 percent of phosphorus, and 0.39 percent of potassium.

Scott (1920) in Florida, reported for Triumph sweetpotatoes a 5-year average total yield of 65 bushels per acre on plots receiving 112 pounds of dried blood plus 224 pounds of superphosphate, whereas plots treated with an additional 84 pounds of murate of potash yielded 204 bushels per acre.

Schermerhorn (1924) in New Jersey, reported a fertilizer experiment on Yellow Jersey consisting of a 21-mixture fertilizer triangle, or balanced ratio comparison in which a 4-8-4 was the basic formula. Each mixture was made up with the sum total of plant-food elements amounting to 16. The three fertilizer elements, nitrogen, phosphorus, and potassium were each used in amounts varying from 2 to 12 percent. The results showed that as the potassium decreased, the yield of marketable roots decreased; and vice versa, as the potassium was increased up to 8 percent there was a decided increase in yield. It was also recorded that as the nitrogen was increased above 3 percent, there was a decrease in yield. He concluded that under average conditions, 1000 to 1500 pounds per acre of a 3-8-8 fertilizer mixture gave the best results.

Zimmerley (1929) in Virginia, conducted a study with a 21-mixture triangle system of treatments, each constituent in the mixture varying in 3 percent steps. One thousand pounds per acre were applied before planting. The 9-year mean yield of prime roots of Big Stem Jersey showed an almost perfect rank-order correlation with potassium percentage in the mixtures. Regardless of the percentage of nitrogen and phosphorus, the mean yield increased from 197 bushels per acre for the 3-15-3 plots to 289 bushels for the 3-3-15 plots.

J. J. Skinner, C. B. William, and H. B. Mann (1932) worked at a number of locations in North Carolina, with several varieties of sweetpotatoes and soil types. With a 21-mixture triangle system of treatments they obtained different results under the various conditions. In most cases yields increased slightly with increasing potassium up to 6 or 9 percent, then decreased for 12 and 15 percent. In several cases the 0-0-15 treatment yielded less than the mixture without potassium, probably because of the absence of the nitrogen and phosphorus from the treatments.

Woodard (1932) in Georgia, studied the effect of increasing potassium in 2 percent steps when nitrogen and phosphorus were held constant at 4 and 8 percent in 800 pounds of the mixtures applied to sweetpotatoes on a sandy loam soil. Yield of No. 1's increased from 70 bushels per acre for no potassium up to 150 bushels per acre for 6 percent potassium. Yields from the 8 and 10 percent potassium treatments were not significantly greater than the 6 percent treatments.

Knapp (1922) in Arkansas working with Nancy Hall and Porto Rico varieties of sweetpotatoes obtained good results from a 3-8-2 mixture, and negative results from the use of additional quantities of potassium.

Scott and Ogle (1952) at the University of Maryland, studied the mineral uptake by sweetpotatoes and emphasized the high rate of potassium utilization by this crop and the relatively low requirement for phosphorus. Nitrogen uptake was found to exceed the amount supplied in the fertilizer program. About half of the total uptake of nitrogen and phosphorus were found in the harvested crop. They recommended high potassium fertilization for sweetpotatoes, emphasized relatively low phosphorus requirement of the crop, and suggested that nitrogen applications may be of value under certain conditions.

Quinn (1926) working with Porto Rico sweetpotatoes on a silt loam soil in the North Eastern part of Missouri, found that only a slight gain was effected by using a fertilizer containing all three constituents. The yields from the mixture were only slightly better than from potassium alone.

Miller and Kimbrough (1936) in Louisiana, set up a study on fertilizer requirements of sweetpotatoes. They found that on land that had not been fertilized for some years, 4-8-0 yielded 290 bushels of No. 1's per acre, and with increase of fertilizer the yield increased gradually up to 321 bushels for 4-8-10. On fields that had been intensively cropped and fertilized for several years there were no significant increases due to potassium application.

Swanson (1933) did not find any relationship between nitrogen fertilizers and carotene content of sweetpotatoes using a biological test for carotene.

Whittemore (1933) and Feller, (1934) reported no increase in the carotene content of sweetpotatoes from the use of potassium fertilizer.

Samuel and Landran (1952) reported that the use of nitrogen fertilizers influenced the carotene content of sweetpotatoes. Where nitrogen applications produced yield increases, there were also increases in the carotene content of the sweetpotatoes. They also found that increases in carotene content were obtained with phosphorus only when the yields were significantly increased by the addition of the element. Potassium applications, even though they increased the yield, had no significant effect on carotene content.

METHODS AND MATERIALS

The Soil

The land on which the sweetpotatoes were grown is located at the northwest corner of the Horticulture farm, which is south of Manhattan, Kansas. The soil, a deep silt loam, was flooded in 1951 and covered with a sandy loam layer about 12 inches deep. Soil tests showed a pH. of 7.4, organic matter content of 0.2 percent, available phosphorus 150 pounds, and exchangeable potassium 388 pounds per acre.

The Fertilizers

Three fertilizer elements, each at three levels, were used in this experiment. These fertilizers and their levels are shown below:

Nitrogen, expressed as "N" lbs per acre	Phosphorus, expressed as "P_2O_5" lbs per acre	Potassium, expressed as "K_2O" lbs per acre
150	200	150
50	100	50
0	0	0

All combinations of these levels have been studied making a total of 27 fertilizer treatments. These treatments are listed under the experimental design. Ammonium nitrate (33.5 % N) was used as the source of nitrogen, treble superphosphate (45% P_2O_5)as the source of phosphorus, and potassium chloride (60% K_2O) as the source of potassium. The amounts required for each treatment were accurately calculated and prepared according to the amount of fertilizer required.

Experimental Design

Sweetpotato slips were planted 15 inches apart in rows spaced 3.5 feet apart. Each treatment had 20 plants. The treatments were randomized within each block and replicated four times. The 27 fertilizer treatments that were used are listed in Table 1.

Table 1. Fertilizer treatments used in the experiment.

Treatment number	Fertilizer application*		
	Nitrogen lbs per acre	Phosphorus lbs.per acre	Potassium lbs. per acre
1	0	0	0
2	0	0	50
3	0	0	150
4	0	100	0
5	0	100	50
6	0	100	150
7	0	200	0
8	0	200	50
9	0	200	150
10	50	0	0
11	50	0	50
12	50	0	150
13	50	100	0
14	50	100	50
15	50	100	150
16	50	200	0
17	50	200	50
18	50	200	150
19	150	0	0
20	150	0	50
21	150	0	150
22	150	100	0
23	150	100	50
24	150	100	150
25	150	200	0
26	150	200	50
27	150	200	150

* Expressed as available nitrogen, (N); P_2O_5; and K_2O.

Planting

The Variety. The Orlis variety of sweetpotatoes was used in this experiment. It is a mutation from the Little Stem Jersey type and was released by Dr. O. H. Elmer, Botany Department of Kansas State College, in 1946. It is adapted to local conditions and has good yielding ability. The roots of this variety are not subject to shriveling during storage, they have a reddish-bronze skin color, are of an oblong shape with blunt ends, and the flesh is of a uniformly dark orange color. More details about this variety is given by Elmer (1950).

Slip Production. The plants were produced according to normal horticultural practices, with the exception that they were grown in a greenhouse instead of a hotbed. Wettable Phygon (two ounces per gallon of water) was used in treating the sweetpotato roots prior to bedding. Special care was taken in pulling the slips from the bed, and in carrying them to the field to prevent drying.

Soil Preparation. The soil was plowed about 6 to 8 inches deep and thoroughly disked four weeks before planting time. The ground was smoothed with a harrow.

Fertilizer Application. On May 4, 1952 the rows were marked with a shallow furrow made with a small plow. Fertilizer was applied by hand in these furrows. The ridges were thrown up over the furrows by back-furrowing twice with a turning plow. After the ridges, which were eight to ten inches high, had been completed they were left undisturbed until transplanting time.

Setting the Plants in the Field. The ridges which had been prepared about four weeks before the date of planting were dragged with a heavy board behind a tractor to smooth the soil for planting.

The roots of the slips were dipped in a solution of wettable Spergon (two ounces per gallon of water) to protect the plants from infectious disease-producing organisms that were present in the field soil or that were being carried on the surface of the slips from the hotbed.

To avoid any injury that might be caused by insects in the field, such as flea beetles which eat the foliage, the tops of the slips were dipped in a solution of DDT. (three tablespoons per gallon of water). Soap was used as the wetting agent for the DDT.

Plants were set in the field by hand. Two men worked together, one placing the plants in their proper position on the top of the ridge and the other pushing the basal part of the slip into the soil 4 to 6 inches deep. The soil was then firmed about the plants. Plants were watered immediately after planting.

Replanting the Whole Experiment. During the night following the setting of the plants in the field the temperature dropped to about 30° F. and all the plants were killed. There were not enough plants left in the bed to replant the whole area. New plants of the same variety to replant the entire experiment were purchased from the same source as the roots previously used. This second planting was made on May 26, 1952. The slips were in good condition and of the right size for transplanting.

Method of planting and setting was the same as for the original planting.

Irrigation and Cultivation

The summer of 1952 was dry, therefore irrigation was necessary to save the crop. Water was applied to the plants when it was needed as determined by a temporary wilting of the vines, especially at midday. An average of one acre-inch of water was given every week in a uniform distribution over the whole experiment by a portable irrigation system.

Weeds were kept under control until the vines became too long and interferred with cultivation.

Harvesting

On October 7, 1952 the roots were dug after the vines had been killed by a light frost. Preventing injury during harvesting is a most important consideration. Injury of the roots during harvesting subsequently causes heavy storage loss due to rotting and shriveling which reduce the value of the crop.

The sweetpotatoes were dug with a regular turning plow equipped with two rolling colters on the beam of the plow, one on each side of the ridge to cut the vines. The operation was not entirely satisfactory because some of the roots were skinned and bruised in being elevated over this type of plow.

The sweetpotato roots were gathered into bushel baskets. Each treatment of each replication was put into a separate container and labeled. The crop then was stored where the temperature and humidity were suitable for curing. The temperature was kept at about 80° F. and the humidity at about 85 percent. The yield from each treatment was graded and weighed as soon as possible after digging.

Grading

Each treatment from each replication was graded to U. S. No. 1's and culls; the weight of each grade was recorded. Grading was done according to the U. S. Standards for sweetpotatoes effective August 2, 1948.

Table 2 shows the observed yield of U. S. No. 1's, the percentage of U. S. No. 1's, and the total yield in bushels per acre.

Table 2. The fertilizer treatments with the corresponding observed yield of U. S. No. 1's, percentage of U. S. No. 1's, and total yield in bushels per acre.

Fertilizer Treatments	Yield of U.S.No.1's in bu. per acre	Percentage of U.S. No.1's	Total Yield in bu. per acre
0 - 0 - 0	140	44	320
0 - 0 - 50	95	38	250
0 - 0 - 150	128	49	260
0 - 100 - 0	105	39	270
0 - 100 - 50	75	38	200
0 - 100 - 150	112	41	270
0 - 200 - 0	75	34	220
0 - 200 - 50	58	28	210
0 - 200 - 150	155	46	340
50 - 0 - 0	215	65	330
50 - 0 - 50	242	54	450
50 - 0 - 150	218	57	380
50 - 100 - 0	55	25	220
50 - 100 - 50	195	46	420
50 - 100 - 150	122	42	290
50 - 200 - 0	120	40	300
50 - 200 - 50	185	50	370
50 - 200 - 150	278	57	490
150 - 0 - 0	188	44	430
150 - 0 - 50	170	46	370
150 - 0 - 150	158	43	370
150 - 100 - 0	148	39	380
150 - 100 - 50	255	55	460
150 - 100 - 150	242	59	410
150 - 200 - 0	170	55	310
150 - 200 - 50	172	46	370
150 - 200 - 150	160	50	320

Carotene Determination

One of the objectives of this experiment was to determine whether fertilizer has any effect on the carotene content of sweetpotatoes.

Sweetpotatoes owe their color, yellow or orange, principally to carotene. Sweetpotato carotene has been found to be nearly all, if not entirely, B-carotene, which is readily converted to Vitamin A in the body and is therefore sometimes called provitamin A. The sweetpotato has a high rating as a source of provitamin A in the human diet and in the livestock ration. Consideration has been given to the possibilities of using the high-carotene sweetpotatoes as a source of pure carotene or carotene concentrates, for which there is some demand for food and feed supplement, food coloring, and scientific purposes.

Some of the sources of carotene on the market at the present time are carrots, leafy green materials, such as alfalfa leaf meal, and vegetable oils which contain carotene. Investigations on the processing of sweetpotatoes for carotene preparations were on a limited scale only; but if, or when, the carotene content of the sweetpotato is improved by selection of new varieties or by new cultural practices, such as fertilizer application (if it has any effect), the picture may alter.

These points show the importance of carotene in sweetpotatoes and a test to determine the effect of fertilizer on the carotene content was run.

Eight samples from three replications, which represented two levels of each of the three fertilizers, nitrogen, phosphorus, and potassium and their combinations were tested. Carotene tests were run according to the procedure which has been given by Mitchell (1948).

Mitchell (1949) extracted carotene from the Orlis variety and found 42.5 mg. per 100 grams dry weight while the carotene test on Orlis sweet-potato in this experiment showed only 18.9 mg. per 100 grams dry weight. Both tests were run on the same variety but on different strains. Mitchell tested strain No. 3561 while in this experiment strain No. 3511, which is the one used by the farmers at the present time, was used. More information on these strains is given by Elmer (1950). Results of carotene tests are given in Table 7.

PRESENTATION OF DATA

The Yield

Effect of the Hedge. The location of the experiment on the east side of a thick mulberry hedge showed a highly significant effect on the yield of the crop. There was definite evidence of this effect. Table 3 shows the yield of each treatment and its location with respect to the hedge. In this table there are four blocks. In each block there are two columns, the column on the left represents the yield in pounds produced by the individual treatment. The column on the right represents the treatment number which has been listed under the experimental design in Table 1.

Table 4 shows clearly the effect of the hedge. The mean yield of each row is listed in the left column of this table. The column on the right in the same table represents the row numbers starting from the hedge. Figure 1 shows the distribution of the yield of the 27 rows which are represented in Table 4. The yields were increased as the rows were located farther from the hedge. Statistically this was significant and in direct correlation; the farther the rows were located from the hedge the higher the yield.

To eliminate the effect of the hedge and to compute an adjusted value for the mean of the total yield, analysis of covariance was used in the statistical treatment.

The analysis of covariance showed that there are detectable, real, fertilizer effects after linear allowance has been made for the position of the treatments relative to the hedge at one end of the area used in this experiment. The analysis of covariance data is given in the Appendix.

The adjusted mean yield of the 27 treatments was computed by using the equation which is given in the analysis of covariance data in the Appendix, Table 5 shows the ordered adjusted means of the 27 fertilizer treatments; also the observed mean of these treatments.

When separate Sums of squares and Mean squares, used in the statistical analysis, are obtained for the N, P, K, NP, NK, and PK effects; with 2, 2, 2, 4, 4, and 4, degrees of freedom respectively, it is found that only the N effect is statistically significant, and it is decisively so (F 18). The F for the K effect is at about the 9 percent level, so it is entirely possible that some small K effect exists. Table 6 shows the effect of the three individual fertilizers and their levels;

Figure 2 shows the same effect.

Table 3. The layout of the treatments and the four replications as they were in the field, also the yield in pounds per plot from each fertilizer treatment. The location of the experiment by the hedge is also shown.

Lbs.	Trt.#	Lbs.	Trt. #	Lbs.	Trt. #	Lbs.	Trt. #
43	14	40	9	67	12	81	18
31	7	43	25	61	17	44	3
34	17	35	14	41	11	51	16
34	20	37	23	61	20	69	14
48	11	41	21	22	7	63	23
44	22	43	19	27	4	39	1
22	9	17	3	35	22	49	21
27	4	19	2	42	19	41	22
36	1	45	18	44	18	34	12
50	19	29	10	30	10	47	15
26	3	13	7	33	1	29	5
21	5	25	16	29	25	45	24
49	10	38	24	53	9	47	6
37	2	32	17	52	27	70	11
23	6	23	26	48	23	40	4
32	8	20	1	42	24	34	19
37	26	24	12	39	26	28	2
30	25	19	11	19	13	21	7
36	24	13	4	17	3	17	8
30	15	32	22	28	21	21	17
26	18	21	15	15	8	33	20
20	13	19	20	7	5	25	10
20	27	16	6	16	2	18	9
20	16	27	27	15	15	30	27
29	21	21	8	22	16	47	26
25	12	22	13	21	14	24	25
33	23	21	5	19	6	27	23

MULBERRY HEDGE

The hedge is about 35 feet high and about 30 feet from the first row of the experiment.

Table 4. The mean yield of the 27 rows as they are listed according to their location from the hedge.

Mean Yield in lbs. per plot	Row Number Starting from the hedge
25	1
23	2
30	3
23	4
17	5
18	6
24	7
28	8
21	9
22	10
32	11
32	12
35	13
48	14
47	15
30	16
25	17
39	18
40	19
32	20
31	21
38	22
43	23
55	24
40	25
45	26
58	27

The correlation between the two columns is 0.85 which is highly significant.

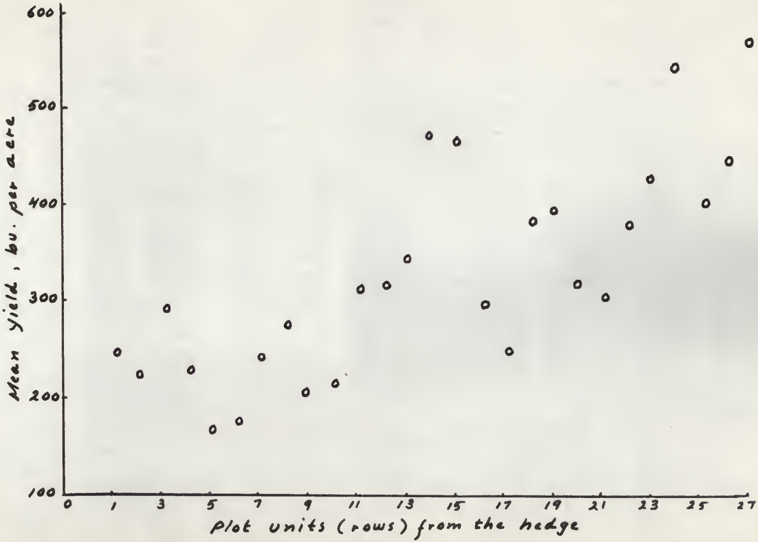

Fig. 1. The distribution of the yield of the 27 rows and their locations with respect to the hedge.

Table 5. The rank of the adjusted yield, the corresponding fertilizer treatment, the observed yield, and the adjusted yield.

Rank	Fertilizer treatment in lbs. per acre	Observed mean in bu. per acre	Adjusted mean in bu. per acre
1	50 - 200 - 150	490	448
2	150 - 100 - 50	460	439
3	150 - 200 - 50	370	415
4	150 - 100 - 150	410	413
5	50 - 0 - 50	450	402
6	150 - 200 - 150	320	400
7	150 - 0 - 150	370	383
8	150 - 0 - 0	430	377
9	50 - 0 - 150	380	373
10	50 - 100 - 50	420	360
11	150 - 0 - 50	370	357
12	150 - 100 - 0	380	340
13	50 - 100 - 150	290	330
14	50 - 200 - 50	370	327
15	50 - 100 - 0	220	327
16	50 - 0 - 0	330	327
17	50 - 200 - 0	300	321
18	0 - 100 - 150	270	321
19	150 - 200 - 0	310	320
20	0 - 200 - 150	340	298
21	0 - 0 - 0	320	282
22	0 - 200 - 50	210	277
23	0 - 0 - 50	250	276
24	0 - 100 - 0	270	249
25	0 - 100 - 50	200	243
26	0 - 0 - 150	260	213
27	0 - 200 - 0	220	168

L. S. D. of the adjusted mean for 5 percent is approximately 135;
L. S. D. of the adjusted mean for 1 percent is approximately 180;
L. S. D. of the adjusted mean for 0.1 percent is approximately 230.

The least significant differences given above are quite approximate, even more so than usual, because the sampling variance of the regression coefficient is being neglected. To partly allow for this the least significant differences given are larger than those actually computed.

Table 6. The yield obtained by the three fertilizers at different levels.

Nitrogen		Phosphorus		Potassium	
rate in lbs./acre	yield in bu./acre	rate in lbs./acre	yield in bu./acre	rate in lbs./acre	yield in bu./acre
150	383	200	330	150	353
50	357	100	336	50	344
0	259	0	337	0	301

L. S. D. for 5 percent is approximately 45;

L. S. D. for 1 percent is approximately 60;

L. S. D. for 0.1 percent is approximately 77.

Nitrogen is the only significant element and its mean for the three levels and their significant differences are as follows:

Rate of application in lbs. / acre	Mean yield in bu. / acre	Significance
150	383	
		not but near
50	357	
		beyond 0.1 %
0	259	

Hence, it appears that the addition of N at the rate of 50 pounds per acre definitely increases the yield, but it is doubtful if the addition of 100 pounds <u>more</u> per acre is worthwhile.

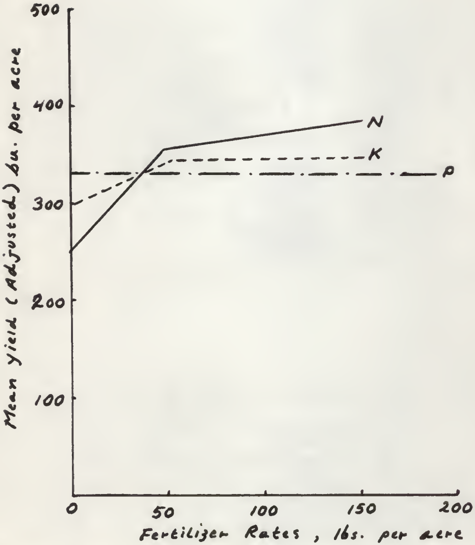

Fig. 2. The effect of the various fertilizer levels on the yield of sweetpotatoes.

Carotene Test

Table 7. The results of the carotene content in the eight different fertilizer treatments.

Fertilizer Treatment	Carotene content mg. / 100 grams dry weight
0 - 0 - 0	20.0
0 - 0 - 150	17.4
0 - 200 - 0	18.7
150 - 0 - 0	20.2
150- 200 - 150	20.1
150 - 200 - 0	19.5
150 - 0 - 150	17.7
0 - 200 - 150	17.6

From this table it seems that the treatment 150 - 0 - 0 produced roots with the highest carotene content while the 0 - 0 - 150 treatment produced the lowest carotene content. However, the analysis of variance showed no significant effect of fertilizers used in this experiment on carotene content in sweetpotatoes.

DISCUSSION

The data presented in this thesis for the adjusted mean of the total yield shows that, almost without exception, the yield of the treatments containing nitrogen was larger than the check treatment. The separate analysis which showed the effect of each level of each fertilizer indicated that nitrogen was the only element which had any effect on the yield of sweetpotatoes under the conditions of this experiment. Moreover, nitrogen at the level of 50 pounds per acre was the only significant factor that affected the yield of sweetpotatoes.

The Soils Department of Kansas State College recommended no phosphorus or potassium when the soil test showed more than 100 pounds P_2O_5 and 200 pounds of K_2O per acre. The use of phosphorus or potassium was apparently unnecessary for maximum production on the type of soil on which this experiment was conducted. A fertilizer containing 5 percent nitrogen when applied at the rate of 1000 pounds per acre was sufficient to give the maximum economical yield of Orlis sweetpotatoes produced on the flooded soil used in this experiment.

The experiment was located on the east side of a mulberry hedge which was about 35 feet high and very thick. The first row of the experiment was located 30 feet from the main stand of the hedge. The hedge significantly effected the yield. This effect was directly correlated to distance, the greater the distance from the hedge the higher the yield. The mean of the four plots in each row was determined and listed beside the row numbers starting from the hedge. Table 4 shows the distribution of the mean yield according to the row number. The correlation between the two, the mean yield and the location of the rows from the hedge, was computed and found to be 0.85, which is highly significant. This correlation includes treatment differences.

Another difference was observed between the treatments themselves. There were four plots for each fertilizer treatment. These plots were located in four blocks and on different locations. Since each replication received the same fertilizer treatment and the same type of cultural treatment they should have given about the same mean yield provided no other factor was involved, but they did not give the same yield. It was observed that the fertilizer treatments located nearest to the hedge gave a lower yield than the same treatment located farther from the hedge. As shown in the Appendix this error of correlation was calculated and found to be 0.67, which is statistically significant beyond the 0.1 % level. These facts plus the lack of any discernable non-linear trend of the Y (the yield) with the X (the plot distance from the hedge), is justification for the use of a covariance analysis.

The manner in which the hedge affected the yield can be explained by two possibilities; first, the roots of the trees might compete with the sweetpotato plants for water and nutrients; and second, by the shading produced by the hedge trees. The hedge caused non-uniform sunshine on the entire area during the growing season. Usually the rows farther from the hedge received more light and produced a higher yield. It seems probable, therefore, that the amount of light received by the different treatments affected the yield.

Grading was done according to U. S. Standards for sweetpotatoes. The effect of the fertilizers on grade U. S. No. 1's has not been shown in this experiment as well as it might have been. In digging the sweetpotatoes a turning plow was used, which was not the ideal tool for digging, therefore, a great amount of injury resulted to the roots which was found principally on the larger sized roots. These large-sized roots were produced by the effect of the fertilizer. According to the grading system of U. S. Standards, these injured roots, though large, should be classified as culls. To avoid this error and to get accurate data on the effect of fertilizer on U. S. No. 1's better equipment could be employed, or include the weight of the injured sweetpotato roots with U. S. No. 1's if they would have been U. S. No. 1's providing no injury had occured. Since neither of these two were employed no further statistical analysis could be made on U. S. No. 1's. Results of the effect of fertilizer on sweetpotato production was calculated on the total yield only.

During the growing season the vines of the sweetpotatoes which had received heavy nitrogen application reached a length of over 15 feet while those with low nitrogen were about 10 to 12 feet in length and those with no nitrogen did not grow over 6 feet in length. Since the treatments were randomized the different applications of nitrogen, (0, 50, 150), might be side by side. In such cases the vines of the plants with heavy nitrogen application would cover a large area and grow over the plants of other treatments which had no, or light applications, of nitrogen and might affect the yield of the treatments. Also, the fertilizer of one treatment might have been used by the plants of the adjoining treatment and this would produce further effect on the yield.

Another observation during the growing season was drought resistance. Those treated with heavy nitrogen showed heavy vegetative growth but usually could not withstand drought periods. When the time for irrigation was due those treatments with heavy nitrogen were the first to show wilting, especially at midday, while those with low applications of nitrogen or without nitrogen could withstand two to three days more. Since many farmers in Kansas do not irrigate and depend only on rainfall heavy nitrogen is not recommended for this reason.

The success of the crop apparently depends upon the vigor with which the plants start growth after being set in the field. In this experiment the top surface of the sandy loam soil dried quickly, consequently it was necessary to set the plants as deep as possible without covering the growing point. Thus the plants were able to get moisture and start growth at once. If the plants were not set deep enough the soil surface dried before the roots became established and the growth of the plants was checked until further irrigation provided moisture in the upper surface of the soil.

A generalization should not be made as to the fertilizer requirements of sweetpotatoes as the initial soil fertility, rainfall, and soil type of any particular region undoubtly are of great importance in determining the amount and kind of fertilizer to be used. Some authors have had a tendency to emphasize the need for applying large quantities of potassium to sweetpotatoes in many localities of the United States. This was not the case in this experiment as the soil apparently had sufficient exchangeable potassium as indicated by the soil analysis and further exemplified by the results of this experiment.

There has been some disagreement in the past as to the effect of fertilizer on the carotene content of sweetpotatoes. The results of this experiment showed no correlation between fertilizer application and the carotene content of the sweetpotato.

SUMMARY AND CONCLUSION

In summarizing this experiment, the following points were concluded:

1. The effect of nitrogen, phosphorus, and potassium alone and in combinations on the yield of sweetpotatoes on a flooded soil was determined.
2. Nitrogen apparently was the only element required. Statistically, it has been shown that fifty pounds of nitrogen per acre is the recommended fertilizer for raising sweetpotatoes on a flooded soil similar to that utilized in this experiment.
3. Phosphorus and potassium showed no significant effect on the yield of sweetpotatoes in this experiment.
4. Carotene tests on different samples and treatments showed that fertilizers used in this experiment had no effect on the carotene content of sweetpotatoes.
5. The experiment was conducted on the east side of a heavy hedge of mulberry trees which showed definite effects on the

yield of the sweetpotatoes; the effect of the hedge was directly correlated to the distance, i.e. the farther the rows from the hedge, the higher the yield.

It seems probable that many of the sweetpotato areas which were covered by the 1951 flood has sufficient amounts of potassium and phosphorus. Applications of these two elements seems to have little value on the yield of sweetpotatoes. Nitrogen apparently is deficient in this type of soil. From the results of this experiment a general recommendation of 50 pounds nitrogen per acre is suggested unless a small increase in yield is sufficient to pay for additional fertilizer. Then perhaps, 50 pounds of potassium and/or 100 pounds of nitrogen should be added. This would depend on the cost of adding each of the latter. There appears to be no reason for adding phosphorus.

ACKNOWLEDGMENT

The author wishes to express his appreciation to the members of the Department of Horticulture, Kansas State College, who have generously helped in this investigation. Special acknowledgment is due to Dr. W. F. Pickett for his interest and cooperation; to Dr. C. C. Singletary, former assistant professor of horticulture at Kansas State College, for suggesting this problem and help in setting it up; to Dr. Elmo W. Davis for his advice and help in the development of the experiment and in writing the thesis; to Mr. James Greig for his help in writing the final copy of this thesis.

Appreciation is also extended to Dr. H. L. Mitchell of the Chemistry Department for his help in carotene analysis; to Dr. H. C. Fryer of the Mathematics Department for his aid in the statistical analysis; and to the many other people who have lent a helping hand when it was needed.

LITERATURE CITED

Anderson, W. S., and F. B. Richardson.
Sweetpotato Experiment. South Missippi Expt. Sta., Miss. Agr. Expt. Sta. Cir. 57, 1924, p. 7.

Elmer, O. H.
Sweetpotatoes in Kansas. Kansas State Agr. Expt. Sta. Bull. 341, 1950, p. 10.

Fellers, C. R., R. E. Young, P. D. Isham, and J. A. Claque.
Effect of Fertilization, freezing, cooking, and canning on the Vitamin C. and A. content of asparagus; Proc. Amer. Soc. Hort. Sci. 31; 145-151, 1934.

Keitt, T. E.
Sweetpotato investigation. S. C. Agr. Expt. Sta. Bull. 165, 1912, p. 6 - 9.

Knapp, B.
Farm help from experiments. Ark. Agr. Expt. Sta. Bull. 181, 1922, p. 103.

Miller, J. C., and W. D. Kimbrough.
Sweetpotato production in Louisiana. La. Agr. Expt. Sta. Bull. 281, 1936, p. 23.

Mitchell, H. L.
Determination of carotene in sweetpotato. Plant Physiology, 2: 323 - 326, 1949.

Quinn, J. T.
Some effects of fertilizer on sweetpotatoes. Amer. Soc. Hort. Sci., Hort, Sci. Proc. 22: 360 - 362, 1926.

Samuel, G. and P. Landran.
Influence of fertilizer on the carotene content of sweetpotatoes. Agron. Jour. 44: 348 - 352, No. 7, 1952.

Schermerhorn, L. G.
Sweetpotato studies in New Jersey. N. J. Agr. Expt. Sta. Bull. 398, 1924, p. 19.

Scott, J. M.
Sweetpotato fertilizer experiment. Fla. Agr. Expt. Sta. Bull. 156, 1920, p. 59 - 63.

Scott, L. E., and W. W. Ogle.
Mineral uptake by the sweetpotato. Better Crops, 36: 1952, p. 12 - 16.

Skinner, J. J., C. B. William, and H. B. Mann.
Fertilizers for sweetpotatoes. U. S. D. A. Tech. Bull. 335; 1932, p. 47.

Swanson, P. A., P. M. Nelson, and E. S. Haber.
Vitamin A content of sweetpotatoes. Report on Agr. Res. Iowa Agr. Expt. Sta., 1933, p. 119.

Voorhees, E. B.
Fertilizers. MacMillan Co., New York, 1898, p. 244 - 248.

Whittemore, M.
The influence of fertilizer treatment on the vitamin A content of spinach. R. I. Agr. Expt. Sta. Bull. 29, 1933, p. 94 - 97.

Woodard, Otis.
Sweetpotato culture in the coastal plain of Georgia. Ga. Coastal Plain Expt. Sta. Bull. 17, 1932, p. 52.

Zimmerley, H. H.
Sweetpotato fertilizers. Va. Truck. Expt. Sta. Bull. 66, 1929, p. 700 - 717.

APPENDIX

Analysis of Covariance

X = plot distance from the hedge Y = yield

Sources of Variation	D/F	$S(x^2)$	S(xy)	$S(y^2)$	SSEE	D/F	Ms
Fertilizers	26	1,825	1,778.25	6,651.6852			
Reps.	3	0	0	2,176.3982			
Error	78	4,727	5,060.75	12,061.3518	6,643.2874	77	86.276
Total	107	6,552	6,839.00	20,889.4352			
F + E		6,552	6,839.00	18,713.0370	11,574.4654		
Corrected Fertilizers					4,931.1780	26	189.66**

F = 189.66 / 86.276 = 2.20 $n_1 = 26$; $n_2 = 77$; $p < .01$

Therefore, there are detectable, real, fertilizer effects after linear allowance has been made for the positions of the plots relative to the hedge at one end of the area used in this experiment.

It was found also that the Error Correlation is r = 0.67, which is statistically significant far beyond the 0.1 percent level. As a matter of fact, the 95 percent confidence interval on the true coefficient of linear correlation is: $0.65 \leq p \leq 0.69$, approximately. These facts plus the lack of any discernable non-linear trend of Y with X is justification for the use of a covariance analysis.

Computing the Adjusted Mean

The adjusted mean of each fertilizer treatment was computed by applying the following equation:

$$\text{adjusted mean} = Yi - bxy\ (Xi - Mx)$$

where:

Yi = the observed mean yield,

bxy = the coefficient of regression, in this case it was 1.071;

Xi = the mean of the independent value; in this case it represents the location or the row number from the hedge;

Mx = the general mean of the independent factor; or the mean row number which is row number 14.

THE EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM ON THE YIELD AND CAROTENE CONTENT OF SWEETPOTATOES

by

AFTAN ZGHEIR AL-RAWI

B. S., Kansas State College of Agriculture and Applied Science, 1953

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Horticulture

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1953

The objectives of this study were to determine: (1) the yield of sweetpotatoes on a flooded soil, (2) the optimum levels of nitrogen, phosphorus, and potassium for the maximum yield of sweetpotatoes on a flooded soil, and (3) to determine whether fertilizer has any effect on carotene content of sweetpotatoes.

In summarizing this experiment, the following points were concluded:

1. The effect of nitrogen, phosphorus, and potassium alone and in combinations on the yield of sweetpotatoes on a flooded soil was determined.

2. Nitrogen apparently was the only element required. Statistically, it has been shown that fifty pounds of nitrogen per acre is the recommended fertilizer for raising sweetpotatoes on a flooded soil similar to that utilized in this experiment.

3. Phosphorus and potassium showed no significant effect on the yield of sweetpotatoes in this experiment.

4. Carotene tests on different samples and treatments showed that fertilizers used in this experiment had no effect on the carotene content of sweetpotatoes.

5. The experiment was conducted on the east side of a heavy hedge of mulberry trees which showed definite effects on the yield of the sweetpotatoes; the effect of the hedge was directly correlated to the distance, i.e. the farther the rows from the hedge, the higher the yield.

It seems probable that many of the sweetpotato areas which were covered by the 1951 flood has sufficient amounts of potassium and phosphorus. Applications of these two elements seemed to have little value on the yield of sweetpotatoes. Nitrogen apparently was deficient in this type of soil. From the results of this experiment a general recommendation of 50 pounds nitrogen per acre was suggested unless a small increase in yield is sufficient to pay for additional fertilizer. Then perhaps, 50 pounds of potassium and/or 100 pounds of nitrogen should be added. This would depend on the cost of adding each of the latter. There appeared to be no reason for adding phosphorus.