A Study in Crop Production on New and Old Soils in Guam.

By

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INTRODUCTION.

Guam, which until recently was the smallest possession on which the United States maintains an agricultural experiment station, is located wholly within the tropics, and is the only oriental station maintained by the United States Department of Agriculture. It is situated approximately 6000 miles southwest of San Francisco and 1500 miles southeast of Manila in the Philippine Islands.

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(1) In presenting this thesis as a partial fulfillment of the requirements for the degree of Master of Science in Agriculture, the author realizes that he presents a subject that is somewhat foreign to the Oklahoma Agricultural & Mechanical College. Such being the case, it is thought that considerable space should be allotted to detailed data which is not necessary to show the amount of work done and how the tabulated results were secured.

Methods of crop production and soil management are very primitive and differ in many respects from those in more temperate regions. The soils exhibit many peculiarities of a local nature and present many difficulties not met with in other countries. No investigations of a scientific nature pertaining to crop production and soil management had been made on the island previous to the establishment of the U. S. experiment station in 1909. The farmers are badly in need of better agricultural knowledge.

In plantings made upon soils that have been under cultivation for a number of years and those that have been newly broken, there is a marked difference in the production of certain crops. With these facts in mind, a preliminary study was made with a number of crops with reference to their adaptability to different soil, soil conditions and to different soil treatments. The investigations have been directed principally toward a study of the newly-broken grasslands in comparison with the older and more productive soils.

Scope of Present Study.

The scope of the present study is, as far as is possible, to determine by rate of growth and yield: (1) the best crop or crops adapted to the newly-broken, unproductive grassland soils; (2) a system of fertilizing to secure a high yield of corn on the old and the newly-broken soils; and (3) a possible cause and remedy for the unproductiveness of the newly-broken soils of Guam.

Importance of Present Study.

The need of greater production of food for the increasing population has made it necessary to cultivate new areas of land in Guam and with the increasing use of modern implements and tools this has become possible in a shorter time than could formerly have been the case. The extreme dwarfing and dying of plants and whole crops often for several successive plantings on the newly boken grassland have given ~~rise~~ to a serious problem. These soils after being broken and allowed to remain fallow for at least two crop seasons and after an occasional plowing during this time are the most fertile and productive on the island.

The necessity of increasing the crop land area and the importance and need of study on this problem can be thoroughly appreciated from the following extracts taken from Executive General Order No. 289, promulgated August 23, 1918 by Capt. Roy C. Smith, Governor of Guam and Commandant Naval Station and Executive General Order No. 316 dates June 25, 1919 by W. W. Gilmer, Governor of Guam and Commandant of Naval Station, respectively: "Executive General Order No. 289.

1. The prevalence of the war, the missing of the monthly transports in the past, and the possibility of similar missings in the future, all point to the necessity of increasing the agricultural and animal food products of the island.

This is necessary in the first place for pure self-preservation, in the second place to relieve the Federal Government of any obligation of supplying food to Guam of a kind that can be grown on the island and which is needed elsewhere."

"2." It is therefore ordered and decreed that from the date of this order every able-bodied male inhabitant of the island between the ages of sixteen (16) and sixty (60) years, not otherwise fully engaged in some useful occupation shall give his whole time, or his whole unoccupied time to agriculture of the raising of cattle, food animals or poultry. This time shall be put in on his own land, or under employment to others, or on idle land under Government or private ownership for a nominal rental.

"3. The work of food production prescribed by this order shall, however, begin at once."

"Executive General Order No. 316.

1. Executive General Order No. 289 is hereby modified to take effect on and after July 1, 1919. The following rules will be observed." "Every able-bodied male inhabitant of Guam over 16 years of age and under 60 years of age whose occupation is farming or who has no regular work will be required to cultivate at least one hectare of land. People who own no land must work for those who have land or must lease or purchase land."

"Each family of three persons able to work all or a greater part of the time will cultivate at least the following crops or their equivalent if the land is better suited for other crops,

namely: one-half hectare of corn; one-fourth hectare of garden crops, which must include beans or peas; 1500 hills of sweet potatoes; 1000 taro plants; 100 banana plants; 30 cocoanut trees; 50 pineapple plants. The sweet potatoes and taro plants should be planted in not less than three plantings so spaced as to insure a supply of food throughout the year.

"Each family will also plant the following trees in localities where they will grow until they have at least the following number growing: 3 alligator pear trees, 3 mango trees, 3 grapefruit trees, 5 lemon trees, 5 orange trees, 10 papaya trees (large variety), 25 coffee trees; one year will be allowed for putting this paragraph in effect."

Although the determinations made in the pot tests may not have the direct value of field tests since the soil in such cases was not in a natrual state, and other conditions were abnormal, they were valuable for studding the relationship of different soil types and the effect of fertilizers upon the physical factors influencing plant growth.

Review of Literature.

Very little investigational work has been accomplished with tropical soils and consequently there is little available literature that pertains to the present study. It seems to be a generally accepted fact that the new soils are not productive until after they have been tilled for some time.

Gilo and Agoton (1)

(1) Numbers in parenthesis refer to literature cited.

In summing up their results on the red clay soil of Porto Rico say: that "it is a fairly heavy clay, often underlaid by an impervious subsoil and so requires good cultivation and drainage to be productive. "This type of soil is characterized by a high percentage of iron and aluminum, moderate amounts of nitrogen, phosphoric acid, and potash, and no carbonates. It is almost uniformly acid and frequently low in organic matter.

"The experiments thus far carried on with sugar cane on this soil show that the normal soil is benefited by liming and fertilizers. Nitrogen is the most essential element and probably increases the yield as much as a complete fertilizer."

"Certain areas of this soil that have long been in continuous cane cultivation are in a "sick" or "tired" condition, not responding to fertilizers, lime, stable manure, nor superficial disinfection."

"In what the "sickness" consists has not been determined, but it may be in the biological condition of the soil." In Speaking of the results of applications to these "sick" soils they found that "this shows plainly that the growth of cane on soil in this condition is limited by some factor other than the supply of mineral nutrients."

In studies on acid soils of Porto Rico, Loew (5) reports that if a "tired" soil be defined as one which, notwithstanding the ample applications of fertilizers, does not produce a satisfactory

harvest, then the following causes of "tired" soils can be distinguished: (1) Excessive acidity or alkalinity, (2) deficient aeration due to poor physical condition in clay soils or to abnormally high bacterial content, (3) abnormally large numbers of parasitic organisms and (4) of injurious organisms not of a strictly parasitic nature. The remedy to be applied can only be determined after careful examination of the soil in question.

Loew also found that the acid soils of Porto Rico owe their acidity not to humic acid but to an acid clay. Jordan (2) of the New York station found that when commercial fertilizers were applied in different combinations and in unlike quantities to two soils, one a highly productive soil from the station farm, and one a soil from a region known as Pine Plains, regarded as inferior for crop production, each soil receiving similar treatment in all respects "that" under forcing house conditions, the Pine Plains soil produced larger crops than the soil from the Station farm.

Kelly (3) of the Hawaii station found that nitrification takes place in Hawaiian soils after aerated conditions have been maintained for a period of several months, but not immediately following tillage. He also believed that the aeration of Hawaiian soils brought about an effective stimulation in bacterial action on the colloidal soil films. His experiments emphasized the importance of maintaining the best aeration possible by rotation of crops including green manuring.

Kelly, McGeorge and Thompson (4) in their study of the acidity of Hawaiian soils say that it has been supposed that the

sod lands are generally acid, but it seems that the slow growth of crops is due more to the lack of aeration than the presence of actual acidity. Lime had been used to considerable extent on the sugar lands with good effects but in many instances negative results had been obtained by the pineapple growers. They also found that when poor drainage and an excess of water in soils prevents the circulation of air that such conditions are favorable for the formation of soluble ferrous iron which is considered to be toxic to plants.

It is a common practice in Hawaii to cultivate new lands several months previous to planting. Kelly, et al, considered that during this aeration, ammonification and nitrification are each stimulated to a considerable extent and the biological condition was improved until the nitrogen became available fast enough for maximum growth of crops.

Previous Investigations.

As far as can be determined no investigations previous to these have ever been conducted with the unproductive newly broken grasslands and the old productive soils with reference to crop production, crop adaptation, and effect of fertilizers on plant growth on these soils in Guam.

Crops and Cultural Practices in Guam.

The most common crop and at the same time the largest and only cash crop grown in Guam is the cocoanut from which is made copra (the dried meat of the cocoanut), the only commercial

product of any importance on the island. The most important cultivated crop is corn which is used largely for human food, taking much the same place in the diet of the Chamorro people as wheat does in United States for the American people. Of somewhat lesser importance are taro, bananas, rice, tobacco, beans, forage plants, pineapples, sugar cane and garden vegetables. Cotton has been grown to a small extent but the plant is now used more for ornamental purposes than for its fiber. Cowpeas and a number of sorghums have been introduced and are slowly being adopted on many farms on the island.

Farming practices in Guam are very primitive compared with those in use in the United States. The farms, or ranches as they are called in Guam, are very small, generally consisting of less than one to only a few acres in size. Much of the farm operation is done by hand labor but on the lowlands it is becoming more common to use a carabou and a small one-handled steel plow that takes a furrow four to six inches in width. This outfit with a small 5-shovel cultivator is the most modern agricultural equipment on the island and is well adapted to local conditions at the present time. A man with a good animal and a steel plow can break an average of about one acre of land during a week and will farm many times over the area of land that a man can handle who does all the work by hand.

Crop Seasons.

The climate of Guam is strictly tropical but is tempered

by the ocean breezes. The temperature is very even during the year ranging from about 70° F. as a minimum to 95° F as a maximum. The seasons are the rainy and the dry. In general the rains are heaviest from July to November and lightest from January to May although one of the seasons may overlap one another. The annual rainfall varies from 90 to 100 inches of which 50 to 60 percent falls during July, August and September. There are two general planting seasons during the year. One of these is in April or May just after the rains begin and the other in November as the rains are decreasing. As a rule, field plantings made during the extremely wet or extremely dry seasons are not a success due to the unfavorable climatic conditions.

Soils.

Color and Formation.

The soils of Guam vary considerable in the different parts of the island. As a whole they are a redish color but are found in all graductions from bright red to black with other mixtures being present. The color varies according to the content and state of oxidation of the iron, the amount of organic matter and the water content. In the lowlands the soil is dark red or brown while that on the hills is a lighter color.

Figure 1 shows the typical topography of the land back of the experiment station and toward the lowland. The tillable lands such as this study deals with generally occur in comparatively small areas of irregular size and shape between the hills and

Figure 1

Typical topography of land extending from lowlands to hills of Guam.

extend from the sea toward the mountains. On account of the high clay content of these soils they are very heavy and pack after rains so that aeration becomes poor.

The chemical and physical composition of the different soils vary to a very marked extent. Comparison shows that the soil from different locations differ chemically very materially and differ physically to an even greater extent. In texture the soils are in all degrees of disintegration from volcanic rock to the finest clays. The soil has been formed by the breaking down and decay of igneous and volcanic rocks and coral and marine formations. The soil in the lowlands is 15 or more feet in depth but has been partially derived from washings from the hills. In the lowlands the surface soil varies from a loam to a heavy clay and is underlaid with a heavy impervious clay subsoil. The uplands soils are shallow, light in color and where badly washed are of a heavy clay type. In the northern part of the island the soil is covered with forests but the southern part of the island where it is more rolling is covered with a dense coarse growth of sword grass (Miscanthus Floridulus).

The virgin lowlands are covered with a heavy growth of small grasses that make good pasture for livestock. One of the principal grasses in this mixture is Andropogan aciculatus, locally known as "enefuk." These lowland soils after being under cultivation for some time produce normal crops and are the most productive soils on the island. It is on this type of soil that corn, bananas, vegetables and rice are found growing most successfully. However, it has long been known that when these grasslands

are newly broken they are not productive for several reasons. This fact is recognized by the native farmer and he generally plows his land two or more times at various intervals after breaking it before attempting to grow a crop. Many plants when grown on the newly broken soil are extremely dwarfed and whole crops often die before becoming many inches high. This is especially true of corn which is the most commonly cultivated crop on these areas. This elapse of time between the breaking of the land and being able to grow a crop means considerable loss in time as well as expense to the farmer and any crop or method that can be found to overcome this factor due to soil conditions will be a great help to the Guam farmer as it is a serious problem with him. It was especially serious during the war when this island was largely cut off from the mainland and had to increase food stuff to a greater extent than ever. Figure 2 shows a panoramic view of the newly-broken grasslands and figure 3 of the old station plots which were used in field tests and from which soil was obtained for the investigations reported in this manuscript.

Physical Characteristics.

The soils of the island present many physical characteristics that are probably peculiar to only such conditions as are found in Guam. The present study is largely confined to the soil of the lowlands and in particular that type found on the Guam Agricultural Experiment Station. Physically this soil is a heavy clay. Mechanical analyses show that 80 percent

Figure 2

Panoramic view of newly-broken grassland on the Guam Experiment Station.

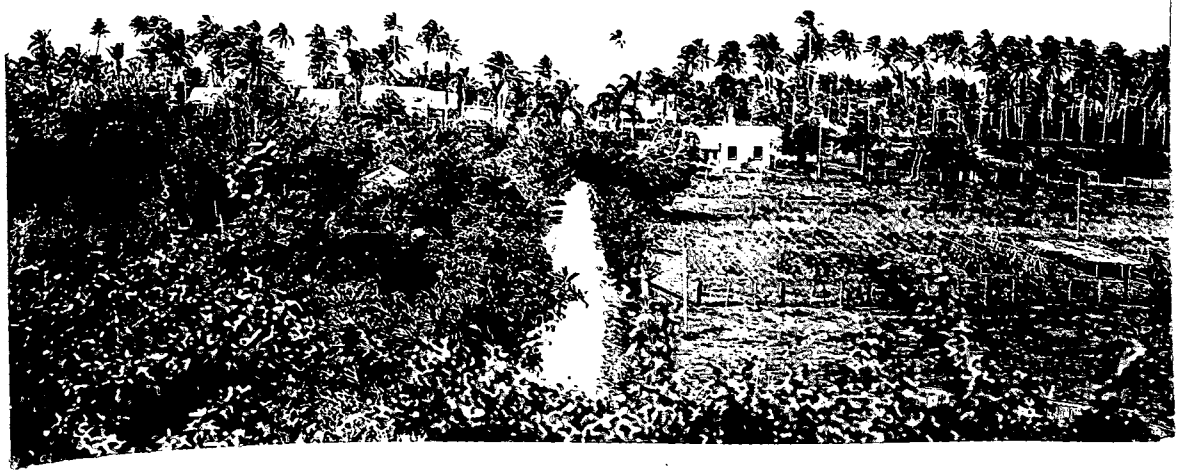

Figure 3

View of the old productive soils on the Guam Experiment Station.

of the soil particles are less than 0.05 m. m. in size. The average composition as shown by the mechanical analyses of 10 samples each of newly broken and old soils was as follows:

Particles	Percent	
	newly-broken soil	old soil
Fine gravel (2 to 1 m. m.)	.5	.0
Coarse sand (1 to 0.5 m. m.)	1.6	.7
Medium sand (0.5 to 0.25 m. m.)	1.1	.8
Fine sand (0.25 to 0.1 m. m.)	8.4	8.9
Very fine sand (0.1 to 0.05 m. m.)	9.0	9.3
Silt (0.05 to 0.005 m. m.)	34.3	34.8
Clay (0.005 to 0.0 m. m.)	45.6	46.2

These analyses show that only a slight difference exists between the two soils. The newly broken soils are not disintegrated to the same extent as is the older soil as is shown by the larger percent of gravel and sand and the smaller percent of silt and clay. Conditions in Guam are favorable for the loss of organic matter due to the very heavy rains part of the year. Because of its heavy nature the soil drains poorly in seasons of heavy rains and bakes badly during the dry months. During prolonged dry periods the soil cracks badly and fissures to a depth of several feet so that it dries out to a considerable distance. After continued heavy rains the soil holds the water for some time unless drainage is exceptionally good. When partially dried or baked it is impossible to cultivate the soil and if cultivated when too wet the clay will puddle

making it impossible to secure a friable soil again for some time. Thus during part of the year the soil is in poor mechanical condition much of the time even with the best of cultivation. The soil can be cultivated best after a few rains following a dry period.

Chemical Characteristics.

Although a large part of the present investigation consisted of work with crops adapted to the two lowland soils already mentioned a brief survey of the chemical composition of the soils will be of interest in showing the wide variation in the soils of the island as well as showing the close relationship that exists between soils of similar formation. Milton Whitney, Chief of the Bureau of Soils, United States Department of Agriculture, says of some of the soil samples from Guam; "These soils(1) are in several respects the most peculiar chemically that we have encountered in our laboratory. Soils of somewhat similar characteristics in composition although not so extreme are found in Hawaii."

Table I shows the chemical analyses of some of the soils of the Island.

(1) Correspondence.

Table I

Analyses of Some of the Guam Soils.

Sample No.	Location	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	Mn O	Ca O	MgO	K_2O	Na_2O	P_2O_5	SO_3	N	Loss of Ignition
1	Dededo-upland	1.08	2.02	18.65	38.35	0.37	2.09	0.10	0.13	0.42	1.84	0.63	0.82	33.6
2	do-subsurface	0.99	2.09	21.31	41.26	0.31	1.40	0.13	0.12	0.40	1.94	0.42	0.38	28.66
3	do-subsoil	0.88	2.12	21.00	41.71	0.24	3.84	0.08	0.11	0.39	1.75	0.51	0.28	27.76
27	Piti-Lowland	44.32	0.82	12.80	23.53	0.10	0.81	2.45	0.60	0.35	0.09	0.13	0.33	13.41
28	do-subsurface	43.86	0.83	14.42	23.61	0.62	0.82	2.93	0.61	0.34	0.08	0.09	0.19	11.74
29	do-rice land	44.03	0.82	13.58	21.41	0.16	0.87	2.44	0.61	0.31	0.05	0.15	0.42	15.16
30	do-subsurface	44.19	0.82	15.61	22.67	0.48	0.72	2.80	0.62	0.32	0.05	0.09	0.37	11.49
31	do-rice land	43.22	0.82	14.89	22.61	0.32	0.72	2.50	0.59	0.35	0.08	0.11	0.34	13.05
32	do-subsurface	44.74	0.82	16.03	20.94	0.20	0.75	2.75	0.55	0.33	0.05	0.09	0.23	10.94
33	Tarague-coconnuts	0.12	0.05	0.26	0.26	trace	49.44	1.66	0.07	0.57	0.27	0.57	0.58	47.33
34	Tarague-Sandy	5.60	0.41	7.78	11.79	0.17	22.07	9.98	0.46	0.41	2.64	0.83	1.52	48.28
35	Tarague-Sandy Loam	4.77	0.43	8.69	13.27	0.30	20.14	1.20	0.27	0.38	3.57	0.76	1.40	45.7
36	Tarague-Coarse Sand	0.61	0.04	1.16	2.12	0.05	47.05	0.33	0.06	0.47	2.19	0.49	0.45	45.06
37	Tarague-Sandy Loam	3.69	0.45	7.99	13.78	0.33	22.58	0.88	0.22	0.46	4.26	0.90	1.25	43.97
48	Tarague-Coconuts	5.47	1.06	11.20	29.10	0.52	6.70	1.45	0.50	0.22	0.40	0.78	1.40	41.70

It will be noted in the first three samples that the striking feature is the small amount of silicon present and the extra high percentage of titanium, iron and phosphorus. In samples 27 to 32 inclusive the silicon content is high as is also the iron and aluminum while phosphorus is relatively low. In the samples from Tarague at the north end of the island the low silicon, iron and aluminum content and the high percent of calcium phosphorus and loss on ignition are striking features. The first three and the last five samples in the table are from soils that produce good cocoanuts while the others are from soils that produce a good quality of grass for pasture, corn, bananas and rice.

Table II shows the chemical analyses of samples of surface and subsurface soils from the Guam Experiment Station. Table III shows the average of each of the surface and subsurface soils, and analyses of composite samples taken from the old station soils and from the unproductive newly-broken grassland soils which were used in much of the present study.

Surface soil samples were taken to a depth of 6 2/3 inches and the average analyses were taken from soil samples Nos. 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24 and 25. Subsurface soil samples were taken from 6 2/3 to 15 inches deep and the average analyses were taken from soil samples Nos. 5, 7, 9, 11, 13, 15, 17, 19, 21, 23 and 26. In table III "new" is sample No. 38 which is a composite of 10 large samples taken from newly-broken grassland on the experiment station. "Old" is sample No. 39 which is a composite of

10 large samples taken from the productive cultivated old soil on the experiment station. The last two are the soils used in most of the pot tests in much of the present study. In all the station soils it will be noted that the analyses show that the soil is not particularly lacking in any one element. From the chemical standpoint the outstanding characteristics of the station soils are the high content of iron and alumimum.

Table II

Chemical Analyses of the Soils on the Guam Experiment Station

No.	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_3	SO_3	N	Loss on Ignition
Surface Soils													
4	44.36	.98	13.80	21.77	.26	.82	2.66	.63	.40	.08	.12	.185	14.22
6	44.26	.98	13.28	23.23	.23	.85	2.09	.65	.34	.08	.05	.22	14.35
8	44.22	1.00	13.36	22.48	.29	.88	2.33	.64	.30	.09	.12	.21	14.10
10	50.10	.80	11.32	20.40	.11	2.48	4.71	.74	.41	trace	.04	.12	9.76
12	46.68	1.05	12.62	22.27	.22	.85	2.34	.74	trace	.10	.08	.21	13.43
14	45.27	.83	12.67	22.44	.31	1.84	1.91	.30	.06	.16	.12	.31	14.65
16	44.75	.72	12.50	21.01	.208	1.01	2.21	.27	.20	.27	trace	.05	16.45
18	44.62	.80	11.00	22.62	.21	1.21	2.27	.27	.13	.24	.08	.20	16.45
20	42.26	.69	11.34	21.94	.13	2.17	2.07	.07	.12	.24	.08	.275	18.63
22	45.70	.49	11.50	21.40	.067	1.91	2.66	.30	.55	.28	.18	.29	14.70
24	39.60	.52	11.00	20.10	.102	5.70	2.00	.33	.98	.33	.178	.37	19.70
25	40.00	.60	11.20	27.00	.115	2.00	2.20	.38	.71	.27	.196	.28	15.10
Subsurface Soil													
5	45.90	.91	13.67	21.12	.19	.90	2.98	.62	.33	.04	.11	.05	11.38
7	45.06	.98	13.52	23.75	.25	.68	2.66	.65	.32	.04	.14	.08	11.70
9	45.90	.90	13.75	23.20	.18	.62	2.93	.63	.35	.07	.05	.10	11.37
11	50.18	.81	11.77	20.34	.11	2.63	4.70	.58	.37	trace	.04	.09	9.13
13	46.73	.96	13.13	24.42	.13	.90	2.66	.45	.21	trace	trace	.09	10.75
15	47.14	.77	13.82	22.88	.30	1.41	2.49	.50	.06	trace	.04	.12	10.88
17	46.60	.92	13.12	23.98	.151	.53	2.45	.33	.12	.38	trace	.05	10.01
19	45.69	.94	13.23	25.02	.15	.75	2.50	.39	.19	.444	.03	.05	10.62
21	46.68	.76	11.34	21.84	.12	1.69	2.17	.03	.11	.26	.04	1.25	14.94
23	50.70	.49	11.90	23.40	.022	1.75	2.62	.24	.57	.30	.11	.066	8.60
26	39.40	.27	10.90	29.20	.118	2.40	1.98	.20	.65	.31	.226	.34	14.00

Table III.

Average Chemical Analyses of Soils on the Guam Experiment Station.

Aver:	SiO_2	TiO_2	Fe_2O_3	Al_2O_3	Mn O	Ca O	Mg O	K_2O	Na_2O	P_2O_5	SO_3	N	Loss of Ignition
Sur-face:	44.11	.79	12.13	22.22	.19	1.81	2.45	.44	.35	.18	.10	.23	15.13
Sub-sur-face:	46.35	.79	12.74	23.56	.16	1.38	2.74	.42	.30	.17	.07	.21	11.22
New	43.68	.92	14.33	21.08	.25	1.17	2.28	.57	.29	.12	.25	.34	14.72
Old	44.57	.92	13.96	21.50	.29	1.22	2.20	.45	.25	.06	.20	.29	14.09
Aver:	44.68	.86	13.29	22.09	.22	1.39	2.42	.47	.30	.13	.15	.27	13.79

Plan of Experiments.

Several field tests were conducted with a number of crops upon the old productive station soils, the unproductive newly broken grassland, and land that had been broken one or more years. These tests formed the basis for preliminary crop and soil studies and are used in comparing the results obtained in the pot tests. Pot tests were conducted to further determine the crops best adapted to the particular soil condition existing on the old and newly broken soils, and consisted of the following experiments: (1) Nemurial requirements of crops, (2) The possibility of grass roots excreting a toxic substance poisonous or detrimental to crop plants. (3) Crops adapted to the old station soil, to the newly broken grassland, and land that had been broken one or more years, (4) Effect of commercial and local fertilizer applications on plant growth on old and new soils of Guam. (5) Effect of lime on plant growth on the old and new soils of Guam.

Description and care of Pots.

Pots consisted of five gallon kerosene or gasoline cans filled with soil and provided with means for drainage. All soils were broken up and run through a wire screen so all would be in as nearly the same physical tilth as possible to make them. All pots were filled to within two inches of the top after settling the soil. Ample drainage was provided in the bottom of the cans by making holes and placing rock and sand in a layer two inches deep.

This made the soil 10 inches deep in the pots. Each pot has a surface area of 81 square inches (9" by 9") which represents 1/7744 of an acre. In all tests each pot treatment was run in triplicate. The pots were arranged on low tables in rows of three with about one foot space between the pots. Guard pots were placed at the ends of the tables so that the pots in the experiment would all be under uniform conditions in respect to light and distance around each plant. Figure 4 shows the arrangement of the pots in the tests. When rain was insufficient to provide suitable moisture for the best plant growth the pots were watered as often as necessary. The surface soil of each pot was stirred often enough to kill weeds and prevent a crust being formed.

Insects were troublesome in many of the tests and it was necessary to exercise considerable care at times to prevent them from damaging the crop to such an extent as to make the results worthless. These were controlled by hand picking the leaf-folding larva, spraying with lead arsenate for leaf hoppers and with nicotine sulphate and kerosene emulsion for the various aphids attacking the plants. Powdered tobacco leaves were also used in some of the tests where infestations were not heavy.

Manurial Requirements of Crops.

This test was of a preliminary nature, and of short duration, to determine the fertiliser needs of the new and old soils on the Guam Experiment Station. The experiment was carried

Figure 4

Showing arrangements of pots in tests

out as suggested in circular No. 13, Bureau of Soils, United States Department of Agriculture with some minor changes due to available equipment and local conditions.

The experiment consisted of paraffined wire pots each containing 800 grams of soil to which fertilizers had been added, using four grams of acid as a basis for applications. The test was run in duplicates on old and of new soils taken from composite samples of station soils. The old soil was taken from the station field plots that had been producing good crops for a number of years and the new soil was taken from across the Nasso river from the newly broken grassland which had failed to produce satisfactory yields of a number of different varieties of crops or had produced none or only dwarfed or inferior plants.

The pots were made of wire screen filled with soil and then dipped in paraffin to make them air and water tight, planted in a row with 6 uniform sprouted kaffir seeds when the shoots were one inch long and one-fourth inch of sand placed on top of the soil. A paraffined cover with a slot for the small plants was sealed over the top of the pot so that practically no evaporation of moisture could take place other than that transpired by the plants and then all pots weighed. About every three days the pots were weighed and water added to bring the pots up to the optimum water content for best plant growth.

Data have been tabulated showing the applications of fertilizers, amount of water added to the pots, amount of transpiration of water from plants during the experiments, weight and

number of live plants at end of experiment. Table IV gives the plan of fertilizer treatment, pot numbers, rate of application of fertilizers per acre, and amount of fertilizers applied to four pounds of soil.

Table IV

Plan and Pot numbers in Test for

Manurial Requirements for Crops.

Treatment	Pot Numbers				Application per Acre	Application to four pounds of soil
	Old Soil		New Soil			
	Orig.	Dup.	Orig.	Dup.		
Untreated	19	54	1	37	None	None
Untreated	~~29~~	~~55~~	2		None	None
Manure	20	55	3	38	5 ton	9 grams
Lime $Ca\ O_3$	21	56	5	39	1 ton	1.8 grams
Sodium Nitrate $Na\ N\ O_3$	22	57	4	40	200#	18 c c
Potassium Sulphate, $K_2S\ O_4$	24	58	6	41	200 #	18 c c
Acid Phosphate $Ca\ H_3\ (P\ O_4)2$	25	59	7	42	200 #	18 c c
$Na\ N\ O_3$, $K_2\ S\ O_4$	26	60	8	43	200 # each	18 c c each
$Na\ N\ O_3$, $Ca\ H_3\ (P\ O_4)2$	27	61	9	44	200 # "	18 c c "
$K,\ S\ O_4$, $Ca\ H_3\ (P\ O_4)2$	28	62	10	45	200 # "	18 c c "
$Na\ N\ O_3$, $Ca\ H_3\ (P\ O_4)2$, $K_2S\ O_4$	29	63	11	46	200 # "	18 c c "
$Na\ NO_3$, $CaH_3(PO_4)2$, K_2SO_4, $Ca\ O$	30	64	12	47	200 # "	18 c c "
					plus 1 ton CaO:	plus 1.8 gro CaO:
Velvet Beans (Chopped)	31	65	13	38	2-1/2 tons:	4.5 grams
Ammonium sulphate $(N\ H_3)\ SO_4$	32	66			150 "	13.5 c c
Ipomoea prescarpae (green Manure)	33	67	15	50	2-1/2 "	4.5 grams
Cocoanut husk ash	34	68	16	51	1 ton	1.8 "
Sea Slugs (chopped)	35	69	18	52	2-1/2 tons:	4.5 "
Sulphur	36	70	18	53	400#	.36 "

Table V shows the amount of water transpired from plants in the manurial requirement test and Table VI shows the amount of transpiration arranged in relative rank with the greatest amounts first. The values of the fertilizers are shown by the amount of transpiration of the growing plants.

In these tests it was found that the greatest amount of transpiration took place from the plants that were growing in those pots that contained soil which had been treated with complete fertilizers and lime, nitrogen, nothing, nitrogen and potassium and complete fertilizer. The smallest amount of transpiration was from plants in pots that had been treated with ammonia sulphate, coconut husk ash, phosphorus and potassium, and Ipomoea pescarpae, a large vine which is common along the seashore and which was used as a green manure. The plants on the old soil also ranked high in amount of transpiration from pots that had been treated with nitrogen and potassium, and velvet beans as a green manure and on the new soil from pots that received lime and potassium.

Table V.

Showing Amount of Transpiration of Water from Plants.

Treatment	Old Soil			New Soil			Average of both soils
	original	duplicate	average	original	duplicate	average	
	c c	cc	c c	c c	c c	c c	
Untreated	12.3	16.6	14.45	12.3	13.9	13.10	13.77
Manure	11.0	13.9	12.45	12.7	12.4	12.55	12.50
Lime	10.2	8.8	9.50	19.1	12.7	15.90	12.70
$Na\ N\ O_3$	11.5	10.1	10,80	14.2	19.6	16.90	13.85
$K_2\ S\ O_4$	11.2	12.6	11.90	16.5	13.6	15.05	13.47
$Ca\ H_2\ (P\ O_4)2$	10.9	10.4	10.65	15.9	8.7	12.30	11.47
N & K	14.8	11.2	13.00	13.6	15.1	14.35	13.67
N & P	14.9	11.2	13.05	13.3	10.6	11.95	12.50
K &P	11.9	10.0	10.95	10.8	11.7	11.25	11.10
N, P & K	8.3	14.4	11.35	15.5	16.3	15.90	13.62
N, P, K, & Lime	12.2	18.0	15.10	14.6	13.2	13.90	14.50
Velvet Bean	12.2	13.1	12.65	12.5	13.9	13.20	12.92
$(N\ H_3)\ 2\ S\ O_4$	9.5	9.3	9.40			(#)	9.40
Impomoea	9.8	10.6	10.20	13.2	11.7	12.45	11.32
Coconut ash	8.8	9.5	9.15	11.0	10.1	10.55	9.85
Sea Slugs	15.4	9.6	12.50	13.5	12.5	13.00	12.75
Sulphur	14.1	10.0	12.05	13.7	14.3	14.00	13.02

Table VI

SOIL EXPERIMENT-MANURIAL REQUIREMENTS.

Showing Relative Rank and Amount of Transpiration.

Relative rank	Old Soil		New Soil		Average of both soils	
	Treatment	Water transpired	Treatment	Water transpired	Treatment	Water transpired
		c c		c c		c c
1	N P K & Ca	15.10	N	16.90	N P K & Ca	14.50
2	Untreated	14.45	N P & K	15.90	N	13.85
3	N & P	13.05	Ca	15.90	Untreated	13.77
4	N & K	13.00	K	15.05	N & K	13.67
5	Velvet Beans	12.65	N & K	14.35	N, P & K	13.62
6	Manure	12.45	S	14.00	K	13.47
7	Sea Slugs	12.50	N? P? K & Ca	13.90	S	13.02
8	Sulphur	10.05	Velvet Beans	13.20	Velvet Beans	12.92
9 9	K	11.90	Untreated	13.10	Sea Slugs	12.75
10	N, P & K	11.35	Sea Slugs	13.00	Ca	12.70
11	K & P	10.95	Manure	12.65	Manure	12.50
12	N	10.80	Impomeao	12.45	N & P	12.50
13	P	10.65	P	12.30	P	11.47
14	Impomeao	10.20	N & P	11.95	Impomeao	11.32
15	Ca	9.50	K & P	12.25	P & K	11.10
16	$(NH_4)_2SO_4$	9.40	Coconut ash	10.65	Coconut ash	9.85
17	Coconut ash	9115			$(NH_4)_2SO_4$	9.40

Table VI shows the relative rank and average weight of live plants at the end of the experiment. The heaviest plants at the end of the test in the old soil were from the pots that had received applications of potassium, velvet beans as green manure, nothing,(check), phosphorus and potassium and sea slugs chopped fine, respectively. In the new soil the heaviest plants were from pots that had received sulphur, manure, nitrogen, complete fertilizer and sea slugs, respectively. Averaging both soils the heaviest yield was from those pots that had received sulphur, manure, sea slugs, velvet beans as green manure,and potassium;and the lowest from phosphorus, Ipomeae, lime, check, and nitrogen and phosphorus, respectively.

Phosphorus on both new and old soil, lime on old soil, check on new soil, nitrogen on old soil, potassium on new soil, nitrogen and phosphorus on old soil, and cocomut husk ash on new soil all made low yields.

Table VII

SOIL EXPERIMENT-MANURIAL REQUIREMENTS.

Showing Relative Rank and Average weight of Plants at end of Experiment.

	Old Soil			New Soil			Average of both Soils		
Relative Rank	Treatment	Plants alive at end of Expt.	Wt. in grams	Treatment	Plants alive at end of Expt.	Wt. in grams	Treatment	Plants alive at end of Expt.	Wt. in grams
1	K	1.5	.490	Sulphur	3.5	.675	Sulphur	3.0	.460
2	Velvet b beans	3.5	.385	Manure	5.0	.480	Manure	4.5	.397
3	Check	3.5	.385						
3	P & K	4.0	.370	N	4.0	.435	Sea Slugs	3.75	.355
4	Sea Slugs	3.5	.350	N, P & K	4.0	.400	Velvet Beans	3.5	.350
	Cocoanut ash	3.5	.350						
5	NH_4	3.5	.325	Sea Slugs	4.0	.360	K	2.0	.345
							N & K	3.5	.345
							N,P,& K	4.0	.345
6	Manure	4.01	.315	N & P	3.5	.335	NH_4 (#)	3.5	.325
7	N, P & K	4.0	.290	Ca	3.5	.325	N	3.0	.315
8	N & K	3.5	.285	N,P, K & Ca	3.5	.315	P & K	3.25	.310
				Velvet Bean	3.5	.315			
9	Ipomoae	3.0	.280	N & K	3.5	.305	N, P, K & Ca	3.5	.295
10	N P K & Ca	3.5	.276	P & K	2.5	.250	Cocoanut ash	2.75	.287
11	Sulphur	2.5	.245	Ipomoae	3.0	.230	N & P	3.0	.272
12	N & P	2.5	.210	Cocoanut ash	2.0	.225	Check	3.25	.265
13	N	2.0	.195	P	2.0	.210	Ca	2.5	.257
14	Ca	1.5	.190	K	2.5	.200	Ipomoae	3.0	.255
15	P	2.5	1.80	Check	3.0	.145	P	2.25	.195

Possibility of Grass Roots Excreting a Toxic Substance.

From Observation of the behavior of crops planted on newly-broken grassland soils it appeared that the difference in the productivity of new and old soils might be due to a physiological condition, the grass roots apparently excreting a toxic substance that was poisonous or detrimental to other plants, or at least to some others. In general, the only apparent difference that existed between the old productive soils and the newly-broken unproductive grassland soils when planted to comparative crops was that the later crop was following a grass crop. Figure 5 shows a crop of ~~corn~~ grain sorghum grown on newly-broken grassland after several repeated plantings had failed. It will be noted that the ~~corn~~ sorghum is ~~tasseling~~ heading and is in a very dwarf condition. Figure 6 shows Sudan grass growing on the old station soil and which was planted at the same time as the corn shown in figure 5.

On November 31, 1918 a test was started to determine if possible the effect of grass growing on soils with later crops planted on the same soil. Eighteen pots were used in the experiment. Three pots of soil were taken from the old station ground that had been planted to Paspalum dilatum, three pots from newly-broken grassland, and three pots from the old soil that had been producing good crops. These pots were planted to corn for comparison. Native wild grasses, such as were growing on the virgin grassland were planted in nine pots containing old soil in order that a study might be made of the effect of these grasses

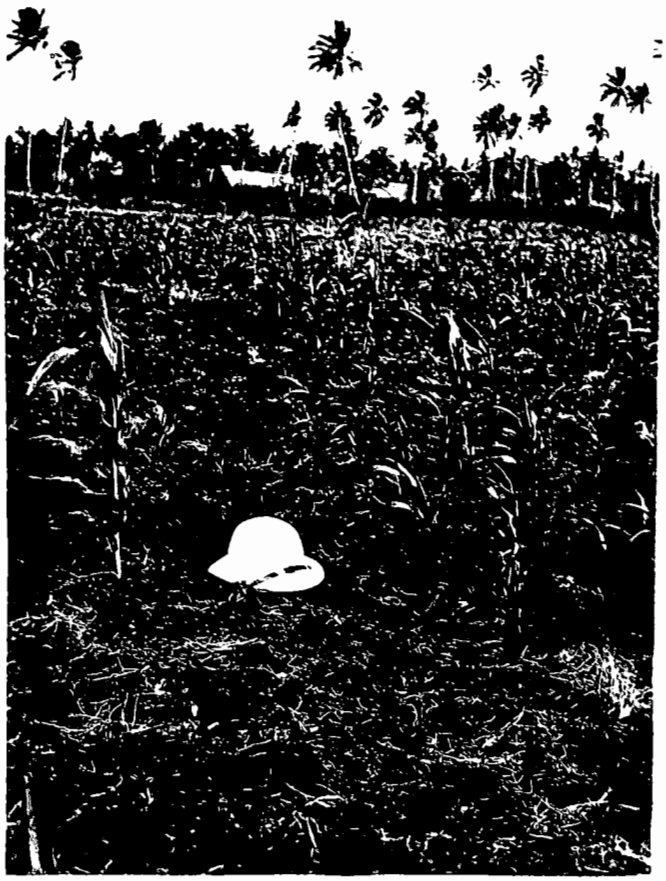

Figure 5

Dwarfed grain sorghums on newly-broken soil after several repeated plantings.

Figure 6

Sudan grass growing on old soil and planted same time as grain sorghum in figure 5 .

on crops planted on this soil at a later date. Three of the nine pots were planted to Andropogon aciculatus, the most common grass growing on the grasslands, three pots to mixed grasses, and three to one each of single varieties of grass found growing on the grassland, one of which appeared to be a sedge, another a form of wild paspalum, and the other an unidentified grass. The pots were well sodded on January 8, 1919 and nearly all of the grasses had put out seed stalks. The pots containing Andropogon aciculatus and mixed grasses had produced a dense heavy sod and were similar in growth to field conditions and continued so until turned under. The single grasses had not made so heavy a growth. On April 1, 1920, the grass in the pots was turned under much in the same manner as was done in the field. On April 3, 1920 these pots were all planted to corn.

Table VIII gives a summary of the results of the corn grown on the paspalum soil, newly-broken grassland and old station soil used as check pots.

Table VIII

Comparison of Corn Grown on Old and Grass Lands.

Date Planted	Date Harvested	Old Soil average		Paspalum Soil average		Newly-broken soil average	
		Height inches	Weight grams	Height inches	Weight grams	Height inches	Weight grams
***							
Nov.21, 1918	Feb.11, 1919		250.99		235.87		160.27 (1)
Feb.11, 1919	June 13, 1919		1209.60		1058.40		1512.00
Oct. 6, 1919	Jan. 15, 1920	44.00	198.07	46.00	226.80	50.00	217.73
April,3,1920	July 8, 1920	43.67	136.33	51.00	143.33	57.00	167.67
Aug.19, 1920	Nov.11, 1920	51.33	111.00	54.67	100.00	48.67	126.50
Average		46.33	381.20	50.56	352.88	51.89	436.83

(1) Planted Oct. 22, 1918. Harvested Jan. 30, 1919.

In the test planted November 21, 1918 the stalks in the check pot of old soil was considerably heavier than those growing in the newly-broken grassland and was somewhat heavier than the stalks in the soil from the paspalum field. However, in the succeeding tests the newly broken soil improved in productivity to such an extent that the average weight per stalk was 436.83 grams compared to 381.20 grams in the check pot and 352.88 grams in the pots containing paspalum soil. The average height of stalks was also greater in the new soil. The results in this test conform to those in all others regarding first trial plantings in newly-broken grassland soil. Whatever the reason for the low yields at first, the cause is evidently removed before the second crop is harvested.

Table IX gives a summary of the effect of previous crops of grass growing on old soil in pots.

Table IX

Effect of Previous Crops of Grasses on Corn.

Date Planted	Date Harvested	Old Soil (Check)		Grass, Mixture		Grass, single		Grass (A. aciculatus)	
		Height	Weight	Height	Weight	Height	Weight	Height	Weight
		inches	grams	inches	grams	inches	grams	inches	grams
April 8,1920	July 8,1920	43.67	136.33	59.33	183.00	56.67	159.33	55.33	172.67
Aug.19,1920	Nov.11,1920	51.33	111.00	51.33	107.00	52.50	118.50	54.00	103.50
Average		47.50	123.67	55.33	145.00	54.59	139.92	54.67	138.09

With the exception of the check pots, grass had grown on the old soil in the pots for a period of 495 days and was well sodded on the surface when broken for planting corn. From these comparative results it would appear that the grasses growing on the old soil had increased production rather than lowered it and that no detrimental effects to plant growth had remained in the soil to affect succeeding crops. In other words the cause of the unproductiveness of the newly-broken grasslands is probably not due to grass roots excreting a toxic substance that is poisonous or detrimental to other plants.

Crop Adaptability.

The investigations during this test have been directed principally toward a study of the newly-broken grasslands in comparison with the older and more productive soils. In view of the fact that greater production of food in Guam made it necessary to cultivate new areas, this work was of some importance. The extreme dwarfing and dying of plants and whole crops often for several successive plantings on the newly-broken grassland gave rise to a serious problem.

The test was conducted to find the crops best adapted to the newly-broken grassland, and to land that had been broken one or more years using the old station soil in comparison as a check. Pot tests consisted of composite soil samples taken from each different kind of soil. All soils had been analyzed (see soil samples Nos. 38 and 39 for composite analyses and Nos. 4 to 32, inclusive, for separate analyses) for mechanical and chemical composition and vary only to a small extent. Seven different crops were planted on each kind of soil to determine the one or ones best adapted to that particular soil condition and to compare one with another on the different soils.

During the year several crops in field tests were tried, to determine if one or more of them could overcome this adverse soil condition. The crops grown on the land were mung beans, cowpeas, Darso, Shrock Kafir, Sudan grass, rice, pineapples (under irrigation).

Figure 7

Dwarf hegari kafir on left, cowpeas between rows, and Shrock kafir on right, growing on newly-broken land after 10 months of unsuccessful planting to other crops.

Figure 8

Second planting of grain sorghums on newly-broken grassland. Whole stand good at first. Darso and Shrock kafir in background still making fair growth.

velvet beans, soy beans, roselle, corn, tobacco, seven additional varieties of sweet sorghum, three varieties of cotton, and vegetables of all kinds. Only the first seven crops gave a satisfactory growth after repeated plantings. All of these did well on the older station ground which is apparently very similar to the newly-broken ground as analyses show that there is not enough difference in the chemical composition to make any difference in productivity of these soils; in fact, the difference is not much greater than would be found in duplicate samples of the same soil. In all tests, as has been stated, a comparison was made between the old station soils and the newly broken, but unproductive soils. The latter continued to improve in productivity with each seasons cultivation. In field tests, cowpeas, pineapples, and grain sorghums seemed better able to maintain themselves than ddd other crops on the newly-broken grasslands. Figure 7 shows Dwarf Hegari kafir on left, cowpeas between the rows and Shrock kafir on right, growing on newly-broken grassland after 10 months of successful planting. Velvet beans grew fairly well after two crops of cowpeas had been turned under. The new soil which at the beginning of the test, (see figure 8) two or three years previously would grow scarcely anything, produced fairly good crops of sweet potatoes, cassava, tobacco, and mung beans, and better crops of cowpeas and pineapples have been harvested with each seasons cultivation.

In the pot tests, composite samples were taken of the soil from the old station plots, ground broken one year or more, and

newly-broken grassland. Each crop was run in triplicate, a series consisting of nine pots, three to each soil, and all planted to the same crop. Seven series containing the following crops were started October 22, 1918: corn, kafir, cotton, cowpeas, radish, peppers, and rice.

After the crops were large enough, weekly measurements were made of the different plants and at the end of a crop season yields were recorded. The following plan gives the arrangement of the pots and crops grown in them:

Plan and arrangement of pots in crop

desirability test.

Number of Pots	Kind of Soil (1)	Crop
3	Old	Corn
3	Newly broken (N. B.)	Corn
3	1-year old (1-yr. old)	Corn
3	Old	Kaffir
3	Newly broken	Kafir
3	1-year old	Kafir
3	Old	Cotton
3	Newly broken	Cotton
3	1-year old	Cotton
3	Old	Cowpeas
3	Newly broken	Cowpeas
3	1-year old	Cowpeas
3	Old	Radish
3	Newly broken	Radish
3	1-year old	Radish
3	Old	Peppers
3	Newly broken	Peppers
3	1-year old	Peppers
3	Old	Rice
3	Newly broken	Rice
3	1-year old	Rice

(1) Legend:-

Old-Soil from station fields that produced good crops

Newly Broken (N. B.) Soil from newly broken land.
1-year old. (1-yr.old) Soil from land that had been broken one year.

Table 1 gives the comparison by weight of the crops grown on the old, newly-broken, and once-cropped soils. In the initial tests planted very little difference could be noted in the plants at first but later the corn, kafir, and milo in the old soil became more stocky, vigorous, and a darker green color than those in the other soils. Very little difference existed between the growth on different soils of cowpeas, rice, and peppers.

Figure 9 shows the comparative size of the corn stalks growing in the three kinds of soils while Figure 10 shows the same in regard to kafir and Figure 11 with cowpeas.

As the tests were carried out from season to season the newly-broken soils became more productive and after the second season gave better results than the older soils. In the pot tests it was found that cowpeas and rice gave the best results on first plantings in the new soils and that kafir and corn were about on an equal in regard to plant growth when grown on the newly broken soils.

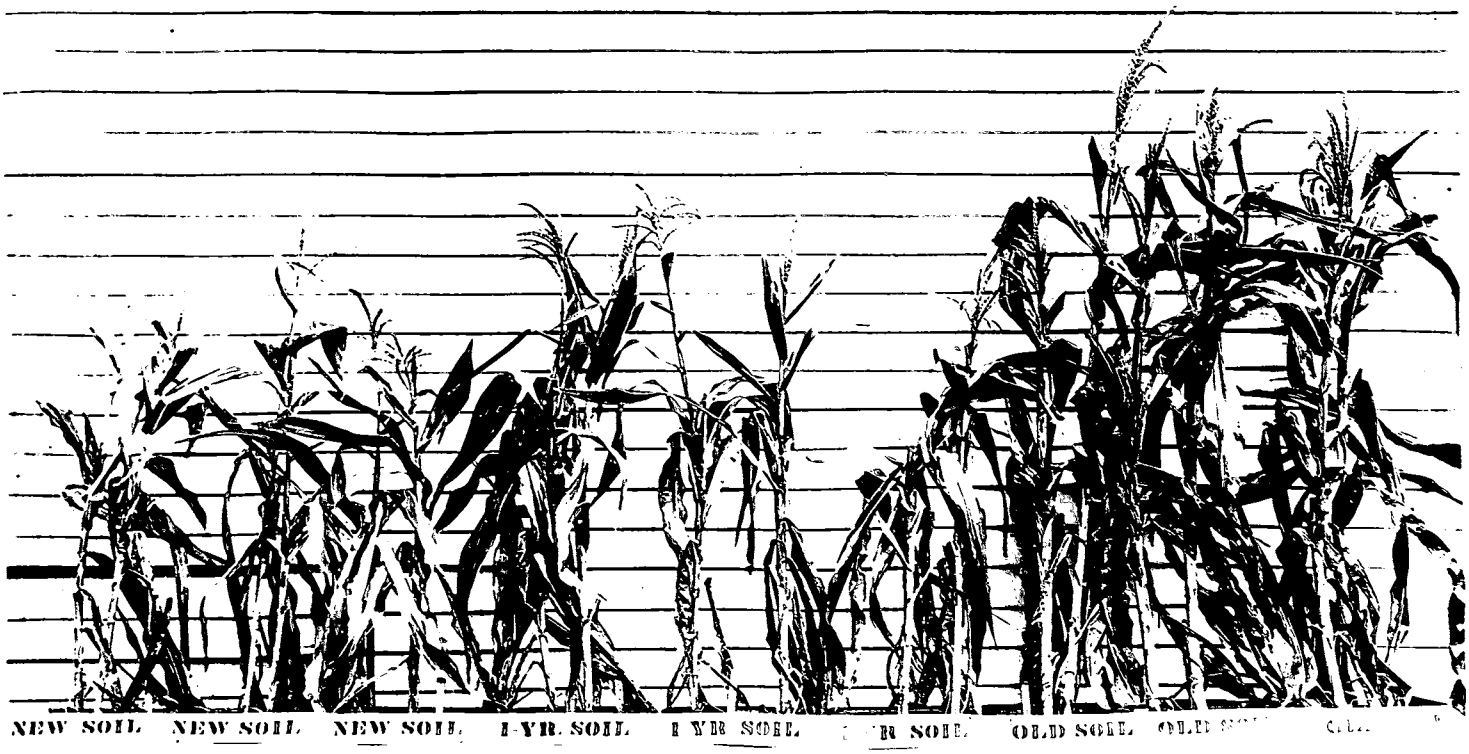

Figure 9

Comparative size of corn plants growing in the old, newly-broken, and one-year old soils at end of first test.

Figure 10

Comparative size of kafir plants growing in the old, newly-broken, and one-year old soil at end of first test. Note the production of grain.

Figure 11

Comparative size of radish plants growing in the old, newly-broken, and one-year old soil at end of first test.

Table X

Comparison by weight of crops grown on the Different Soils.

Corn

Date Planted:	Date Harvested:	Weight		
		Old Soil	Newly Broken Soil	1-yr. old Soil
Oct. 22, 1918:	Jan. 30, 1919:	3.875 lbs.	1.06 lbs.	1.125 lbs.
Feb. 11, 1919:	June 13, 1919:	7.00 "	10.00 "	8.00 "
Oct. 6, 1919 :	Jan. 13, 1920:	1.19 "	1.44 "	1.31 "
Jan. 11, 1919 :	Yield test	3100. 0 per A.	1147.0 per A.	1022.0 per A.
April 3, 1920:	July 8, 1920 :	120.0 grams	167.67 grams	211.35 grams
Aug. 19, 1920:	Nov. 11, 1920:	98.67	126.50	145.00

Kafir

Oct. 22, 1918:	Jan. 30, 1919:	2.435 lbs.	1.850 lbs.	1.156 lbs.
Feb. 11, 1919:	June 13, 1919:	1.000 "	1.458 "	1.375 "
Oct. 6, 1919:	Jan 12, 1920:	.75 "	.938 "	.813 "
April 3, 1920:	July 8, 1920:	187.7 grams	253.38 grams	231.72 grams
Sept. 9, 1920:	Dec. 16, 1920:	107.00grams	148.34 "	154.67 "

Cotton

Oct. 22, 1918:	Feb. 11, 1919:	.436 lbs.	.25 lbs.	.25 lbs.
Feb. 11, 1919:	June 13, 1919:	.688 "	.625 lbs.	.625 "
June 14, 1919:	Oct. 6, 1919:	.437 "	.37 lbs.	.437 "
Oct. 8, 1919:	Jan. 12, 1920:	.25 "	.50 "	.375 "
April 3, 1920:				
Aug. 19, 1920:	Dec. 16, 1920:	38.00 grams	37.00 grams	55.67 grams.

Table X (Continued)

Comparison by weight of crops grown on the Different Soils.

Cotyledon

Date Planted	Date Harvested	Weight		
		Old Soil	Newly broken Soil	1-yr old Soil
Oct. 22, 1918	Jan. 21, 1919	17 lbs.	14 lbs.	15 lbs
Feb. 11, 1919	Killed by Insects.			
June 14, 1919				
Oct. 6, 1919	Jan. 15, 1920	.180 lbs.	.25 lbs.	.125 lbs.
Jan. 15, 1919 (field test)	May 1, 1919	15 tons plus 500 lbs.seed	6.19 tons	5.36 tons
April 5, 1920	July 1, 1920	186.87 grams	147.37 grams	169.03 grams
Sept. 2, 1920	Nov. 11, 1920	135.83 "	244.33 "	219.66 "

Radish

Oct. 22, 1918	Nov. 29, 1918	1.644 lbs.	.438 lbs.	.614 lbs.
Nov. 30, 1918	Jan. 8, 1919	.312 "	.086 "	.188 "
Jan. 8, 1919	Feb. 11, 1919	.261 "	.136"	.344 "
Feb. 11, 1919	April 5, 1919	.551 "	.094 "	.406 "
June 14, 1919	Killed by insects.			
Oct. 6, 1919				
April 5, 1920	June 10, 1920	127.57 grams	83.55 grams	56.70 grams
Aug. 19, 1920	Nov. 11, 1920	57.33 grams	77.00 "	77.67 "

Peppers

Oct. 22, 1918	Jan. 8-June 13, 1919	.875lbs	.876 lbs.	1.251 lbs.
June 14, 1919	No records			
Oct. 6, 1919	Jan. 15, 1920	.313 lbs.	.250 "	.375 "
April 5, 1920				
Aug. 19, 1920	Dec. 16, 1920	Dee2.00 grams	79.67 grams	48.00 gram

Table X (Continued)

Comparison by weight of crops grown on the Different Soils.

Rice

Date Planted	Date Harvested	Weight		
		Old Soil	Newly broken Soil	1-year old Soil
Oct. 22, 1918	Jan. 6, 1919	.078 lbs.	.094	.094
Oct. 22, 1918	Feb. 11, 1919	.063 lbs.	.094	.081
Oct. 22. 1918	Feb. 11, 1919	1.313 lbs.	1.500	1.250
Total		1.454 lbs.	1.688	1.376

During November 1920, nine more pots were added to the test to compare the results obtained on soil that had grown several crops in the pots. Three pots each of soil from the old section fields, the newly-broken grassland, and land that had been broken one year were obtained and planted to corn November 22, 1920. Table XI gives the detailed data in tabular form. The highest average height of stalks in old soil was 87.67 inches, in newly-broken soil, 55.33 inches and in one-year old soil 47.33 inches. The average weight of the normal stalks at time of harvest was 80.00 grams on old soil, 64.50 grams on newly-broken soil and 140.00 grams on one-year old soil. These results are somewhat comparative to the ones that were obtained from the first test planted October 22, 1918.

Table XI

Results of check pots to compare fresh soil with that used in pots during four tests.

Corn planted - November 13, 1920

Date of measurements 1920	Old Soil from Field				Newly Broken Soil from Field				1 year old soil from Field			
	POTS			Aver. Height	POTS			Aver. Height	POTS			Aver. height
	K	M	S		K	M	S		K	M	S	
	Measurements in Inches											
11/29	10	8	9	7.33	8.5	6	7.5	7.33	6	7	12	8.33
12/6	18	12	16	15.33	15	14.5	13	14.17	14.5	14	18	15.50
12/13	30.5	21	26	25.83	22	20	23	21.67	18.5	16.5	24	19.67
12/20	38	28	32	32.67	31	25	26	27.33	28	24	34	28.67
12.27	35	33	43	37.00	37	26	28	30.33	34	27	43	34.67
1921												
1/3	34	35	43	37.33	39	27	29	31.67	37	29	48	38.00
1/10	34	36	43	37.67	41	29	30	33.333	42	34	50	42.00
1/17	33D	36	42	37.00	41	29	29D	33.00	45	38	51	44.67
1/24	33D	35	43	37.00	40	28	29D	32.33	51	39	52	47.33
Weight in grams	34D	98	78	88.00	98	41	11D	64.50	156	84	180	140.00
Date of tasseling		1/13	1/17		1/17				1/18		1/14	

- D - dying or dead and not included in average.

EFFECT OF COMMERCIAL AND LOCAL FERTILIZERS ON PLANT GROWTH.

This experiment was to determine the effect of commercial and local fertilizer applications on plant growth on old and new soils of Guam. Tests with old station soils and the newly broken grassland soil were each conducted in triplicate to determine the needs of both soils. The test consisted of 156 pots and was conducted with five successive crops of corn on the same soils. Measurements were made of the growth of the corn plants every week in order to study the effect of fertilizers through the growing seasons. At maturity, the crops were harvested and weights recorded except for the first two tests. All residues were finely chopped and returned to the soil after each harvest.

The soil was taken from the different fields and composite samples were made by thoroughly mixing together those from the old fields and those from the new field and placing in their respective pots. This work was done in March while the soil was very dry. Soil was taken to a depth of 6 2/3 inches. These soils are the same as have been worked with the former field tests and field work in comparing old and new soils. The fer-

tilizers were first applied and the corn planted in the pots on April 3, 1919. Fertilizers were applied before planting each crop.

Chemical and mechanical analyses made before starting the experiment showed the composition of the new and the old soils varied only to a small extent, not more than might be expected from two samples taken from the same soil bin in a laboratory. However the ability to produce the same crops under field conditions was markedly different as shown in the preliminary tests.

In the field experiments it was found that applications of barnyard manure and the turning under of green manuring crops offered the best means of increasing productivity and the organic content of the soils. Nitrogen fertilizers and acid phosphate increased yields, but were not as lasting in their effects as barnyard manure. Results of the soil tests showed along with other things, that although phosphorous was present in large quantities, it was evidently not in an available form, and most soils were benefited by its application in soluble form as acid phosphate.

Table XII shows the fertilizer treatment, arrangement of pots, rate of application per acre, and amount of fertilizer applied to each pot.

Table XII

Pot Experiments showing pot numbers, applications and amount of Fertilizers on old and new soil.

Pot No.	Treatment	Per acre Application	Per Pot Application
	Commercial Fertilizer		
1	Guard	None	None
2	Check	None	None
3	Nitrate of soda	200 #	1.17 grams
4	Potassium sulfate	200 #	1.17 "
5	Acid phosphate	200 #	1.17 "
6	Nitrate of soda	200 #	1.17 "
	Potassium Sulfate	200 #	1.17 "
7	Nitrate of soda	200 #	1.17 "
	Acid phosphate	200 #	1.17 "
8	Potassium sulfate	200 #	1.17 "
	Acid phosphate	200 #	1.17 "
9	Nitrate of soda	200 #	1.17 "
	Acid phosphate	200 #	1.17 "
	Potassium sulfate	200 #	1.17 "
10	Nitrate of soda	200 #	1.17 "
	Acid phosphate	200 #	1.17 "
	Potassium sulfate	200 #	1.17 "
	Lime (imported)	2000 #	11.70 "
11	Ammonium sulfate	150 #	.8775 "
12	Bonemeal	200 #	1.17 "
13	Check	None	None
14	Check	None	None
15	Sulphur	400 #	2.34 grams
16	Lime (imported)	2000 #	11.70 "
Local products			
17	Manure (barnyard)	10,000 #	58.50 "
18	Lime (local)	2000 #	11.70 "
19	Velvet beans (Gr. man)	10,000 #	58.50 "
20	Cowpeas(Green Man.)	10,000 #	58.50 "
21	Coconut husk ash	1000 #	5.85 "
22	Sea Slugs(chopped Fine)	2000 #	11.70 "
23	Sea Weeds(chp.fine,wet)	2000 #	11.80 "
24	Guano (bat)	300 #	1.75 "
25	Check	None	None
26	Guard	None	None

The commercial products were standard fertilizers bought from companies handling these in the United States. The local products consisted of green manures, and other products with a fertilizing value that were available on the island. Manure was taken from the station barnyard where cattle and horses were stabled. Lime was secured by gathering limestone rocks from the sea along the coasts at low tide. These rocks were burned in crude kilns and the lime left exposed to the weather. Velvet beans and cowpeas were taken in the green stage, chopped fine and mixed with the upper three or four inches of soil in the pots. Coconut husk ash was secured by burning the dry husks of coconuts and saving the ashes for applying to the soil. Sea slugs, which are a species of trepang, locally known as balete, are found in large quantities on the sand in the shallow sea water inside the coral reefs. They have a muscular outer body and the inside of this body is filled with sand and very small shells. These slugs were gathered and chopped fine, being applied to the pots and worked into the soil while still wet. Sea weeds were cut from the shallow sea water, chopped fine and applied to the pots while still green. Guano was taken from caves on the island

which bats inhabit in very large numbers. Analysis made by the Bureau of Soils, United States Department of Agriculture, showed the guano to have the following composition: total nitrogen (N) 6.78 per cent; total phosphoric acid (P_2O_5), 6.31 percent; potash (K_2O), 0.83 percent.

Average weekly measurements of height of stalks of each of five tests are given in tables XIII to XVII, inclusive.

It will be noted that in the first test that the plants in the pots containing the new soils were not as tall as were those in the old soils by an average difference of nearly three inches. Stalks in the pots to which nitrogen and phosphorous, coconut husk ash, guano, cowpeas as green manure, and barnyard manure had been supplied gave the best results on the new soil. The smallest plant growth was from pots to which nothing, nitrogen, sulphur, imported lime, and local lime, respectively, had been applied. This is shown graphically in figure 12. In all the graphs the blue lines represent the growth of the plants in the first five pots having the greatest plant growth during the test. The red lines represent the plant growth during the test of the five pots having the smallest growth. The black lines repres-

Table XII(a)
New Soil

The effect of commercial and local fertilizer applications on plant growth
Average weekly measurements in inches during first test.

Planted April 3, 1919

Pot No.	5/8	5/15	5/22	5/29	6/5	6/12	6/19
1	16.50	18.33	20.00	22.00	22.50	24.67	25.16
2	17.00	16.50	17.33	19.83	20.67	22.67	24.16
3	11.50	11.16	19.50	20.50	20.50	21.00	21.00
4	16.50	19.00	21.50	23.83	23.16	25.33	26.50
5	18.50	18.83	21.67	23.83	26.67	27.50	26.33
6	18.83	19.50	23.33	23.16	25.33	25.83	24.33
7	22.67	25.50	29.50	31.33	32.83	28.33	34.00
8	23.33	25.83	28.16	30.00	30.33	30.33	29.67
9	16.83	20.16	22.50	24.33	24.16	23.33	23.25
10	15.33	19.00	22.67	24.00	24.67	26.00	27.50
11	15.83	19.33	23.33	25.50	26.50	26.50	25.30
12	18.83	22.00	24.00	25.67	26.50	25.83	24.33
13	12.50	14.67	17.33	19.00	19.00	19.33	21.00
14	17.50	20.50	22.00	23.33	22.67	24.16	26.33
15	14.67	18.83	21.00	20.83	21.00	21.67	21.83
16	16.16	20.50	22.50	23.16	23.83	23.00	22.00
17	21.50	27.00	28.33	28.83	29.83	29.00	28.67
18	20.83	22.00	24.83	25.33	28.83	24.57	22.67
19	18.50	21.50	24.16	26.67	24.83	28.33	27.50
20	23.67	25.50	28.67	29.00	28.33	27.67	29.00
21	25.00	29.33	32.00	32.67	32.33	31.83	33.33
22	17.00	21.67	23.33	22.67	26.50	22.50	24.16
23	19.16	26.67	24.33	24.67	26.67	26.50	26.16
24	24.50	20.33	28.67	30.00	29.83	30.33	29.50
25	17.00	18.33	22.67	25.50	25.83	25.67	25.50
26	21.50	25.83	28.16	30.00	29.67	29.16	27.67

Table XIII(b)
(Old soil)

The effect of commercial and local fertilizer applications on plant growth.
Average weekly measurements in inches during first test.

Planted April 3, 1919

Pot No.	5/8	5/15	5/22	5/29	6/5	6/12	6/19
1...	20.00	22.15	23.83	25.16	26.16	25.50	26.50
2...	22.00	23.00	26.83	28.16	25.50	30.00	31.67
3...	22.33	25.33	27.67	30.00	31.83	31.67	29.50
4...	19.16	21.83	24.83	28.50	30.00	30.50	31.83
5...	19.00	22.67	25.67	27.17	28.33	29.33	30.00
6...	21.00	25.83	28.33	31.67	37.50	32.33	36.67
7...	23.50	26.50	27.83	30.33	31.00	30.67	31.50
8...	24.16	27.50	31.16	37.67	41.67	41.67	41.83
9...	18.16	19.50	22.33	24.83	25.16	24.67	25.83
10...	19.16	23.67	27.16	30.67	31.67	30.67	32.00
11...	15.00	18.33	21.67	24.33	25.16	27.00	27.00
12...	18.16	23.33	25.83	28.16	29.33	30.50	29.33
13...	13.50	15.67	18.50	21.83	25.16	24.67	24.83
14...	15.33	19.33	21.00	22.33	23.50	24.00	24.00
15...	16.33	19.50	20.00	24.83	24.50	25.33	25.50
16...	17.67	20.83	23.33	25.00	25.83	26.67	27.00
17...	22.50	24.00	26.50	31.16	32.50	31.33	32.50
18...	15.50	22.33	24.33	26.33	27.00	27.83	25.50
19...	14.50	17.67	21.00	23.00	24.67	26.50	27.33
20...	14.33	18.33	20.33	21.67	22.50	25.16	24.67
21...	15.33	19.67	21.50	22.67	22.50	23.16	25.83
22...	13.67	20.33	22.50	23.83	24.00	30.00	31.17
23...	21.16	25.16	29.83	30.83	31.67	32.34	34.83
24...	19.50	20.16	24.83	26.50	26.16	27.00	27.50
25...	14.67	17.50	24.00	25.33	26.83	25.00	28.67
26...	10.33	27.50	16.67	28.33	19.50	19.83	20.00

Table XIV (a)
(new soil)

The effect of commercial and local fertilizer applications on plant growth.
Average weekly measurements in inches during second test.

Planted October 5, 1919

Pot.No	10/22	10/29	11/5	11/12	11/19	11/26	12/3	12/10	12/17	12/24	12/31	1/7	1/14
ml...	4.83	15.17	24.67	32.67	40.67	44.33	48.33	48.67	48.33	48.67	49.33	49.33	48.67
2...	5.37	14.67	24.00	33.33	39.00	43.00	48.00	49.33	51.67	52.33	52.00	51.67	52.33
3...	5.25	14.83	26.00	35.00	42.33	47.00	50.33	53.00	55.00	54.33	52.67	53.00	51.67
4...	5.33	14.42	26.00	33.33	39.67	45.00	49.67	51.00	54.00	48.33	48.00	48.00	47.33
5...	5.50	14.25	24.33	34.33	38.67	47.33	50.00	53.00	53.00	52.00	51.00	51.33	51.00
6...	5.50	15.17	26.33	36.67	46.67	51.33	53.67	53.33	57.00	55.67	58.67	58.00	57.00
7...	5.67	15.75	30.00	39.67	47.00	51.00	52.67	53.67	51.67	53.33	51.33	51.67	49.67
8...	5.25	13.50	26.67	34.33	43.00	46.00	50.00	49.33	50.33	50.00	50.33	50.00	49.67
9...	5.25	15.16	25.33	36.00	44.00	49.33	54.00	54.00	55.00	52.33	52.33	56.67	55.67
10...	5.42	15.00	27.00	37.67	47.33	52.33	54.67	56.33	56.67	56.67	52.67	52.33	51.67
11...	5.33	14.50	24.67	35.67	46.33	52.67	55.00	53.33	53.00	52.33	51.00	51.33	51.00
12...	5.00	14.83	26.33	37.33	45.33	50.33	54.00	53.67	56.67	56.67	56.00	56.00	56.00
13...	5.25	11.50	20.00	29.33	35.67	43.67	44.67	46.00	48.33	48.33	46.67	48.00	45.00
14...	5.08	15.16	24.67	30.33	35.67	39.00	40.67	41.00	45.00	45.00	45.00	44.67	42.00
15...	4.83	13.50	24.33	30.67	36.33	39.33	41.33	41.33	41.00	40.00	40.00	40.00	39.00
16...	5.17	13.67	23.67	31.67	37.67	41.00	46.00	48.67	53.33	53.33	51.33	53.33	52.33
17...	4.92	12.83	23.67	32.33	40.00	41.33	44.67	46.00	46.33	45.67	46.33	47.67	45.67
18...	5.42	15.33	24.67	33.33	40.67	44.67	42.67	46.00	47.00	47.33	47.00	47.00	45.33
19...	4.42	14.00	26.00	34.33	42.33	48.00	50.00	48.67	46.00	47.67	47.00	47.33	47.00
20...	4.75	13.67	22.33	32.67	42.00	45.67	49.00	50.67	53.67	54.33	53.33	53.00	52.67
21...	4.58	15.33	27.67	38.33	46.67	50.00	52.67	55.67	59.67	58.00	57.00	57.67	56.33
22...	5.00	15.50	27.33	36.33	43.33	47.67	50.00	48.67	47.33	48.33	48.00	47.67	45.67
23...	5.17	14.58	25.33	33.33	41.67	44.67	46.00	50.67	53.00	52.67	52.67	52.67	50.67
24...	5.58	16.16	28.00	32.00	45.33	49.67	51.67	52.33	53.33	53.00	51.67	51.67	48.33
25...	5.17	14.50	25.33	33.67	39.67	42.67	45.33	49.00	50.67	51.33	49.67	50.67	50.00
26...	5.33	14.17	23.33	34.00	41.67	44.33	48.00	48.00	49.00	49.33	47.67	47.33	46.67

Table XIV(b)
(Old soil)

The effect of commercial and local fertilizer applications on plant growth.
Average weekly measurements in inches during second test.

Planted October 5, 1919

Pot No	10/22	10/29	11/5	11/12	11/19	11/26	12/3	12/10	12/17	12/24	12/31	1/7	1/14
1	4.79	14.79	24.00	30.00	33.00	36.67	39.33	38.67	40.67	37.33	37.67	38.67	36.00
2	5.42	13.50	22.67	30.33	34.33	37.67	41.67	40.67	40.67	42.33	43.67	41.33	40.00
3	4.75	14.67	26.67	36.00	42.67	47.33	50.66	48.67	49.67	49.33	50.67	48.33	47.00
4	4.87	14.25	24.67	31.67	38.67	41.33	43.67	44.00	41.33	44.67	42.67	43.67	39.67
5	4.33	13.58	21.67	32.67	38.67	42.67	45.00	43.33	41.67	44.33	44.67	44.00	43.67
6	5.17	14.33	25.67	41.33	44.00	44.67	42.67	47.33	47.00	47133	46.67	46.33	46.33
7	4.17	14.33	26.67	35.67	41.67	47.33	48.33	49.00	50.33	50.67	49.00	49.33	48.00
8	4.83	12.83	22.00	30.00	35.33	39.33	42.00	42.00	40.33	42.00	40.67	41.33	38.67
9	4.83	15.25	27.00	31.67	41.00	44.33	45.67	49.00	49.00	49.33	49.00	48.67	46.67
10	4.58	13.50	27.00	36.00	42.67	46.00	47.33	44.33	46.67	47.67	46.33	47.33	43.00
11	6.50	17.67	30.33	40.00	47.33	53.00	55.00	51.67	52.00	54.33	52.00	51.67	49.67
12	5.00	13.50	23.00	31.33	36.67	41.67	42.67	42.67	44.33	42.33	42.33	41.67	42.00
13	4.75	13.17	21.00	29.33	34.33	37.33	39.00	40.00	40.33	43.00	39.00	40.67	38.33
14	4.58	13.83	23.00	30.33	35.67	37.67	40.00	39.33	39.00	38.33	38.00	38.33	34.67
15	4.75	11.67	19.67	27.67	32.67	36.67	39.33	39.67	40.67	40.67	40.00	39.67	39.67
16	4.58	14.08	22.00	29.33	36.00	39.67	41.33	40.67	41.00	40.00	39.67	41.00	40.00
17	4.92	13.00	20.33	28.33	33.00	36.33	38.00	38.00	37.67	37.33	36.67	37.33	37.00
18	5.33	12.67	22.67	29.33	34.33	38.67	38.33	38.33	39.00	39.00	39.00	39.00	37.00
19	4.50	14.33	24.00	31.00	36.67	39.33	40.67	41.00	42.67	42.00	42.00	41.67	42.00
20	5.17	15.58	24.67	32.67	38.67	38.67	41.00	42.00	41.67	42.00	41.00	42.00	37.33
21	4.58	14.67	24.00	30.33	35.67	38.33	40.67	40.33	40.67	40.33	39.67	39100	33.00
22	5.00	14.00	24.33	33.33	36.00	43.33	44.67	44.00	44.67	44.00	43.33	46.00	39.33
23	4.25	14.67	23.33	33.00	37.67	41.67	42.33	45.67	44.33	46.33	45.33	46.00	44.67
24	5.50	14.67	26.00	32.33	36.67	28.67	40.00	41.00	39.33	39.00	39.33	39.67	36.33
25	5.25	15.00	25.00	33.33	38.67	42.33	44.33	45.00	42.33	42.67	39.00	43.67	38.00
26	4.50	14.00	24.00	32.00	37.00	40.00	42.00	42.67	43.00	42.33	40.00	42.33	37.00

The effect of commercial and local fertilizers on plant growth.

Table XV(a)
(New soil)

Average weekly measurements in inches during third test

Planted Apr. 3, '20

Pot No.	4/16	4/23	4/30	5/7	5/14	5/21	5/28	6/4	6/11	6/18	6/25
1...	10.58	18.50	28.33	34.67	42.33	66.00	71.33	71.33	69.67	63.33	69.67
2...	12.50	21.33	30.00	37.00	44.62	55.33	61.33	78.33	78.00	78.00	77.67
3...	11.25	20.58	30.67	38.00	45.00	55.33	61.67	75.00	74.33	74.33	75.00
4...	11.92	19.67	31.67	36.33	44.00	52.33	57.67	67.00	72.00	71.67	72.33
5...	11.75	21.67	30.67	38.33	49.00	54.33	57.67	66.33	66.67	65.53	66.67
6...	11.58	19.67	31.00	38.00	46.00	48.67	51.00	66.00	66.00	65.00	67.00
7...	13.67	20.25	32.00	37.33	43.33	53.33	57.67	60.00	59.67	58.67	58.67
8...	13.67	21.92	30.67	36.33	43.67	50.33	59.33	68.33	67.67	66.67	66.67
9...	13.42	23.67	32.00	40.00	51.33	63.67	68.33	71.00	70.00	71.33	72.00
10...	12.17	20.08	31.67	35.33	46.67	57.67	69.67	79.33	81.33	81.33	81.67
11...	12.42	19.83	29.33	35.67	43.67	56.33	64.00	78.67	82.00	82.50	82.50
12...	11.25	18.33	27.67	34.67	45.00	61.00	70.33	74.33	75.67	75.67	76.33
13...	12.67	20.83	28.00	33.33	41.67	53.00	57.33	61.00	67.00	67.00	67.50
14...	12.17	20.83	29.33	34.67	41.33	50.67	62.00	76.67	77.67	77.00	78.00
15...	11.00	17.00	28.00	32.00	39.00	50.00	59.33	61.00	63.00	63.33	58.67
16...	11.42	18.42	27.33	33.67	43.33	58.00	65.00	74.67	75.00	74.33	74.33
17...	11.25	17.92	23.67	29.67	36.33	57.00	64.50	66.50	66.00	66.00	66.50
18...	13.25	22.42	30.33	34.00	41.33	54.33	63.00	76.00	77.00	76.67	77.00
19...	11.67	18.92	28.33	35.00	47.67	61.67	73.00	75.33	76.33	75.67	76.67
20...	15.17	22.83	31.33	35.00	45.67	55.67	60.67	64.33	64.00	64.00	64.33
21...	12.17	20.25	31.00	37.00	50.00	60.67	68.67	80.50	81.00	81.00	81.50
22...	12.25	18.08	27.00	31.67	43.33	60.67	69.00	78.67	79.00	79.33	80.67
23...	12.25	17.92	26.33	33.33	42.67	56.50	59.00	75.00	75.33	78.50	78.50
24...	14.00	23.92	31.33	34.33	41.67	51.50	55.00	58.00	58.00	55.00	57.50
25...	14.33	24.00	33.00	37.00	44.00	53.00	58.00	73.00	58.00	55.00	57.50
26...	13.50	22.58	30.67	36.33	43.67	51.33	55.67	62.67	62.67	62.33	62.67

Table XV(b)
(Old soil)

The effect of commercial and local fertilizer applications on plant growth.
Average weekly measurements in inches during third test.

Planted April 3, 1920

Pot No:	4/16	4/23	4/30	5/7	5/14	5/21	5/28	6/4	6/11	6/18	6/25
1...	10.17	30.00	34.33	39.33	43.00	48.33	62.00	63.33	63.00	63.00	63.00
2...	10.08	28.67	34.67	40.67	45.33	49.50	66.00	70.00	69.50	68.50	68.50
3...	10.75	20.67	30.67	35.33	40.33	47.33	52.00	67.50	67.50	67.00	67.50
4...	11.92	20.83	31.00	35.00	42.67	51.33	57.00	73.00	72.67	72.00	72.67
5...	11.33	21.67	32.67	36.33	42.00	50.00	43.67	69.00	68.00	67.00	68.50
6...	12.58	23.33	33.33	36.67	43.00	53.00	58.67	67.00	66.33	65.00	66.33
7...	10.50	18.75	30.00	35.67	44.00	55.33	66.33	74.00	74.67	74.00	74.00
8...	11.50	21.75	31.33	36.67	47.33	56.33	64.67	69.00	68.33	67.00	68.33
9...	10.50	20.80	32.00	38.33	53.67	63.00	75.33	85.33	85.00	83.33	84.67
10...	12.50	22.92	32.00	37.67	49.67	56.67	65.33	75.00	74.00	73.00	72.50
11...	11.13	16.25	27.67	37.33	51.67	60.00	64.67	70.00	74.33	73.67	73.00
12...	12.33	19.92	30.67	35.33	44.67	50.00	54.00	55.50	53.00	52.67	53.00
13...	11.25	21.67	29.00	36.00	48.00	56.00	60.67	63.33	62.33	60.00	62.00
14...	12.08	21.42	29.67	34.67	44.67	52.33	59.00	60.33	63.33	63.00	63.00
15...	11.50	19.92	27.67	32.67	40.67	46.00	51.33	52.00	54.00	52.00	53.33
16...	11.92	22.42	30.33	36.67	46.67	54.67	60.33	67.33	67.00	66.33	67.33
17...	14.83	22.50	31.67	36.00	42.33	48.67	51.67	56.67	56.33	55.67	57.00
18...	8.92	20.33	29.00	34.00	43.67	52.33	59.00	62.33	62.33	62.00	63.22
19...	10.33	18.17	31.00	38.67	51.67	59.33	63.00	67.67	66.00	65.33	66.00
20...	9.83	19.92	29.67	35.67	46.00	58.33	67.67	74.33	78.33	78.33	77.67
21...	10.83	21.00	29.67	34.00	41.00	45.67	48.33	54.00	53.33	53.00	52.00
22...	12.83	20.42	31.00	37.00	47.67	56.33	60.00	64.00	63.67	62.67	63.67
23...	9.75	22.33	29.67	26.67	47.00	54.33	58.67	65.33	67.00	66.33	67.00
24...	13.33	22.75	31.67	35.33	44.00	49.33	52.33	52.33	51.00	50.00	50.67
25...	10.75	20.25	28.67	35.00	46.00	53.00	58.67	58.67	63.00	62.67	62.33
26...	13.75	24.33	31.00	35.00	42.67	48.33	53.00	55.00	54.67	54.00	54.33

Table XVI(b)
(New soil)

The effect of commercial and local fertilizer applications on plant growth
Average weekly measurements in inches
fourth test.

Planted August 19, 1920

Pot No.	9/2	9/9	9/16	9/23	9/30	10/7	10/14	10/21	10/28	11/4
1..	12.50	19.67	29.00	33.33	59.33	67.67	71.33	72.67	70.67	72.67
2..	13.50	23.67	33.33	41.33	52.00	69.00	71.00	71.50	70.50	70.50
3..	13.00	25.50	35.00	44.67	54.67	63.67	69.00	72.67	72.33	71.78
4..	12.67	20.50	31.67	44.67	55.33	66.33	74.00	76.67	76.00	77.00
5..	12.67	22.67	33.00	44.67	55.33	59.67	65.67	65.33	63.33	64.67
6..	12.33	23.33	33.00	44.33	59.33	67.33	76.33	83.67	83.67	83.33
7..	12.67	23.16	33.00	44.00	56.33	63.67	66.67	63.67	62.00	68.00
8..	12.50	23.67	33.33	42.00	53.33	59.67	63.33	66.00	66.33	75.00
9..	12.33	21.16	31.33	41.67	57.00	64.67	69.00	77.00	77.00	77.00
10..	11.50	20.50	28.67	34.67	43.00	48.00	51.00	60.50	60.50	60.00
11..	13.33	20.67	28.67	38.67	51.00	57.33	61.00	64.00	66.00	63.00
12..	10.50	17.33	26.00	31.67	40.67	44.00	47.33	75.00	75.00	74.000
13..	12.00	20.33	28.33	36.67	49.00	56.67	59.33	61.67	61.67	61.67
14..	11.83	18.67	26.00	35.00	42.67	46.67	48.33	34.40	45.50	0.00
15..	11.33	15.67	22.00	28.67	37.00	48.00	52.00	58.50	59.00	58.00
16..	11.33	19.83	24.67	30.67	34.33	49.00	44.00	44.00	49.00	00000
17..	12.83	21.83	29.33	38.33	51.33	59.33	62.33	62.00	62.00	62.67
18..	11.50	21.67	30.33	40.67	48.00	52.33	53.33	52.33	52.33	51.00
19..	12.83	24.00	33.00	42.00	51.67	62.00	68.67	69.00	69.00	68.33
20..	12.17	20.00	26.33	34.67	43.67	48.33	51.33	50.67	56.50	0.00
21..	11.50	21.50	31.67	40.33	48.33	54.00	61.00	64.00	65.00	62.33
22..	11.83	19.50	25.33	32.67	38.67	46.00	51.33	51.00	51.33	49.50
23..	10.67	16.83	25.33	35.67	50.33	57.33	60.67	66.00	63.00	63.67
24..	10.17	15.67	22.33	30.67	40.00	45.67	46.67	44.33	45.00	39.00
25..	13.33	21.67	31.33	39.33	50.00	53.00	53.33	54.33	54.67	53.33
26..	13.33	21.33	32.33	42.33	52.33	57.67	62.00	63.33	65.33	64.00

(High winds during the last two weeks of tests. Some stalks broken.)

Table XVI(b)
Old soil

The effects of commercial and local fertilizer applications on plant growth
Average weekly measurements in inches during fourth test.

Planted August 19, 1920

Pot No:	9/2	9/9	9/16	9/23	9/30	10/7	10/14	10/21	10/28	11/4
1...	11.33	18.00	26.33	34.67	41.67	47.33	48.33	49.00	49.67	46.67
2...	13.17	19.33	28.33	34.67	42.00	44.00	44.67	50.00	50.00	0.00
3...	12.50	18.67	29.67	33.33	39.67	41.00	43.67	45.00	44.50	42.50
4...	13.83	19.83	28.67	35.67	41.67	45.33	44.00	43.00	44.00	42.50
5...	11.50	18.33	26.00	34.67	42.67	48.00	49.33	51.33	50.00	50.33
6...	12.17	18.16	26.33	34.67	46.00	51.00	49.00	54.33	55.33	55.00
7...	10.67	19.17	29.00	38.67	46.00	51.00	52.33	55.00	53.00	52.00
8...	12.33	20.17	28.67	33.67	43.33	50.00	51.00	60.00	59.00	58.50
9...	12.50	18.00	27.33	35.33	43.33	47.67	52.67	62.00	62.00	61.33
10...	12.00	20.17	27.33	35.00	42.00	46.00	46.67	42.33	41.33	44.00
11...	11.33	19.17	27.67	33.67	43.67	49.67	54.33	59.00	57.67	58.00
12...	12.17	18.00	26.33	32.00	38.67	40.67	42.33	44.33	45.00	45.33
13...	11.67	19.83	26.67	36.33	42.67	45.33	47.00	46.00	57.00	56.00
14...	9.67	16.33	25.00	30.33	34.33	43.00	44.00	48.00	48.00	49.00
15...	12.17	19.17	24.67	29.00	37.67	42.00	44.00	49.00	48.00	42.00
16...	12.33	18.00	26.67	32.33	40.00	43.33	46.33	44.33	44.67	43.67
17...	10.00	15.50	24.00	32.00	40.33	43.33	46.33	54.00	54.00	54.00
18...	12.50	18.83	25.67	30.67	34.33	42.00	52.00	44.00	53.00	53.00
19...	9.17	17.33	25.33	34.33	42.33	47.67	51.33	49.33	52.00	54.00
20...	12.33	19.67	29.00	38.00	47.33	51.33	52.67	54.67	54.67	54.33
21...	10.33	16.50	27.67	29.33	35.00	40.00	44.00	50.33	47.33	47.33
22...	12.33	18.50	27.67	33.33	39.33	43.33	48.33	52.33	52.00	51.67
23...	10.17	17.33	25.00	31.33	38.00	40.33	42.67	45.33	43.67	44.33
24...	12.00	18.83	26.00	33.00	42.67	47.67	49.00	50.00	49.67	49.33
25...	11.17	17.33	24.00	32.67	41.00	39.67	46.67	52.00	52.67	52.33
26...	10.83	19.67	27.67	36.00	46.33	51.00	53.33	59.00	56.67	58.67

Table XVII(a)
(New Soil)

The effect of commercial and local fertilizer application on plant Growth
Average weekly measurements in inches during the fifth test

Planted April 3, 1920

Pot No.	11/29	12/6	12/13	12/20	12/27	1/3	1/10	1/17	1/24
1...	12.17	20.67	29.33	35.33	45.33	47.67	48.00	50.67	52.67
2...	13.50	22.50	33.7	45.00	50.50	53.00	53.00	52.00	51.50
3...	11.25	13.67	26.00	39.67	47.33	50.67	52.33	53.00	53.33
4...	9.33	18.83	28.83	39.33	46.67	49.67	50.67	53.33	55.33
5...	11.33	19.33	27.50	35.00	41.67	45.67	45.67	45.67	45.67
6...	12.33	23.33	33.67	44.00	50.67	52.67	53.00	53.33	52.33
7...	12.67	23.33	33.83	44.67	49.33	49.33	50.00	50.00	47.50
8...	12.50	23.00	30.67	39.67	46.00	44.67	46.67	46.33	45.67
9...	11.50	19.50	30.00	35.67	47.33	49.67	52.00	52.67	53.67
10...	10.83	18.50	28.00	40.00	47.33	48.33	51.00	51.00	52.67
11...	11.17	15.50	25.57	32.67	42.67	45.00	48.67	50.00	51.00
12...	12.67	24.17	32.17	42.67	49.33	50.33	50.67	50.33	49.33
13...	10.33	19.33	29.33	38.33	44.67	46.33	48.00	46.33	46.67
14...	13.17	24.00	34.33	43.33	50.67	50.67	51.00	51.33	51.67
15...	11.67	21.50	29.33	36.00	45.67	47.67	49.67	49.33	49.00
16...	12.33	22.67	33.33	41.33	48.00	49.00	48.67	48.33	48.33
17...	12.67	23.83	35.67	40.00	50.33	50.00	50.33	50.67	50.33
18...	8.67	19.33	27.67	38.33	45.67	47.00	48.67	49.67	51.67
19...	9.33	18.00	28.50	37.67	45.67	46.67	47.33	48.33	47.67
20...	7.83	15.17	24.00	34.33	39.00	41.33	43.33	44.67	44.67
21...	10.83	19.67	33.00	37.00	45.00	46.67	47.67	48.33	48.33
22...	12.83	23.83	35.00	43.67	49.67	49.00	49.67	47.33	49.33
23...	11.50	20.67	32.83	32.33	40.33	41.33	41.67	40.67	40.33
24...	11.67	21.33	30.67	39.67	45.67	46.33	47.00	49.33	49.00
25...	11.50	20.67	30.83	38.33	44.33	44.33	45.00	45.00	44.33
26...	12.67	21.67	38.33	46.67	43.33	47.33	49.33	49.00	49.00

Table XVII (b) (Old soil)

The effect of commercial and local fertilizer applications on plant life.
Average weekly measurements in inches during fifth test.

Planted April 3, 1920

Pot No.	11/29	12/6	12/13	12/20	12/27	1/3	1/10	1/17	1/24
1...	11.50	20.50	29.00	35.33	41.00	42.33	42.00	42.00	41.33
2...	12.50	23.17	30.33	37.30	43.00	43.00	43.00	43.00	42.00
3...	11.33	17.17	25.83	30.67	44.00	45.67	47.00	46.67	46.00
4...	12.17	21.83	37.00	44.00	45.00	45.00	45.00	44.00	44.00
5...	12.33	21.33	28.00	36.33	41.67	43.00	42.00	42.67	42.00
6...	12.00	21.17	22.83	34.33	50.00	49.00	50.33	49.67	49.00
7...	12.33	22.83	33.33	40.33	44.67	44.67	45.67	45.67	44.67
8...	12.50	22.00	29.33	36.33	43.00	44.67	41.33	45.00	45.00
9...	13.00	23.67	31.33	38.00	44.67	45.00	45.67	47.00	46.67
10...	12.83	23.00	30.00	38.33	44.00	43.33	43.33	43.33	43.33
11...	12.33	22.00	30.67	37.67	41.33	42.00	42.00	42.00	42.00
12...	12.67	21.67	30.00	38.00	43.00	40.67	40.67	41.00	40.00
13...	10.67	20.33	30.00	38.68	42.67	43.33	43.33	43.00	42.33
14...	11.67	20.00	27.67	38.00	39.00	38.67	40.00	39.67	38.67
15...	11.00	20.50	29.17	36.00	41.33	41.67	43.00	42.33	42.00
16...	11.33	20.33	28.67	35.00	39.67	40.00	41.33	41.33	41.00
17...	11.33	20.50	28.83	36.00	41.33	42.00	42.33	42.33	42.00
18...	8.33	14.17	21.33	27.33	33.33	35.33	37.33	38.33	37.67
19...	12.17	21.50	31.00	39.67	49.33	49.00	49.33	49.67	49.67
20...	8.50	15.33	24.17	37.00	40.67	42.33	42.33	45.67	42.33
21...	12.50	27.33	33.67	37.67	38.00	39.00	38.33	38.33	38.00
22...	10.83	19.33	26.17	31.33	34.33	35.00	36.00	36.67	36.33
23...	10.83	19.33	26.17	31.33	34.33	35.00	33.67	34.00	34.00
24...	9.17	15.33	22.67	30.67	32.00	33.00	33.67	32.67	33.00
25...	9.67	15.33	22.67	30.67	32.00	33.00	33.67	32.67	33.00
26...	8.17	16.83	23.33	30.33	35.67	38.33	38.67	38.67	38.33

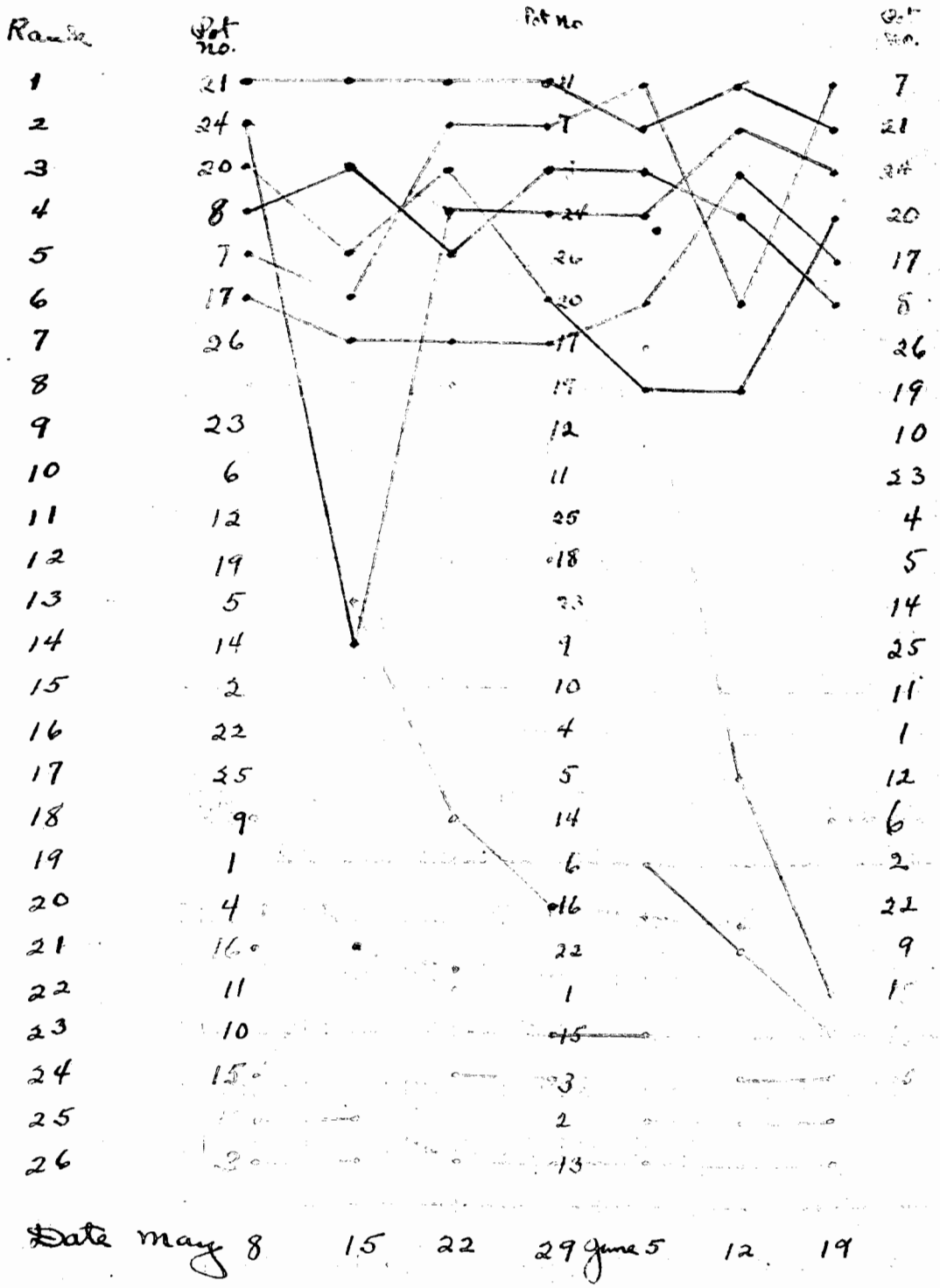

Figure 12

Graph showing plant growth in first test in new soil.

ent the growth of the plants in the pots having plants that were the largest at the first measurement of the test. The green line represents the growth of the average of the four check pots.

The best growth on the old soil was made in the pots to which had been applied phosphorous and potassium; nitrogen and potassium; sea weeds, barnyard manure, and a complete fertilizer plus lime. The poorest growth was made in those pots to which had been applied; nothing(two checks), cowpeas, nothing(check), and sulphur. Figure 13 shows in graphic form the results of the first test on old soil. The growth of the plants on the new soil, while small and rather spindly was much greater than it was possible to secure under field conditions.

In the second test and in all of the three following tests, the plant growth as indicated by the heights of corn stalks in the pots was greater than that on the old soils. This was rather surprising after the results that had been secured in the field, even after several crops had occupied the land.

In the second test it was found that the greatest plant growth on new soil was made in pot 6 to which nitrogen and potassium had been applied. This was follow-

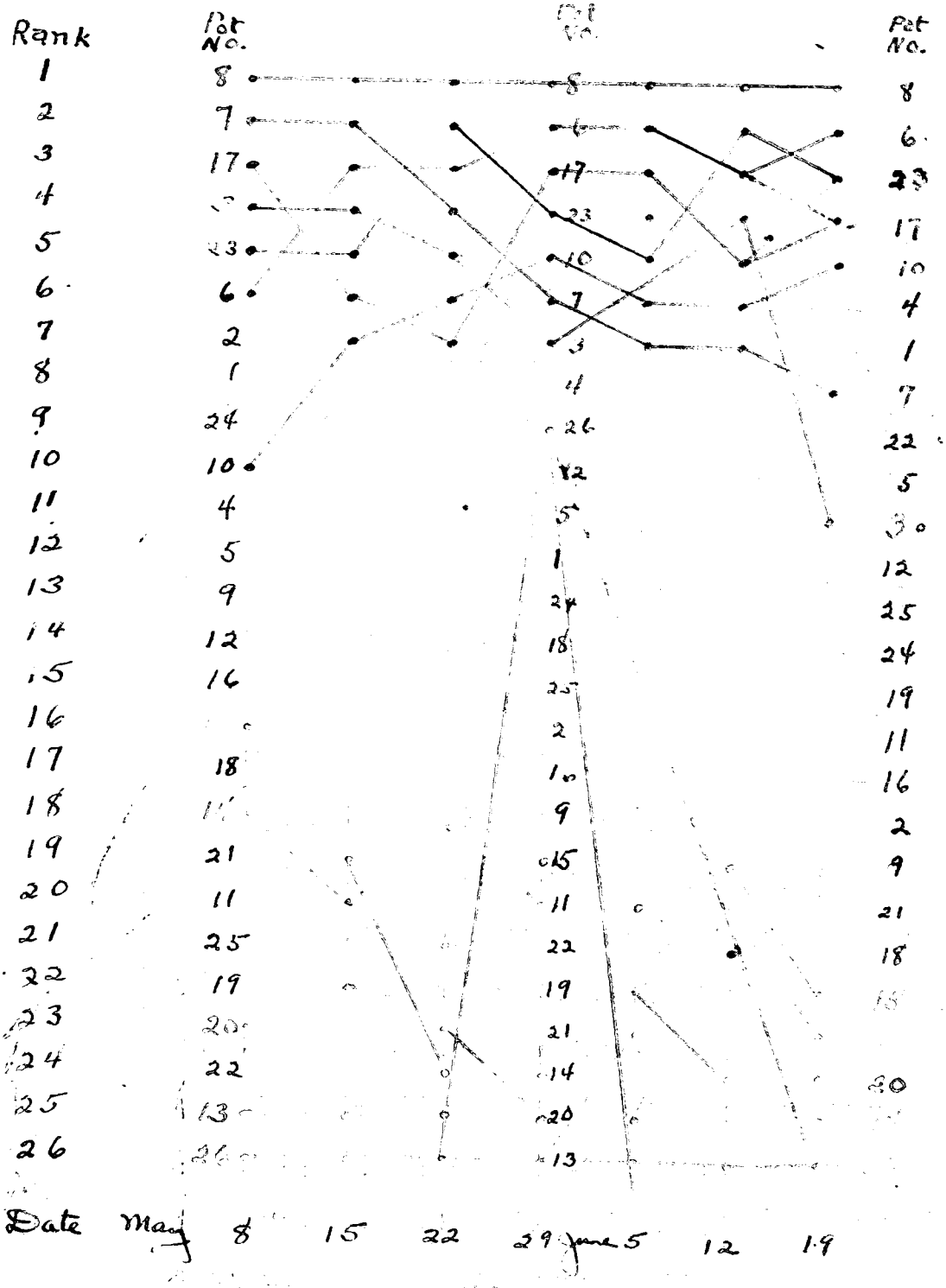

Figure 13

Graph showing plant growth in first test on old soil.

ed by pots 21, 12, 9, and 20, to which had been applied; coconut husk ash, bonemeal, a complete fertilizer, and cowpeas as a green manure, respectively. The plants making the smallest growth were in pots 15, 14, 18, 13, and 17, in the order named. Treatment given to these pots had been as follows; sulphur, nothing(check), local limes, nothing(check), and barnyard manure. The plant growth as shown by the graph in figure 14 was very irregular between the different pots. For instance pot 20, which was fifth in plant growth at the end of the test was twenty-fourth in rank at the first measurement, while 18 which was sixth at the first measurement, was only third from the bottom in making the smallest growth.

In the old soil during the second test the greatest plant growth was made in pot 1[illegible], to which nitrogen in the form of ammonium sulfate had been added. The plants in these pots took the lead at the start of the test and had at all times the largest plant growth during the 13 weeks in which the measurements were made. Pots 7, 3, 9, and 6 were next in rank of greatest plant growth. These pots had received applications of; nitrogen and phosphorous, nitrogen, complete fertilizer, and nitrogen and potassium, respectively. It will be noted from the graph in figure 15 that the plants in pot 7 during the first four weeks of measurement climbed

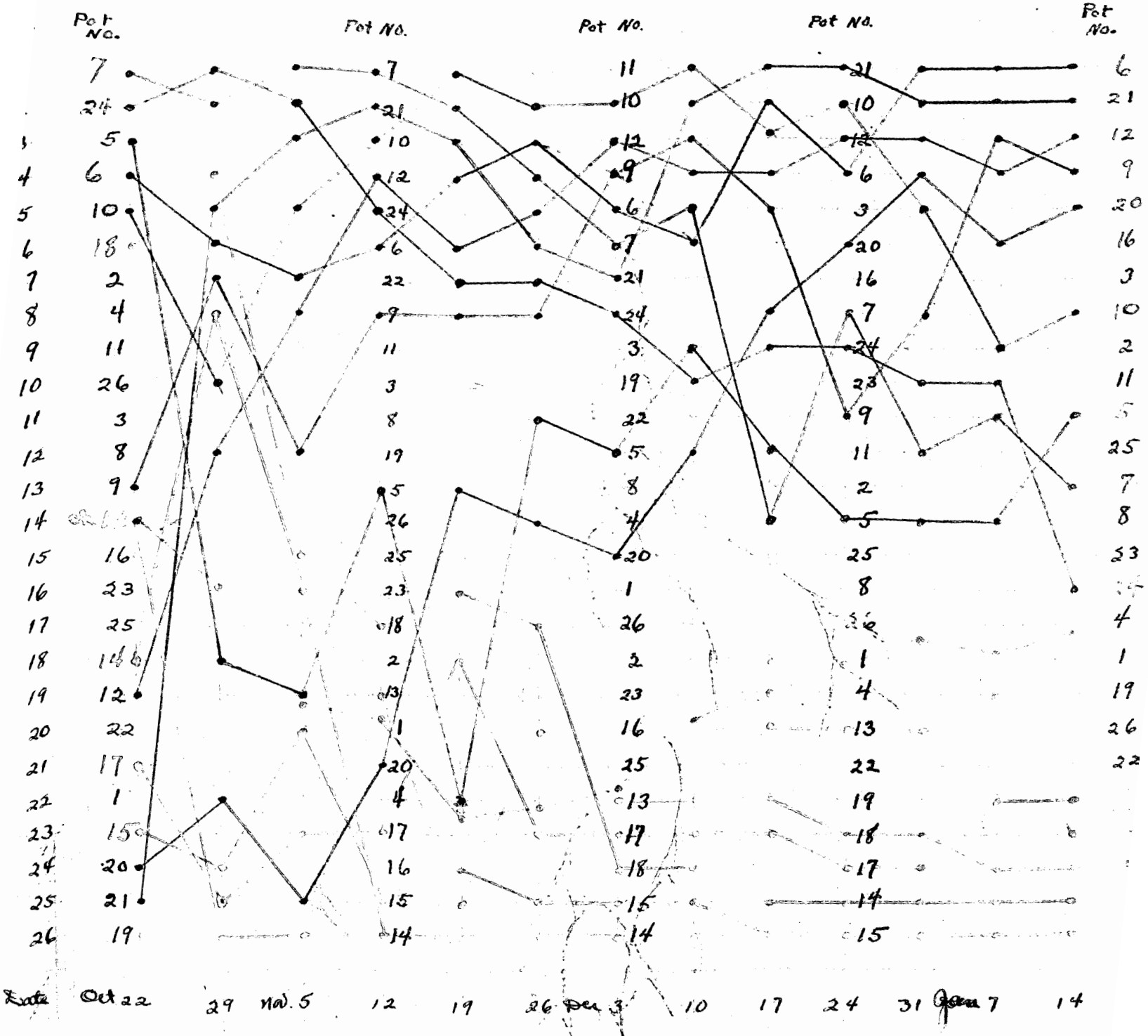

Figure 14

Graph showing plant growth in second test on new soil.

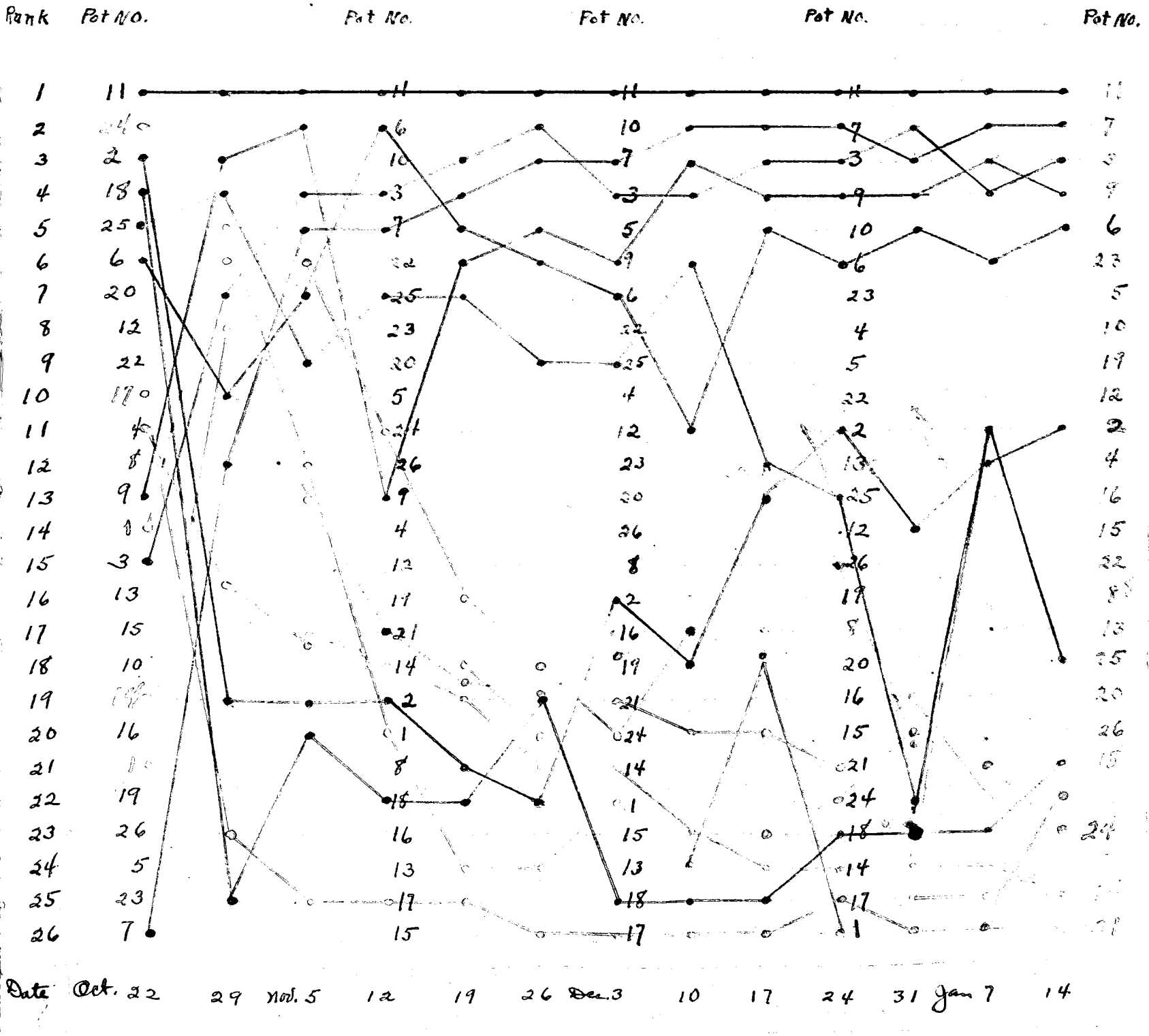

Figure 15

Graph showing plant growth in second test on old soil.

from the bottom rank to thesecond in rank in plant growth as measured by height. The smallest plant growth was recorded from pots 21, 14, 1, 24, and 17, which had received the following fertilizer treatment; coconut husk ash, nothing(check), nothing(guard row), guano, and barnyard manure, respectively.

In the second test the plant growth on new soil as a whole improved until it surpassed that made on the old soil. This was noticed to an even more marked extent in the third, fourth and fifth tests.

Table XVIII summarizes and gives the average results of the five crops or tests conducted to find the effect of commercial and local fertilizers on plant growth on the new and old soils of Guam. In the summary the measurements are an average of the highest recorded heights of the corn plants during the five tests. The average for all pots in the tests show the new soil averaged plants in height that exceeded those on the old soil over four inches.

The average of the plants grown in the pots containing new soil showed that the greatest height during the five tests was from pot 6 with an average height of 57.70

Table XVIII(a) (new soil) Effect of commercial and local fertilizer on plant growth as denoted by average of highest recorded stalks.

Pot.No	Commercial fertilizers Treatment	3 stalks Test 1	2 stalks 2nd test	1 stalk 3rd test	1 stalk 4th test	1 stalk 5th test	av. tot. growth	Average	Rel. rank
1	Guard	25.16	49.33	71.33	72.67	52.67	271.16	54.23	12
2	Check	24.16	52.33	78.33	71.50	53.33	279.65	55.93	8
3	$NaNO_3$	21.00	55.00	75 .00	72.67	53 .33	277.00	55.40	10
4	K	26.50	54.00	72.33	77.00	55.33	285.16	57.03	5
5	P	27.50	53.00	66.67	65.67	45.67	258.51	51.70	17
6	N, K	25.83	58.67	67.00	83.67	53.33	288.50	57.50	1
7	N, P	34.00	53.67	60.00	66.00	50 .00	265.67	53.13	15
8	K, P	30.33	50.00	68.33	75.00	46.67	270.33	54.07	13
9	N, P, K	24.33	56.67	72.00	77.00	53.67	283.67	56.73	6
10	N, P, K, CaO	27.50	56.67	81.67	60.50	52.67	279.01	55.80	9
11	NH_3	26.50	55.00	82.50	66.00	51.00	281.00	56.20	7
12	Bone meal	26.50	56.67	76.33	75.00	50.67	285.17	57.03	4
13	Check	21.00	48.00	67.50	61.67	48.00	246.17	49.23	24
14	Check	26.33	45.00	78.00	48.33	51.67	249.33	49.87	23
15	Sulphur	21.83	41.33	63.00	59.00	49.67	234.83	46.97	26
16	Lime(imported)	23.83	53.33	75.00	49.00	49.00	250.16	50.03	22
	Local Products								
17	Manure	29.83	47.67	66.50	69.00	50.67	263.67	52.73	16
18	Lime(local)	28.83	47.33	77.00	53.33	51.67	258.16	51.67	19
19	Velvet beans	28.83	50.00	76.67	69.00	48.33	272.33	54.47	11
20	Cowpeas	29.00	54.33	64.33	56.50	44.67	248.83	49.77	2
21	Coconut husk ash	33.33	59.67	81.50	48.33	65.00	287.83	57.57	3
22	Sea Slugs	26.50	50.00	80.67	51.33	49.67	258.17	51.63	18
23	Sea weeds	26.67	53.00	78.50	66.00	41.67	265.84	53.17	14
24	Guano	30.33	53.33	58.00	46.67	49.33	237.66	47.53	25
25	Check	25.83	51.33	75.00	54.67	45.00	251.67	50.37	21
26	Guard	30.00	49.33	62.67	65.33	49.00	256.33	51.27	20

Table XVIII (b)
(Old Soil)

Effect of commercial and local fertilizer on plant growth as donated by average of highest recorded Stalks in Five Tests.

Pot. No.	Treatment	Commercial fertilizers: 3 stalks Test I	2 stalks 2nd test	1 stalk 3rd test	1 stalk 4th test	1 stalk 5th test	Av. tot. growth	Average	Rel. Rank
1	Guard	31.67	40.67	63.33	49.67	42.33	227.67	45.53	16
2	Check	27.16	43.67	70.00	50.00	43.00	233.83	46.77	12
3	Na NO3	31.83	50.67	67.50	45.00	47.00	242.00	48.40	8
4	K	31.83	44.00	73.00	45.33	45.00	239.16	47.83	10
5	P	30.00	45.00	69.00	51.33	43.00	238.33	47.67	11
6	N, K	36.67	47.33	67.00	55.00	50.33	256.33	51.27	5
7	N,P	31.50	50.67	74.67	55.00	45.67	257.51	51.50	3
8	K,P	41.86	42.00	69.00	60.00	45.33	258.19	51.64	2
9	N? P? K	25.83	49.33	85.00	62.00	47.00	269.16	53.83	1
10	N, P,K, CaO	32.00	47.67	75.00	46.67	44.00	245.34	49.07	6
11	N H_3	27.00	55.00	74.33	59.00	42.00	257.33	41.47	4
12	Bonemeal	30.50	44.33	55.00	45.33	43.00	218.16	43.63	22
13	Check	25.16	43.00	63.33	57.00	43.33	231.82	46.36	13
14	Check	24.00	40.00	63.33	49.00	40.00	216.33	43.27	23
15	Sulphur	25.50	40.67	54.00	49.00	43.00	212.17	42.43	24
16	Lime(Imported)	27.00	41.33	67.33	46.33	41.33	223.32	44.66	19
	Local Products:								
17	Manure	32.50	38.00	57.00	54.00	42.33	223.83	44.77	18
18	Lime (Local)	27.83	39.00	62.67	53.00	38.33	220.83	44.17	20
19	Volvet Beans	27.33	42.67	67.67	54.00	49.67	241.34	48.29	9
20	Cowpeas	25.16	42.67	79.00	54.67	42.67	244.17	48.83	7
21	Coconut husk ash	25.83	40.67	54.00	50.33	39.00	209.83	41.97	25
22	Sea Slugs	31.17	46.00	64.00	52.33	36.67	230.17	46.03	14
23	Sea Weeds	34.83	46.33	67.00	45.33	35.00	228.49	45.70	15
24	Guano	27.50	41.00	52.33	50.33	33.67	204.50	40.90	26
25	Check	28.67	45.00	63.00	52.67	30.00	219.34	43.87	21.
	Guard	28.33	43.00	55.00	59.00	38.67	224.00	44.80	17

inches. The smallest plant growth was made by the plants in pot 15 which averaged 46.97 inches in height. The pots producing the greatest plant growth had received applications of nitrogen and potassium and those that produced the smallest plant growth had been treated with sulphur. The next four pots in rank producing the greatest plant growth were 20, 21, 12, and 4, which had received the following treatment; cowpeas as green manure, coconut husk ash, boneneal, and potash, respectively. The five pots producing the smallest plant growth were in the order of their heights, 15, 24, 13, 14, and 16. These pots had received the following fertilizer treatments; sulphur, guano, none(check), none (check), and imported lime, respectively. The average height of the plants in the four check pots was 51.35 inches, which is about ninteenth in rank of greatest growth, when compared to the other pots in the tests on new soil.

In the pots containing old soil, the greatest plant growth as shown by the averages of the five tests was made by the plants in pot 9, which had an average of 53.83 inches, and had received applications of a complete fertilizer, consisting of nitrogen, phosphorus,

and potassium. The smallest plant growth was made by the plants in pot 24, which averaged 40.90 inches in height and which had been treated with applications of guano. The average height of the plants in the four check pots was 45.07 inches or 6.28 inches less than the average of the check pots in the new soil. These checks averaged a little less than seventeenth in rank when compared to the plant growth made in the other pots, containing old soil. The next four pots having the greatest plant growth were 8, 7, 11, and 6, which had received the following fertilizer applications; phosphorus and potassium, nitrogen and phosphorous, nitrogen in the form of ammonium, and nitrogen and potassium. The pots with plants making the smallest growth were 24, 21, 15, 14, and 12, which had received the following treatments; guano, coconut husk ash, sulphur, none(check), and bone-meal, respectively.

Figures 16 and 17 show in graphic form the rank at the end of each test and the average for the five tests of the five pots having the greatest plant growth, the five pots having the smallest plant growth, the five pots having the greatest growth at the end of the first test.

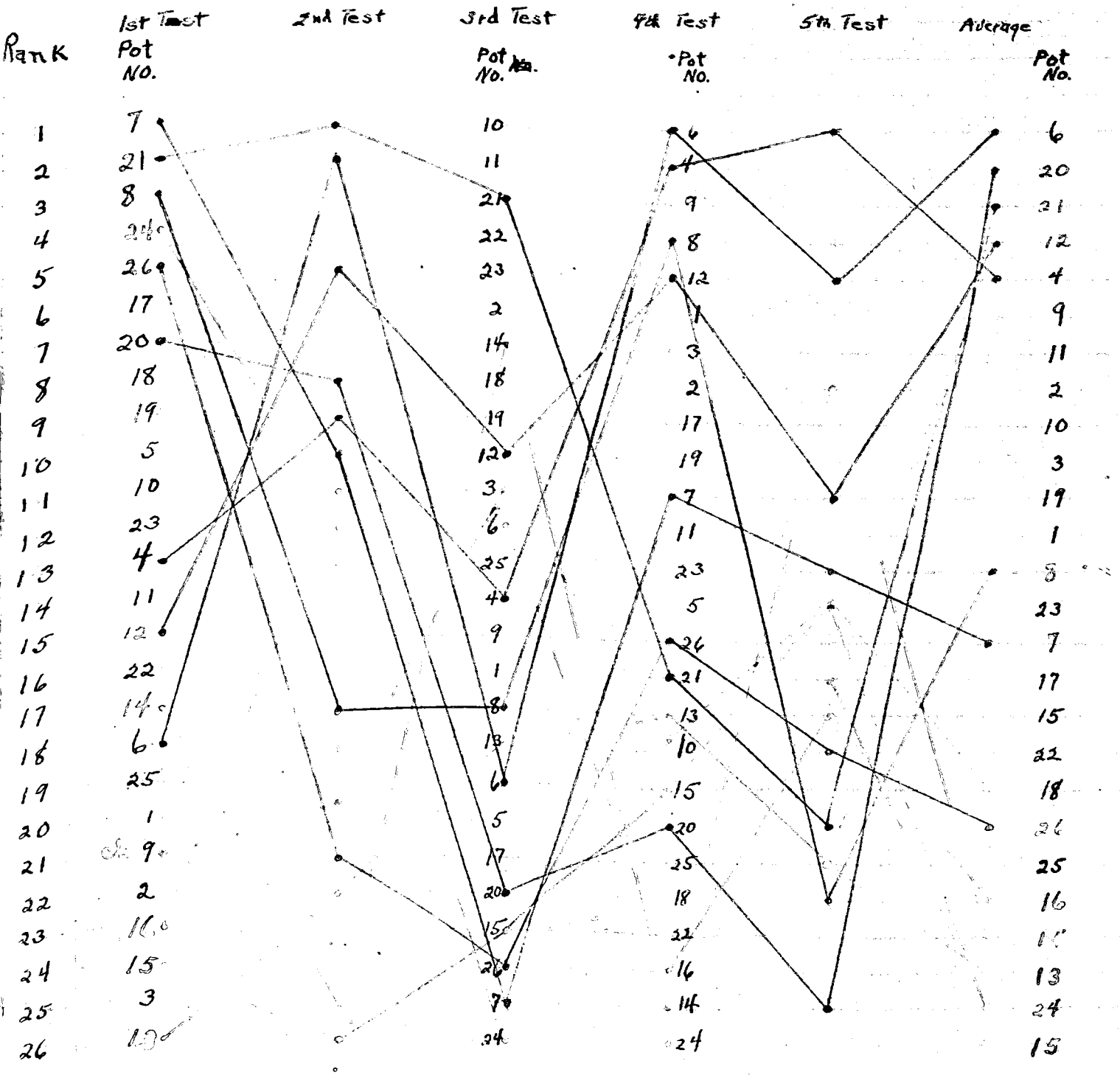

Figure 16

Graph showing average rank of plant growth in pots at end of test on new soil.

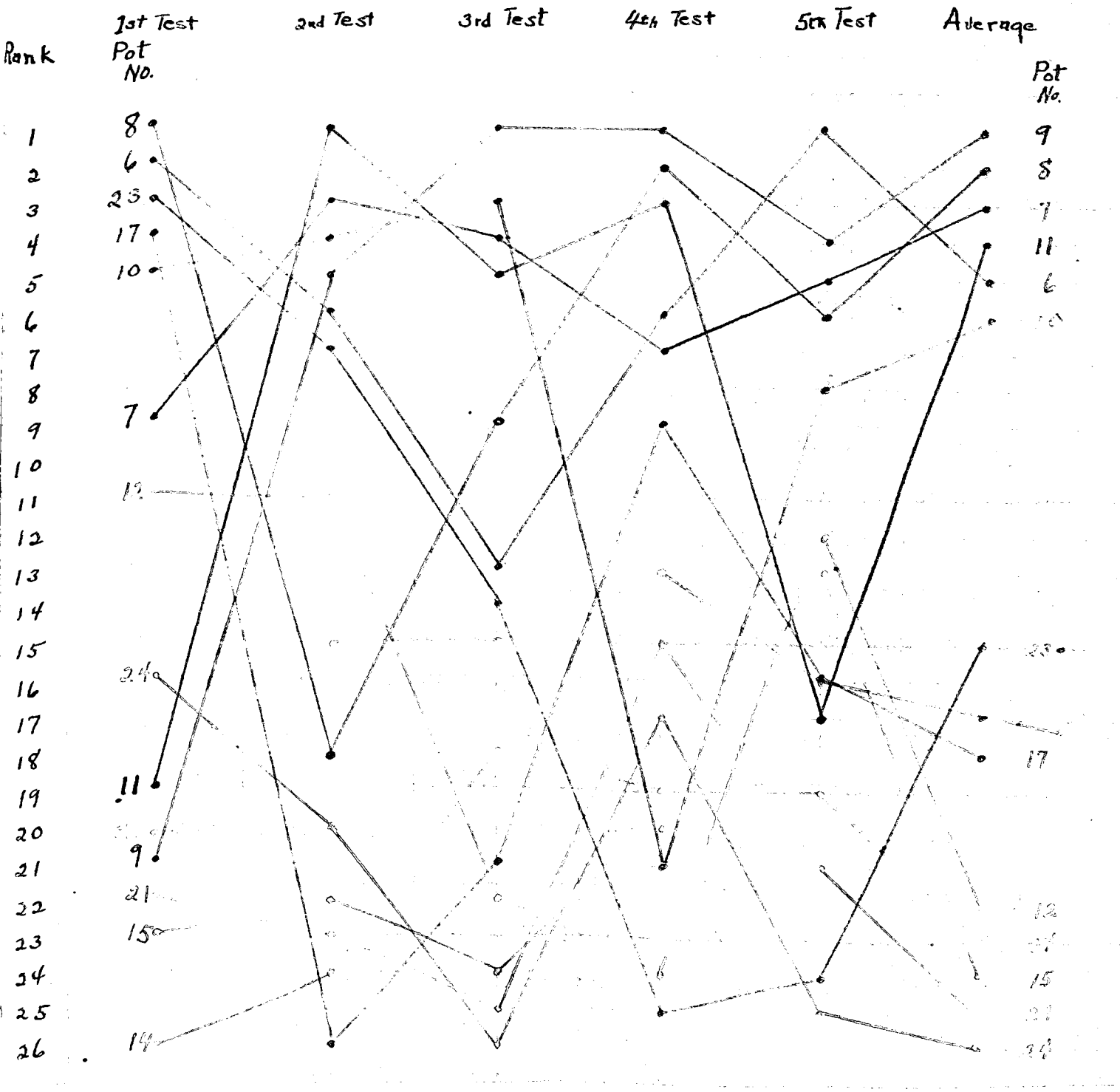

Figure 17

Graph showing average rank of plant growth in pots at end of tests on old soil.

and the average of the four check pots in each of the new and the old soils.

Figures 18 and 19 show the mature crop grown on the old soil during the fourth test. Figures 20 and 21 show the mature crop grown on the new soil during the fourth test.

Weights of the stalks were taken at the completion of each of the last three tests. It is realized that a much greater difference existed in the weights of the plants growing on the new and old soils during the first two tests. In fact, the plants growing on the new soil were more slender and not as tall as those growing on the old soil. It is regretted that the weights from the first two tests are not available as they would more nearly show the true state of unproductiveness that exists when crops are first planted on this type of soil. However, the check pots which will be mentioned later, show this difference to a marked extent. Figures 9, 10 and 11, illustrate the differences in plant growth that existed at the first planting.

Table XIX shows the average stalk weights at the end of the third, fourth and fifth tests, the average of these tests, and the rank of each pot containing new and

Table XIX (a)

The Effect of Commercial and Local Fertilizer Applications on Plant Growth.

Average weight in grams of stalks at end of each test.

NEW SOIL

Pot No.	Treatment	3rd test	4th test	5th test	Average	Relative Rank
	Commercial Fertilizers.					
1	Guard	215.33	283.00	152.67	217.00	9
2	Check	258.67	381.00	174.50	274.72	2
3	Na NO_3	281.00	320.00	201.33	267.44	5
4	K	236.33	287.50	162.00	228.61	6
5	P	244.00	222.50	157.67	204.06	14
6	N, K	302.33	385.50	168.67	285.50	1
7	N, P	206.33	217.00	184.00	202.44	16
8	K, P	195.33	214.33	171.50	193.72	18
9	N,P,K	336.00	256.67	183.67	259.45	4
10	N,P,K,Ca O	268.00	160.00	215.67	214.56	10
11	N H_3	223.33	245.67	150.33	206.44	12
12	Bonemeal	228.33	260.00	175.00	221.11	8
13	Check	213.33	260.50	140.67	204.83	13
14	Check	206.33	115.00	175.67	165.67	24
15	Sulphur	199.33	135.00	160.00	164.78	25
16	Lime(Imported)	262.67	120.00	172.33	185.00	22
	Local Products.					
17	Manure	231.50	230.00	160.67	207.39	11
18	Lime (local)	257.00	176.50	178.00	203.83	15
19	Velvet beans	319.00	229.00	178.67	242.22	5
20	Cowpeas	208.33	118.00	156.33	160.89	26
21	Coconut husk ash	238.67	158.33	154.67	183.89	23
22	Sea Slugs	316.67	192.50	154.67	221.28	7
23	Sea Weeds	271.67	211.67	118.00	200.45	17
24	Guano	182.50	223.00	168.33	191.28	19
25	Check	269.00	163.33	137.00	189.78	27
26	Guard	223.33	186.00	162.00	190.44	20
Avg.		246.39	221.23	127.26	211.18	

Table XIX (b)

The Effect of Commercial and Local Fertilizer Applications on Plant Growth.

Average weight in grams of stalks at end of each test.

Pot No.	Treatment	OLD SOIL 3rd test	4th test	5th test	Average	Relative Rank
Commercial Fertilizers.						
1	Guard	160.67	132.67	117.33	136.89	19
2	Check	177.00	60.00	106.67	114.56	26
3	Na NO_3	194.00	109.00	127.00	143.33	15
4	K	233.33	145.00	108.33	162.22	10
5	P	191.00	127.67	100.67	139.78	17
6	N,K	212.33	141.67	160.00	171.33	6
7	N, P	211.33	157.67	152.50	173.83	5
8	K, P	215.00	175.00	109.67	165.56	8
9	N, P, K	306.00	170.00	158.33	211.44	2
10	N,P,K, Ca O	244.33	135.00	124.67	168.00	7
11	N H_3	282.67	160.67	115.50	186,28	4
12	Bonemeal	183.33	111.67	111.00	135.33	20
13	Check	212.00	153.00	106.67	157.22	11
14	Check	209.67	108.00	93.00	136.89	18
15	Sulphur	175.00	96.00	95.33	122.11	24
16	Lime(imported)	240.33	160.00	97.33	165.89	9
17	Local Products Manure	203.67	158.00	109.33	157.00	12
18	Lime (local)	230.00	140.00	95.33	155.11	13
19	Velvet Beans	283.67	195.00	166.67	215.11	1
20	Cowpeas	278.00	138.33	160.00	192.11	3
21	Coconut husk ash	161.00	127.50	84.67	124.39	23
22	Sea Slugs	216.67	145.67	52.67	138.67	16
23	Sea Weeds	177.33	125.00	57.33	119.89	25
24	Guano	161.00	162.00	63.50	128.83	21
25	Check	190.67	101.00	92.00	124.56	22
26	Guard	169.33	175.00	90.00	144.78	14
Avg:		212.27	133.87	109.44	153.53	

Figure 18

Maturo cro growing in first thirteen pots of old soil during fourth fertilizer test.

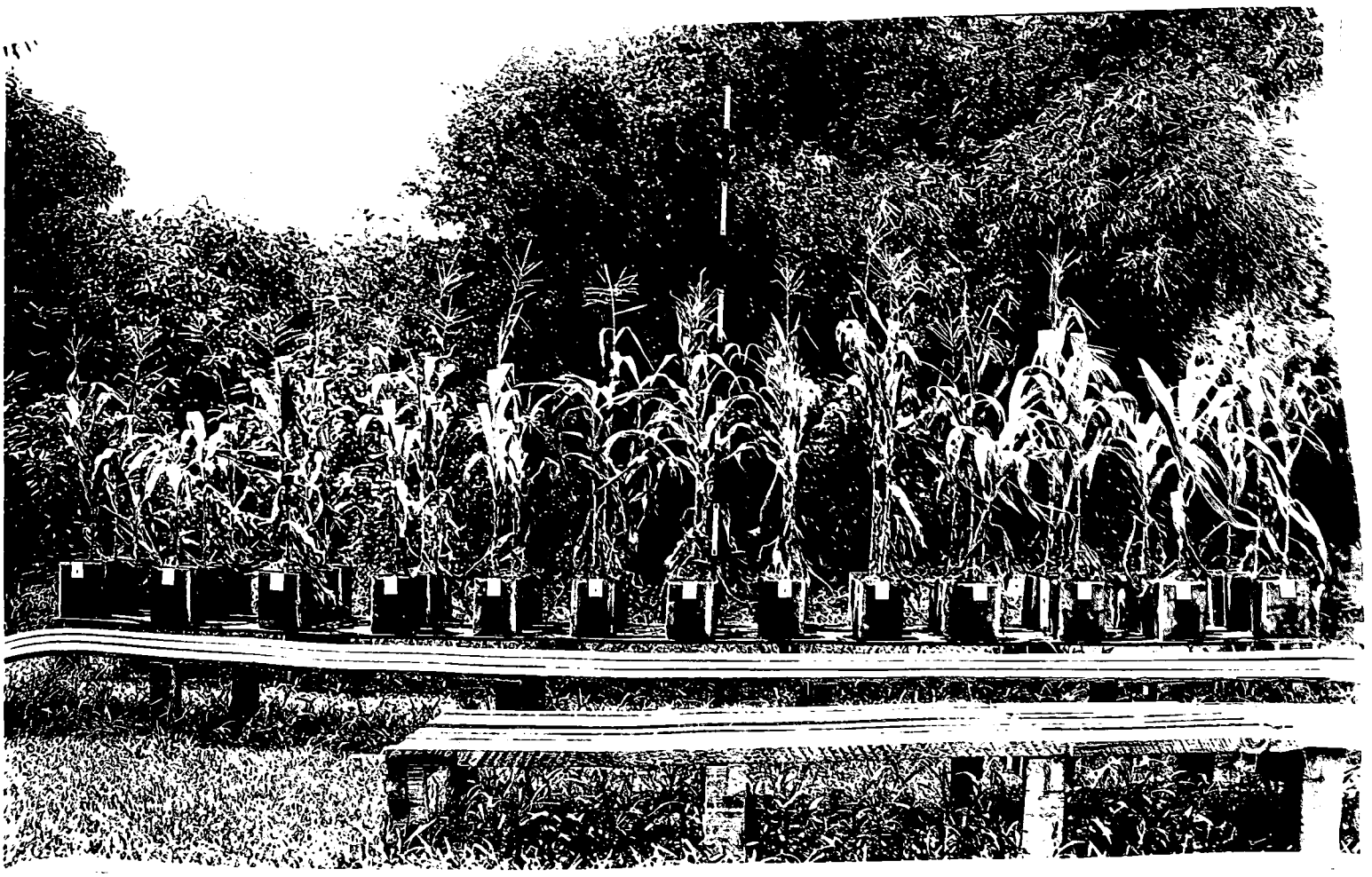

Figure 19

Mature crop growing in last thirteen pots of old soil during fourth fertilizer test.

Figure 20

Mature crop growing in first thirteen pots of new soil during fourth fertilizer test.

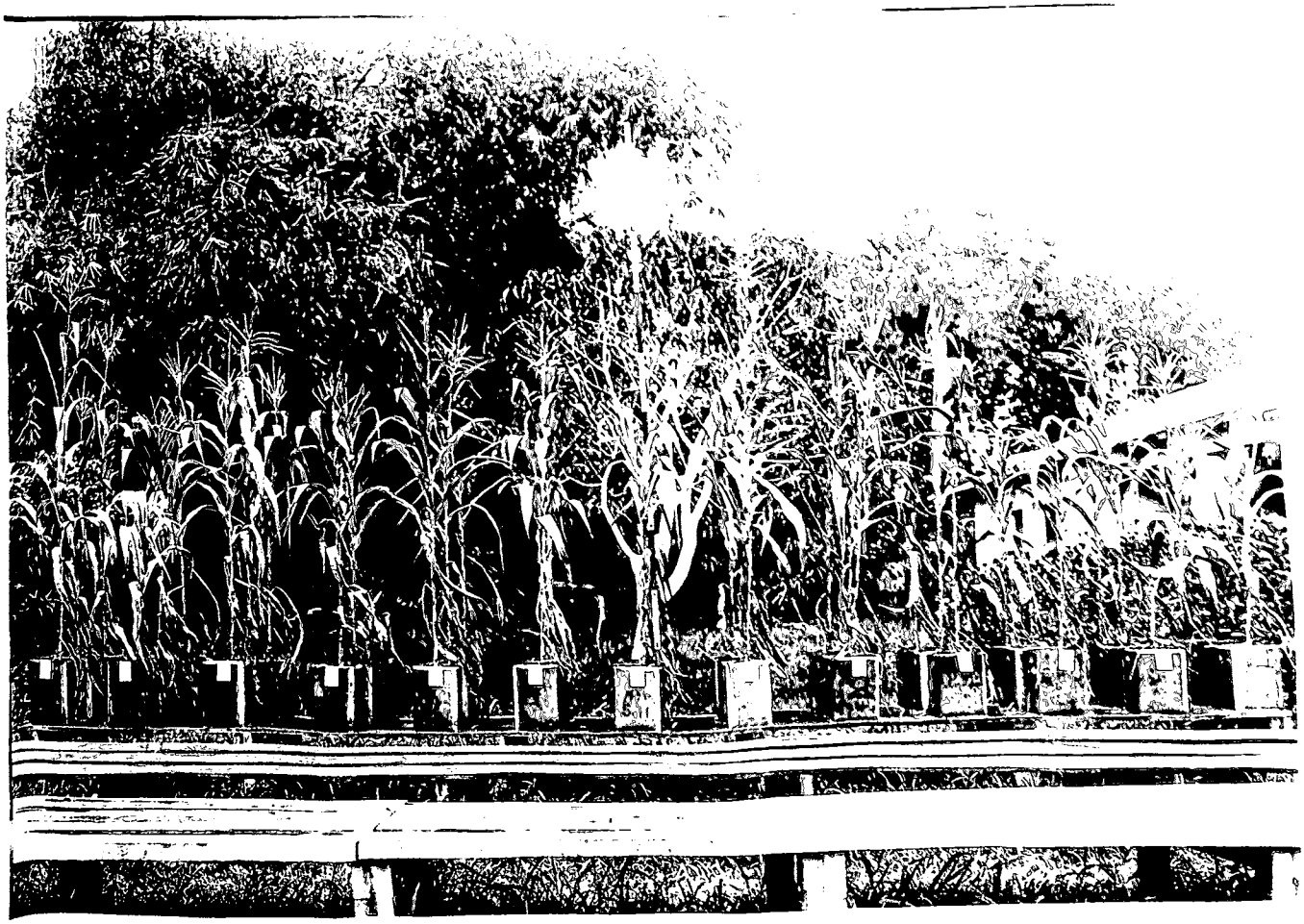

Figure 21

Mature crop growing in last thirteen pots of new soil during fourth fertilizer test.

old soil.

In the new soil the five heaviest plants were grown in pots 6, 2, 3, 4, and 19, which weighed on an average, respectively, 285.50 grams, 274.72 grams, 267.44 grams, 259.45 grams, and 242.22 grams. The soil treatment in these five pots was; nitrogen and potassium, nothing(check), nitrogen, complete fertilizer, and velvet beans as a green manure. The five pots containing plants that weighed the least were, 20, 15, 14, 21, and 16, to which had been applied; cowpeas as a green manure, sulphur, nothing(check), cocoanut husk ash, and imported lime.

The old soil gave the heaviest yields from pots 19, 9, 20, 11, and 7, which had received the following fertilizer treatments: velvet beans as green manure, complete fertilizer, cowpeas as green manure, nitrogen in the form of ammonia, and nitrogen and phosphorus, respectively. The smallest yields in weight were from pots 2, 23, 15, 21 and 25, to which had been applied; nothing(check), sea weeds, sulphur, cocoanut husk ash, and nothing(check), respectively.

When the fertilizer pot tests were first started a large quantity of each soil was kept in covered bins in the plant house. When the fourth test of this experiment was started, duplicate check pots had been stored

and also duplicates from the fields where the original soils were secured. The summarized results of those check pots for the fourth and fifth tests are given in the table XX.

From these results it will be noted that the corn on the new soil that had been in the pot tests during the experiment made the greatest plant growth and gave the heaviest yields, followed by those growing on soil from the bins, while those plants growing on the soil from the field were considerably smaller and especially on the new soil was this true.

Table XX

Comparison of Plant Growth on new and Old Soil in Check Pots.

Source and Kind of Soil	Checks at fourth Test			Checks at fifth Test		
	Average			Average		
	Weight of stalks	Height of stalks	Days tasseling	Weight of stalks	Height of Stalks	Days to tasseling
	Grams	Inches		grams	inches	
New Soil from bins	83.67	50.33	70	107.67	42.33	73.0
Old Soil from bins	190.00	62.00	64	80.67	37.33	74.3
New Soil from field	39.50	37.33	did not tassel	50.00	33.33	75.0
Old Soil from Field	79.67	52.00	65	70.00	37.67	73.0
New soil from pots (average Checks)	266.10	58.79	57.4	156.96	50.09	69.5
Old Soil from pots (average of Checks)	136.17	52.17	58.5	97.09	38.92	71.5

Table XXI, which is taken from the average of all of the five regular tests gives a comparison of plant ~~of plant~~ growth on the new and old soils and shows the effect of the different soil treatments on weight and height of plants. The pots are arranged in the order of the soil treatment that gave the greatest weight and height of plants.

From these data is was found that on the new soil the application of nitrogen and potassium gave the greatest weight and height of plants, while coconut husk ash and cowpeas gave tall plants they also weighed less than other plants. On the old soils velvet beans, cowpeas, and combinations with nitrogen and phosphorus gave the greatest weight and height of plants. In height the greatest difference existed between pots 21 which had received applications of coconut husk ash. On new soil this pot ranked third and on old soil ranked twenty-fifth. In weight the rank on each soil was the same, being twenty-three. In height, it will be noted that a difference exists in rank on the new and old soil between pots 12, 15, 7, and 8. Pot 12 which had received bonemeal ranks fourth on the new soil, and twenty-third on the old. Pot 13, which was a check, was thirteenth in rank on old soil and twenty-fourth on new soil. Pot 7, to which nitrogen and p

Table XXI

Comparison of Plant Growth on New and Old Soil.

Rank	New Soil		Old Soil	
	Three tests Average weights	Five tests Average Heights	Three tests Average Weights	Five tests Average Heights
1st	N, K	N, K.	Velvet Beans	N,P,K
2nd	Check	Cowpeas	N, P, K.	P, K
3rd	Na NO_3	Cocoanut husk ash	Cowpeas	N,P
4th	N,P,K	Bonemeal	N H_3	N H_3
5th	Velvet Beans	K	N P	N K
6th	K	N, P, K	N K	N, P, K, Ca O
7th	Sea Slugs	N H_3	N, P, K, Ca O	Cowpeas
8th	Bonemeal	Check	P, K	Na NO_3
9th	Guard	N,P,K,Ca O	Lime (imported)	Velvet Beans
10th	N, P, K, CaO	$NaNO_3$	K	K
11th	Manure	Velvet beans	Check	P
12th	N H_3	Guard	Manure	Check
13th	Check	K,P	Lime (Local)	Check
14th	P	Sea Weeds	Guard	Sea Slugs
15th	Lime (Local)	N, P	Na NO_3	Sea Weeds
16th	N, P	Manure	Sea Slugs	Guard
17th	Sea Weeds	P	P	Guard
18th	P, K	Sea Slugs	Check	Manure
19th	Guano	Lime (Local)	Guard	Lime (Imported)
20th	Guard	Guard	Bonemeal	Lime (LOcal)
21st	Check	Check	Guano	Check
22nd	Lime(imported)	Lime(Imported)	Check	Bonemeal
23rd	Cocoanut husk ash	Check	Cocoanut husk ash	Check
24th	Check	Check	Sulphur	Sulphur
25th	Sulphur	Guano	Sea Weeds	Cocoanut husk ash
26th	Cowpeas	Sulphur	Check	Guano

phosphorus had been added, ranked third on old soil and fifteenth on new soil and pot 8, which was treated with phosphorous and potassium ranked second on old soil and thirteenth on new soil.

The greatest difference existing between relative ranks in weight on the new and old soils was in pots 20, 16, 3, 12, 7, and 8. Pot 20 had cowpeas turned under as a green manure. On old soil this pot ranked third in weight but on new soil it was twenty-sixth. Pot 16 which had received applications of imported lime ranked ninth in weight on old soil and twenty-second on new soil. Pot 3, to which had been applied nitrogen, was fifteenth on old soil but third on new soil. Bonemeal applied to the soil caused pot 12 to drop to twentieth place on old soil, but on new soil it ranked eighth. and sixteenth on new soil, after being treated with nitrogen and phosphorous. Pot 7 ranked fifth on old soil Phosphorous and potassium was applied to pot 8 and plants on the old soil ranked eighth on old soil and eighteenth on new soil. Pot 7 ranked fifth on old soil and sixteenth on new soil after being treated with nitrogen and phosphorous.

Table XXII shows the number of days from time of planting to date of tasseling and is to a certain ex-

Table XXII

EFFECT OF FERTILIZER ON NEW AND OLD SOIL ON TIME OF MATURING.

AVERAGE NUMBEROOF DAYS FROM TIME OF PLANTING TO DATE OF TASSELING

	OLD SOIL					NEW SOIL					
	2nd test	3rd test	4th test	5th test	Average	2nd test	3rd test	4th test	5th test	Average	
1	66	58	45	60	57.25	64	55	44	60	55.75	1
2	66	41	46	61	53.50	68	56	46	59	57.25	2
3	66	57	47	58	57.00	66	58	40	61	56.25	3
4	68	58	42	60	57.00	66	59	40	61	56.50	4
5	66	61	42	58	56.75	66	58	40	61	56.25	5
6	66	60	43	58	56.75	66	56	41	61	56.00	6
7	66	57	46	63	58.00	66	61	39	61	56.75	7
8	66	58	44	61	57.25	66	58	44	59	56.75	8
9	61	55	44	62	55.50	64	60	41	60	56.25	9
10	64	55	45	60	56.00	64	58	43	62	56.75	10
11	66	60	40	61	56.75	66	58	43	64	57.75	11
12	66	62	46	60	58.50	66	57	46	60	57.25	12
13	68	58	44	60	57.50	68	62	44	60	58.50	13
14	66	62	43	60	57.75	68	57	42	61	57.00	14
15	66	58	45	63	58.00	66	59	47	61	58.25	15
16	73	57	42	62	58.50	68	59	44	60	57.75	16
17	66	58	43	60	56.75	66	56	39	59	55.00	17
18	66	60	44	63	58.25	64	60	46	61	57.75	18
19	66	58	44	64	58.00	66	59	40	59	56.00	19
20	68	59	45	64	58.75	66	57	45	63	57.75	20
21	68	63	46	64	60.25	64	59	40	61	56.00	21
22	66	61	41	66	58.50	66	57	43	59	56.25	22
23	66	59	46	67	59.50	68	61	42	63	58.50	23
24	68	57	43	63	57.75	66	59	49	61	58.75	24
25	66	56	46	65	58.25	64	59	43	58	56.00	25
26	68	60	43	67	59.50	66	58	44	59	56.75	26
Average for test:	66.46	57.96	44.03	61.92	57.59	65.92	58.31	42.88	60.54	56.91	

tent a guide to the effect of soil treatment on the time of maturing of the plants. On the new soil it was found that the average time from planting to tasseling was 56.91 days and on the old soil it was 57.59 days. On the new soil the smallest average number of days from the time of planting to date of tasseling was 55.0 days in pot 17, which had been treated with barnyard manure. The greatest number of days was 58.75 and was required by the plants in pot 24, which was given applications of guano. On the old soil the smallest average number of days was 53.5 in pot 2, which was a check. The greatest average number of days on the old soil was 60.25 and was required by plants in pot 21 which had received applications of guano.

EFFECT OF LIME ON PLANT GROWTH...

This experiment was conducted to determine the effect of lime on plant growth on the new and old soils of Guam and the amount to apply for the best results under conditions as they existed on the Guam Experiment Station. From other experiments it had been found that the soils of Guam were peculiar and did not always respond readily to good cultural methods. In November, 1920 a large

number of soil samples taken from the station farm at depths ranging from 6 2/3 inches to 30 inches and while the soil was still full of moisture from the rainy season and tested for acidity. None of the old surface soils showed any reaction to litmus paper and only one sample gave any reaction to hydrochloric acid, showing carbonates to be present. The sub-surface soils showed in most cases a very slight pinkish color on the blue litmus paper and the subsoil gave a decided pink color to the paper. With the new soils, tests showed there to be no carbonate present. The surface soil gave a pinkish color to blue litmus paper, the subsurface soils gave a pink color, and the subsoils turned blue litmus paper from pink to red in the various samples. These tests showed the presence of acid in the new soil to be greater than in the old soil. These same tests were conducted in March, 1918, when the samples were taken from soils that were very dry and no reaction to litmus paper could be observed after the papers had remained in the moistened soil for 30 minutes and for this reason it had generally been thought that the soils were neutral. It may be that the litmus paper used was old or that the soils are not as acid during the time of

drought as they are during the rainy season.

In December, 1919, samples of these new and old soils were submitted to Mr. Oswald Schreiner, Biochemist, Bureau of Soils, United States Department of Agriculture, Washington, D. C., for analysis. These samples were designated as No. 4 and No. 5. Sample No. 4 was from the newly broken grass land after being cultivated one year during which time it produced only dwarf plants. Sample No. 5 was from old soil that had been cultivated for at least 10 years and was considered good soil.

The following extracts are taken from the report of Dr. Oswald Schreiner. "Both samples were examined for unusual constituents only. The organic constituents, except total organic matter, could not be determined on so small a sample. The samples were examined for manganese, total organic matter, ferrous iron, nitrogen, carbon dioxide(existing as carbonate) and hydrogen ion exponent, with the following results:

	Sample No.4	Sample No. 5
Manganese	0.32%	0.25%
Nitrogen	0.28%	0.23%
Iron(ferrous)	0.36%	0.08%
Total organic matter,	2.86%	1.95%
Total carbon,	1.77%	1.13%
Total carbon dioxide	6.50%	4.40%
Carbon dioxide	Trace	0.27%
Hydrogen ion exponent,	P_H 6.4	P_H 7.7

You will note that the older and better soil contains somewhat less manganese, very much less iron in the ferrous state and some carbon dioxide as carbonate, and accordingly the hydrogen ion exponent is higher. In regard to the hydrogen ion exponent, I would say that the exponont 7 represents neutrality, approximately, and the figure, therefore, indicates that the older soil is slightly alkaline, whereas, the new and unproductive soil is acid. The main significance, however, lies in the higher ferrous content and the higher organic matter. The presence of this ferrous iron indicates that the soil is not well oxidized of aerated, and in addition to the poisonous properties of ferrous iron itself, this condition of low oxidation or aeration would tend towards the existance of other unfavorable compounds.

This is perhaps as far as it would be safe to draw conclusions fromthhe analysis of samples which have stood for months and been transported a great distance, but the examination for the ferrous iron in these samples suggests that this subject, if pursued further should be done at Guam with fresh samples of soil from the fields in question. It is highly proba-

ble that the ferrous iron content in fresh samples might be found to be infinitely larger than is indicated by these dry samples.

As these tests and analyses showed the new and unproductive soil to be slightly acid a pot experiment with application of lime in various amounts was started in November, 1920. Soil was secured from across the river on the newly broken areas, and from the old station ground. A quantity of soil was taken from various places and each kind well mixed before placing it into pots. Lime was applied to both the new and old soils as given in the following outline:

No. of pots	Rate of lime per acre	Amount per pot
3 pots	No treatment	None
3 pots	1 ton of lime	11.70 grams
3 pots	2 tons of lime	23.40 grams
3 pots	4 tons of lime	46.40 grams
3 pots	8 tons of lime	93.60 grams
3 pots	16 tons of lime	187.80 grams

3 pots for guards at each end of the experiment.

Corn was planted in all the pots and weekly measurements of the height of stalk was taken during the growing season. After the stalks had reached maturity they were cut and weighed, chopped up into small pieces, mixed with the soil from the three pots of their own series, and all returned to their respective pots ready for planting another crop.

Table XXIII shows the effect of lime on the height of the stalks in the test. It will be noted that the plants growing on old soil in the first test averaged almost three inches higher than those on new soil, but that in the next three tests the stalks on the new soil averaged taller than those on the old soil and the average of the four tests show the stalks on the new soil were almost five inches taller than those growing on the old soil. The highest average height on the new soil was made by plants growing on soil that had received four tons of lime at the beginning of the experiment and the lowest average height was from plants which had received no lime at all. On the old soil the highest average height was made by plants growing on soil that had not had an application of lime and the lowest average height was from plants receiving an application of eight tons of lime at the beginning of the test.

Table XXIV gives the results of the effect of lime on plant growth as shown by weight of stalks on new and old soils during four successive tests. These data show that in the first test the old soil produced the heaviest crops but that the total average of each of the three succeeding crops was greater on the new soil. On the old soil

Table XXIII

Effect of Lime on Plant Growth on new and old soils.

Average of Highest recorded stalks in each pot.

Treatment	New Soil					Old Soil				
	1st test	2nd test	3rd test	4th test	Average	1st test	2nd test	3rd test	4th test	Average
	inches	ins.	ins.	ins.	inches	ins.	ins.	ins.	ins.	inches
Check	29.00	31.67	48.67	38.67	36.75	36.67	29.33	48.00	42.33	39.08
1 ton lime	33.67	26.67	51.67	43.00	38.75	34.33	27.00	49.33	38.00	37.17
2 ton lime	38.33	32.67	46.00	52.00	42.25	36.00	26.00	51.00	42.67	38.92
4 ton lime	31.00	39.33	50.33	56.00	44.17	36.00	26.33	51.33	39.67	38.33
8 ton lime	30.33	36.00	57.33	49.00	43.17	35.33	26.00	48.67	33.33	35.83
16 ton lime	17.33	47.67	55.67	46.00	41.67	23.33	38.33	53.67	38.33	38.42
Average	29.94	35.67	51.61	47.28	41.15	33.61	28.83	50.33	39.06	37.96

EFFECT OF LIME ON PLANT GROWTH ON NEW AND OLD SOILS
Average weight of stalks in each pot

TABLE XXIV

No. of test- / Date planted-	1st. Jan. 13, '20		2nd. Jan. 25, '21		3rd. Apr. 19, '21		4th. Jul. 18, '21		AVERAGE		
Kind of soil	Old	New	Old	New	Old	New	Old	New	Old	New	BOTH
	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.	grs.
Check	61.67	59.67	40.00	70.00	102.67	149.67	71.67	72.33	69.00	87.92	78.46
1 ton lime	69.67	76.67	33.00	20.00	149.00	143.00	83.00	98.67	83.67	84.59	84.13
2 tons lime	81.00	73.00	54.00	73.50	156.00	191.00	87.00	99.50	93.75	109.2	101.50
4 tons lime	78.00	68.33	39.67	87.00	164.33	203.67	82.33	128.00	91.08	119.25	105.17
8 tons lime	77.33	75.00	49.00	109.00	147.33	267.33	70.33	124.33	86.00	143.92	114.96
16 tons lime	25.00	21.50	101.33	183.67	158.00	222.00	54.50	108.50	84.71	88.42	86.56
Total average each crop	392.67	364.17	543.17	874.33	1176.6	448.83	631.33	508.21	633.35	631.33	570.

the heaviest average from a single pot was made by the plants growing on the soil that had received applications of lime at the rate of two tons per acre at the beginning of the test and on the new soil by the soil having eight tons of lime applied to it per acre. The smallest average yield was made on the old soil from pots receiving no lime and on the new soil from pots having soil that had received applications of lime at the rate of one ton per acre.

SUMMARY.

The soils of Guam present many characteristics that are peculiar only to that island and other tropical places of similar formation. Climatic conditions are such that the soils run together during the rainy seasons and pack very tightly.

Investigational work with these soils was conducted at the Guam Agricultural Experiment Station and on their farm.

Chemically, the soil contains a high percent of iron, aluminum and titanium. The new soils contain a higher percent of the iron in the ferrous state than does the older soil. Chemical analyses show that no element is lacking for plant growth. There was practically no difference in the chemical composition of the two soils used in the investigations, known as newly-broken grassland soil and old productive soils.

Physically the soils are a clay loam underlaid with a stiff clay. The newly-broken soils are poorly aerated and exhibit a tendency toward acidity.

The newly-broken grassland soils are not productive until some months after being broken. When first planted to crops, they produce only dwarf plants which often die in a short time. Each succeeding crop is better than the preceding one until the crops produced yield normal returns when compared with the older more productive soils.

Investigations consisted of field and pot tests in a comparative way and results were determined by the effect of the treatment on plant growth as measured by height of plants and

total yield by weight at the end of each crop season.

Results in field and pot tests did not check closely except in a comparative way. First plantings in the field on new soil invariably grew slowly and the plants were dwarfed, many crops dying before reaching a height of six inches. Each succeeding crop produced better yields untill all equaled or were better than those grown for comparison on the old productive station soils. First plantings in the pots did not make the growth that the crops on the old soil made but no difficulty was experienced in securing a stand. Second plantings grew slowly at first but in most instances had made as good plant growth at the end of the season as crops planted on the old soil. Later tests on the same soils gave greater yields and larger plant growth on the new soils than was secured from the old soils.

In the manurial requirement tests made in paraffined pots, it was found that the heaviest weights were made by the plants growing in the soil that had been treated with: potassium, velvet beans, and phosphorus and potassium on old soil; and sulphur, barnyard manure and nitrogen on the new soil. The greatest amount of transpiration occurred from those plants in pots treated with nitrogen alone or nitrogen in combination with phosphorus or potassium or with both.

In the work to determine the possibility of grass roots excreting a toxic substance poisonous to other plants, the data all show negative results.. However, the first season crop yields were all less than on the older soils. This is accounted for by the

poor aeration of the soil until it has been cultivated for some time. The reason the soil in the pot tests recovered productiveness sooner than the old soil is probably because they were in better tilth and for this reason were better aerated.

Crop adaptability tests showed that where it was possible to irrigate, rice could be grown successfully on the newly-broken grasslands. In field tests, grain sorghums, especially Darso and Shrock Kafir, mung beans, cowpeas, Sudan grass and pineapples were grown with partial success soon after the land was broken and with fairly good results during the second season. Corn, tobacco, soy beans, velvet beans, cotton, roselle and several varieties of sorghum and vegetables were planted three or more times in succession and although a good stand was secured in all tests, the plants all died or produced dwarf and inferior plants to those grown on the old soil. Pot tests with new soil, probably due to their better physical condition were not so long in reaching a productive state. In the pot tests, kafir, cowpeas, corn and rice gave normal yields after the first test when compared with the old soil. In determining the effect of commercial and local fertilizers on plant growth on the new and old soils of Guam during five consecutive tests with 156 pots, it was found that the greatest growth and heaviest yields of corn were secured from applications of nitrogen and phosphorus or combination of these two fertilizers, green manures from turning under cowpeas and velvet beans and from barnyard manure. Sulphur, coconut husk, ash, bat guano and sea weeds gave the smallest plant growth and the

lightest yields. No fertilizer was found that would overcome the unproductiveness of the newly-broken grassland soils during the first plantings made soon after breaking the land.

In a liming test each soil was given applications of lime at the rate of 1, 2, 4, 8 and 16 tons per acre. One set of pots was also used as a check and received no lime. Lime applied at the rate of 8 tons per acre on the new soil and two tons per acre on the old soil gave the largest corn yields. In none of the pots did lime overcome the unproductiveness of the new soil during first crop tests.

Conclusions.

The crops best adapted to the newly-broken, unproductive grassland soils, during the first season after breaking the sod, as found by these experiments, were cowpeas, rice, certain grain sorghums and pineapples. After they have been cropped with these plants for three or more seasons the soils become normal, probably through better aeration from cultivation and other crops may be planted with the expectation of securing normal yields.

The use of cowpeas and velvet beans as green manures, barnyard manure, nitrogen and phosphorus, singly and in combinations of readily available forms of commercial fertilizer proved to be the best fertilizers to secure high crop yields with corn on both the new and old soils. No fertilizer improved the new soil sufficiently in first tests as to be comparative with production

from old soils. Lime on new soils greatly increased yields.

The unproductiveness of the newly-broken grasslands is probably not due to grass roots excreting a toxic substance but to an acid condition and lack of aeration. This can only be remedied by cultivation and perhaps more quickly overcome by the addition of lime at the rate of 8 tons per acre. Growing cowpeas and velvet beans on the tilled soil and returning the vines to the soil improves the physical condition in a short time.

Tillage to improve the mechanical condition and aerate the soil, green manures to improve the physical condition and add fertility, growing crops adapted to the soil, and applying lime when necessary are the only practical means of soil management suited to overcoming the unproductiveness of the newly-broken grassland soils of Guam except by fallow cultivation for several months during which time the soil becomes productive.

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