THE EXTENT OF PLANT FOOD CONSTITUENTS

IN PLANT MATERIAL

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Introduction

The fertilizer that will give the maximum yield at a minimum cost is sought by every farmer. There are so many factors affecting crop yields that it is very difficult for even the experienced man to select fertilizers which carry the nutrients required by any given soil. Climatic factors play an important part, soil type varies from one locality to another, kinds of crops used, soil treatment, type of farming, and the native fertility of soil vary along with many other factors which materially affect crop production. Many persons feel that a soil analysis should completely solve the many problems, both theoretical and practical, regarding the economic management of the soil, especially as to its fertilizer needs. This is a general misunderstanding in regard to the research and applied value of chemistry to soils. Many methods have been suggested, from a chemical standpoint to solve the problem of fertility, but the problem is still unsolved. However, considerable knowledge has been gained from the study.

Chemical analyses of plants give results that correlate with fertilizer treatments and presumably reflect the supply of available constituents in the soil. As early as 1869, Hellriegel discussed the amounts of potash in oat straw as related to the supply in the soil. In 1880, Heinrich from analyses of roots of the oat plant deduced that specific manuring is necessary if the composition falls below a certain fixed point. In 1905, Hall published an article entitled, "The analysis of the soil by means of the plant." He states that the interpretation of soil conditions from analysis of plant ashes is not a practical method by which chemical analysis of the soil can be made.

Considerable work was started by early agricultural investigators which has continued to the present time and probably will continue for years to come. The main question at stake was, "what method can be used to determine the nutrients that a given soil needs?" One of the first attempts was based upon the chemical analysis of the ash of plants grown on the soil in question. Extensive investigation, however, showed the method to be of little or no practical value. Years of study by many investigators seem to indicate that, "there is no useful method of predicting nutrient requirements from the composition of crops when these are grown to maturity under field conditions where enviromental factors are always inconstant and uncontrollable. Doubtless, the factors influencing the intake of any given nutrient by a plant are so numerous as to preclude the hope of using plant composition as a guide to the soil requirements unless steps are taken either to control or measure the influence of these factors."

Other investigators have used the bulk method of determining the total nutrients present in the soil. Since the bulk method of determining mineral constituents gave no information as to the availability of certain elements or as to the fertilizer needs of the soil, extraction methods were devised. These are listed under three heads: 1. Digestion with strong acids, 2. Digestion with dilute acids, 3. Extraction with water. The nutrient materials in a soil that are not dissolved by digestion with weak acids are assumed to be in a condition in which plants can not use them. The difficulty with this assumption is that, while treatment with an acid of a given strength markes a definite point in the solubility of the compounds in the soil, it does not bear a uniform relation to the natural processes by which these compounds become available to plants. We have no facts that would indicate that the nutrients extracted in the laboratory by an acid is the same amount that a plant would extract.

Dyer, (5) Fraps (6) and many others have used varying strengths of citric and nitric acids. The most popular seems to be one percent citric acid and one fifth normal nitric acid.

A great deal of work has been done on the water extraction method, because it seemed to be the most accurate method of extracting the same materials as the plant would ordinarily use. The water extract does not, by any means, contain the entire quantity of nutrients which were in the soil solution and is not an exact measure of the fertility in this form. Adsorption holds back an undetermined and variable quantity of the important constituents. Schulze (27) leached a rich soil by allowing one leter of water to pass through one kilo of soil every twenty-four hours for six days. His results show that all the nutrients were not obtained in twenty-four hours. The practical value of such a method as a means of estimating fertility is, however, somewhat questionable, since much time and labor are required to make the necessary extractions and analysis before reliable conclusions may be drawn.

Neubauer (23) devised a method of determining soil deficiencies on a large scale. His hope was to give every farmer, who requested it, information as to the choice of the best fertilizers for his particular soil in a relatively short time. His method in brief was to plant one hundred rye seed or some similar seed on one hundred grams of the soil and after eighteen days, analyze the plants for their total nutrient content. One of the big difficulties of this method is to translate these laboratory results to field conditions.

Mitscherlich (20) has revised the Wagner pot method for testing soil dificiencies. This method consists of a series of enameled sheet iron pots with various fertilizer treatments. The fertilizers are applied in quantities of six grams of basic slag, three grams of potassium sulphate, and three and one half grams of ammonium nitrate or equivalent amounts supplied for other sources. Some plants, such as oat is used for experimental purposes. The drainage water is collected beneath the pots and returned to the soil at the next period of watering. From the weights of the plants at maturity, the nutrient needs of the soil are determined.

Hoffer (16) has developed a method of testing soil deficiencies which is being used extensively in Indiana by County Agents and other agricultural workers. It consists of testing the corn plant in the field by chemical means. "The stalk of corn is cut open and two or three drops of diphenylamine solution are applied to the freshly cut tissue of the stalk between the nodes. If nitrates are present a blue color develops. If no color appears and if the leaves are a yellowish-green, a deficiency of nitrogen is indicated. In testing for potash, a few drops of a ten percent solution of potassium thiocyanate in water and a few drops of Hydrochloric acid (1-2) are applied to the nodal tissues. If a dark red color develops, heavy deposits of iron are present. This is an indication that there was a potash deficiency during the period of growth of the plant. If the corn plants are stunted in growth and do not show the symptons of either nitrogen or potash starvation, then a lack of available phosphorus is indicated. So far, no chemical tests have been devised for phosphorus deficiencies in the plant."

Gilbert and co-workers (8) at the Rhode Island Station have recently attempted to gain information regarding the current nutrient needs of crop plants by determining the amount of phosphate-phosphorus, potassium and nitrate-nitrogen present in the juices of different plant tissues sampled at some particular period of the growing season. They report results with various field and garden crops grown upon the soils variously fertilized with nitrogen, phosphorus and potassium. They find a general correlation between the concentration of mineral nutrients in the plant solutions and the applications of chemical fertilizers."

"The utility of this method may be questioned on the ground that the nutrients in the plant solution at any one time do not reflect the supply during the entire growing period, but rather the supply for the period just preceding the sampling date."

"Gilbert, McLean and Adams (9) found that with low applications of phosphorus the nitrate-nitrogen in the plant was high, and with high applications of phosphorus, the nitrate-nitrogen in the plant was low. The lack of available manganese, leading to a chlorotic condition also greatly increased the nitrate-nitrogen content of the plant solution. Fluctuations in weather conditions materially influenced the concentration of all three elements in the plant solution. The authors feel that much further study is needed upon the plant solution method before an accurate opinion can be formed as to its probable utility."

The Virginia Agricultural Experiment Station is now seeking a solution for the problem of nutrient deficiency indicators. The problem is being attached similar to the method used in Rhode Island namely, the sap of corn plants as an indicator of nutrient needs of the soil. The data obtained by the Virginia station seems to warrent the conclusion, that this is a promising mode of attack. It gives promise of being an accurate method by which the fertilizer needs of a soil can be determined. This method consists of cutting sections, near the base, representative stalks of corn grown on the soil that is to be tested. The juice is then pressed from the stalks with a hydraulic press using a pressure of 6,500 pounds per square inch. The juices are kept in a frozen state until the chemical analysis are made. If any of the plant food elements fall below a certain concentration, it is assumed that the soil is deficient in this particular element. There are many factors which tend to place doubt upon the accuracy of this method; however, steps are being taken to either eliminate some of these factors or to measure their influence. The question naturally arises and leads one to wonder whether deficiencies in the plant juice imply deficiencies in the plant tissue and in the soil also?

Object.- The object of this investigation is to determine whether deficiencies of plant food in the juices of corn plants imply deficiencies in the plant tissues. Thus, if the phosphorus or nitrogen content in the juices of plants is low, then how far does this deficiencies extend in the plant direction of the plant-soil cycle? The investigation reported in this paper, however, deals only with the amount of phosphorus and nitrogen in corn tissue as compared to the amounts of these elements found in the juices of corn plants taken from the same plats.

Preparation of Tissue Sample - Representative stalks of corn was cut from various plats on August 29, 1928, September 28, 1928 and August 30, 1929. These were taken to the laboratory and allowed to air dry. Ten stalks with accompanying sheaths, leaves and grain from each of the twenty-eight plats were chopped into very small pieces with a corn knife. The samples were then placed in a steam dryer until practically all moisture was driven off. They were then ground into very fine particles. An aliquot sample was taken and stored in quart jars until chemical analysis could be made.

Chemical Methods - The following methods were used to determine the amount of the constitutents found in the tissue: Total nitrogen, the Modified Gunning method; phosphorus, the Magnesium nitrate method. These are standard methods, approved by the Association of Official Agricultural Chemists.

Explanation of Data - The data obtained from the analysis of the tissue is given in tabular and chart form on later pages of this paper. There are two tables for tissue and two for juices for each sampling date. One gives the concentration of phosphorus along with the plat number and the fertilizer treatment, and the other gives the nitrogen content along with the plat number and the fertilizer treatment. The tables also give the total yield of grain and stover per plat. The phosphorus in the juices is expressed as milligrams phosphorus pentoxide (P_2O_5) per cubic centimeter of juice, and in the tissue as percent phosphorus pentoxide. The nitrogen in the juices is expresed as parts per million of nitrate-nitrogen, while in the tissue, it is expressed as percent total nitrogen. There are also two sets of charts for each sampling date, one of which gives the phosphorus content of tissue as compared with the phosphorus content of the juice. The other gives the nitrogen content of tissue as compared with the nitrogen in the juice. These charts also make it easy to compare the phosphorus and nitrogen content of both tissue and juices of corn as affected by the fertilizer that the plats received. In each case, the fertilizer treatments are given just below the bars. It was necessary to use symbols or letters to represent the fertilizer treatment, in such cases the following were used:

N_b - nitrogen from dried blood
N_a - nitrogen from ammonium sulfate
M - stable manure
F - floats
P_a - phosphorus from acid phosphate
P_f - Phosphorus from floats
K - potassium from muriate of potash

Materials and Methods

Field Plots - The plants which were used for this investigation were grown on the "continuous Corn" plat and the "rotation with fertilizer" plats of the Virginia Agricultural Experiment Station, Blacksburg, Virginia. These experiments were started in 1909 and have, therefore, passed through twenty-one cropping seasons. The continuous corn plat (plat 1) has been cropped to corn every year, while the rotation plats (plats 2 to 14 inclusive) carry in rotation the following crops: First year, corn; second year, wheat; and third and fourth years, hay (mammoth clover, redtop, and timothy). The latter plats extend over four series of plats which are designated as series A, B, C, and D. This arrangement enables yields to be obtained each year from all crops. The crops shift from one series to the next from year to years, and each series undergoes a complete rotation of crops in four years.

In 1914 the continuous corn plat was divided in half. From 1914 to date, the north half has received no treatment, while the south half has received a specified fertilizer treatment. The rotation plats were not divided until 1917. The south halves of these plats continued to receive the specified fertilizer treatment, while the north halves, which previously had received the same treatment as the south halves were left unfertilized. As originally started in 1909, all plats were 165 x 33 feet in dimension, or an eighth of an acre in area. The division into halves, therefore, reduced them to 88 1/2 z 33 feet, a sixteenth of an acre. The plats within each series were separated by six-foot grassed alleys and the four series of plats were separated by grassed roadways nine feet wide.

Fertilizer treatment - The original scheme of fertilizing the rotation plats embodies three main features, viz., (1) to determine the response of the crops used to nitrogen, phosphorus, and potassium applied alone and in combination, (2) to test the value of raw rock phosphate as compated to superphosphate, and (3) to determine the relative value of farm manure and complete commercial fertilizer. The kinds and amounts of fertilizers applied are given in Figure 1. For the plats receiving commercial materials, potassium has been applied as muriate of potash, phosphorus as raw rock phosphate and superphosphate, and nitrogen as dried blood and sulfate of ammonia. Ground limestone is applied to all plats every fourth year at the rate of two tons per acre. The last application was made in 1926.

Soil - The soil on which the plats used in this investigation are located on a Hagerstown silt loam of moderate fertility.

Variety of Corn - An open-pollinated strain of the Silver King variety was used. The plants were spaced twenty inches apart in the row with the rows forty inches apart.

Juice Extraction - In gathering plants from which juice was to be obtained, care was always taken to select only plants which

As indicated below		1909 to date	
$1A_1$	1909-to date, no treatment	$1A_2$	1909-1914, same as $1A_1$ 1914-to date, 16 tons manure 219 lbs. rock phosphate
$2D_1$	1909-1917, same as $2D_2$ 1917-to date, no treatment	$2D_2$	438 lbs. superphosphate
$3D_1$	1909-1917, same as $3D_2$ 1917-to date, no treatment	$3D_2$	308 lbs. dried blood 438 lbs. superphosphate 200 lbs. muriate of potash
$4D_1$	1909-to date, no treatment check	$4D_2$	200 lbs. sulfate of ammonia 219 lbs. rock phosphate
$5D_1$	1909-1917, same as $5D_2$ 1917-to date, no treatment	$5D_2$	438 lbs. superphosphate 200 lbs. muriate of potash
$6D_1$	1909-1917, same as $6D_2$ 1917-to date, no treatment	$6D_2$	200 lbs. muriate of potash
$7D_1$	1909-1917, saem as $7D_2$ 1917-to date, no treatment	$7D_2$	308 lbs. dried blood 200 lbs. muriate of potash
$8D_1$	1909-1917, same as $8D_2$ 1917-to date, no treatment	$8D_2$	308 lbs. dried blood 438 lbs. superphosphate
$9D_1$	1909-1917, same as $9D_2$ 1917-to date, no treatment	$9D_2$	308 lbs. dried blood
$10D_1$	1909-1917, same as $10D_2$ 1917-to date, no treatment	$10D_2$	16 tons manure once in four years before corn
$11D_1$	1909-to date, no treatment check	$11D_2$	16 tons manure once in four years before corn, 219 lbs. rock phosphate
$12D_1$	1909-1917, same as $12D_2$ 1917-to date, no treatment	$12D_2$	4 tons manure annually
$13D_1$	1909-1917, same as $13D_2$ 1917-to date, no treatment	$13D_2$	16 tons manure once in four years before corn, 438 lbs. superphosphate
$14D_1$	1909-1917, same as $14D_2$ 1917-to date, no treatment	$14D_2$	219 lbs. rock phosphate

Figure 1.- Diagram of field plats used in this investigation and fertilizer treatments.

were typical of the corn plant populations of the plats. Enough plants were taken to provide an abundance of juice for the various tests to be made. This usually required ten to twelve plants from the more fertile plats and fifteen or twenty plants from the plats of low productiveness. After pulling, the plants were taken to the laboratory for physical measurements and for juice extraction.

The juice samples were obtained from fifteen-inch sections of the stalks immediately above the surface of the soil. The stalks were cut at the ground line and at fifteen inches above the ground line, the leaves and leaf sheaths were removed, and any adhering soil particles were removed by washing. The washwater was then removed with a clean towel. The fifteen-inch sections were cut into small pieces approximately an inch in length, placed in a small Carver laboratory hydraulic press, and subjected to a pressure of 6,500 pounds per square inch. The juices obtained were measured, clarified with G-elf carbon black, and then stored in the Dairy department refrigerator at 7°C. where they remained in a frozen condition until removed for analysis.

<u>Methods of Chemical analysis</u> - Nitrate-nitrogen concentrations were determined by the phenoldisulphonic acid method. In clarifying and decolorizing the juices previous to determining the nitrate content, an attempt was made at first to use the procedure reported by Gilbert. Difficulty was experienced, however, in obtaining clear extracts and nesslerized solutions free from brown-

ish tints. A modified procedure suggested by Hill (15) was then tried and adopted. Total phosphorus was determined by the magnesium nitrate method as given on page thirty-two of the second edition of the "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists."

Results

<u>Nitrogen in Tissue</u> - The nitrogen content of the tissue was determined on samples gathered August 29, 1928, September 28, 1928 and August 30, 1929. It seems from tables 1, 2 and 3 and figures 2, 3 and 4 that the applications of nitrogenous fertilizers had very little, if any, affect upon the composition of the tissue. The samples gathered August 29, 1928 (Fig. 2) varied from .955 percent in plat $1A_2$ to 1.675 percent in plat $9D_2$ with an average of 1.482 percent for the twenty-eight plats. The fourteen untreated plats average 1.477 percent, while the treated plats averaged 1.487 percent. The samples gathered September 28, 1928 (Fig. 3) vary from 1.2213 percent in plat $5D_2$ to 1.4947 percent in plat $4D_1$. The average concentration of nitrogen in the tissues from the untreated plats was 1.3565 percent, while the treated plats contained 1.3700 percent. The samples gathered in September (Fig. 3) seem to be lower in total nitrogen than those gathered in August (Fig. 2). The past season (1929) was especially favorable for nitrification. As a result of the favorable season the concentration of nitrogen in the tissue was higher than either set of samples gathered in 1928. The concentration seems to be higher in all plats, however, it does not follow very closely the fertilizer treatments. The percentage varies from .955 in plat $1A_2$ to 1.675 percent in plat $9C_2$ with average concentration for the untreated plats of 1.473 percent and 1.487 for the treated plats.

Table 1.- Nitrogen content of tissue of corn plants growing on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 29, 1928.

Plat Nos.	Treatment	Sample No.	Percent Nitrogen	Ave. percent nitrogen	Total Yield grain &stover in lbs. 1929
$1A_1$	Continuous Corn, no treatment	1	1.5001		
		2	1.4968	1.4984	80.5
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons manure once in four years	1	1.2996		
		2	1.3286	1.3141	185.0
$2D_1$	No treatment	1	1.3338		
		2	1.3634	1.3486	168.0
$2D_2$	70 lbs. P_2O_5 from acid phosphate annually	1	1.3178		
		2	1.2894	1.3036	208.5
$3D_1$	No treatment	1	1.3099		
		2	1.3581	1.3340	219.0
$3D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	1.2549		
		2	1.2806	1.2677	259.5
$4D_1$	Check, no treatment	1	1.3791		
		2	1.3789	1.3790	205.0
$4D_2$	40 lbs. N. from sul. of ammonia annually, 70 lbs. P_2O_5 from floats annually	1	1.4525		
		2	1.4726	1.4625	216.2
$5D_1$	No treatment	1	1.3689		
		2	1.3777	1.3733	235.5
$5D_2$	70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	1.0477		
		2	1.0430	1.0453	256.0
$6D_1$	No treatment	1	1.3007		
		2	1.3873	1.3440	198.2
$6D_2$	100 lbs. K_2O from mur. of potash annually	1	1.4280		
		2	1.4186	1.4233	318.5
$7D_1$	No treatment	1	1.5563		
		2	1.5237	1.5400	170.5

Table 1 continued.

Plat Nos.	Treatment	Sample No.	Percent Nitrogen	Ave.per-cent nitrogen	Total yield grain & stover in lbs. 1929
$7D_2$	40 lbs. N. from dried blood annually, 100 lbs. K_2O from mur. of potash annually	1	1.8488		
		2	1.8486	1.8487	310.5
$8D_1$	No treatment	1	1.6822		
		2	1.7098	1.6960	124.5
$8D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually	1	1.5024		
		2	1.5712	1.5368	145.5
$9D_1$	No treatment	1	1.5712		
		2	1.5729	1.5720	100.5
$9D_2$	40 lbs. N. from dried blood annually	1	1.5512		
		2	1.5834	1.5673	102.5
$10D_1$	No treatment	1	1.5310		
		2	1.4928	1.5119	186.2
$10D_2$	16 tons manure once in four years before corn	1	1.5806		
		2	1.5676	1.5741	452.0
$11D_1$	No treatment	1	1.4130		
		2	1.4270	1.4200	129.0
$11D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annually	1	1.3516		
		2	1.3781	1.3648	441.2
$12D_1$	No treatment	1	1.3294		
		2	1.3220	1.3257	252.5
$12D_2$	Four tons manure annually	1	1.2642		
		2	1.3043	1.2842	475.0
$13D_1$	No treatment	1	1.2258		
		2	1.2762	1.2511	206.5

Table 1 continued.

Plat Nos.	Treatment	Sample No.	Percent Nitrogen	Ave. percent nitrogen	Total yield grain & stover in lbs. 1929
$13D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from acid phosphate annually	1	1.2532		
		2	1.2388	1.2460	385.5
$14D_1$	No treatment	1	1.2115		
		2	1.2807	1.2461	168.0
$14D_2$	70 lbs. P_2O_5 from floats annually	1	1.4065		
		2	1.3762	1.3913	205.0

The data in the above table were furnished by the Agronomy department.

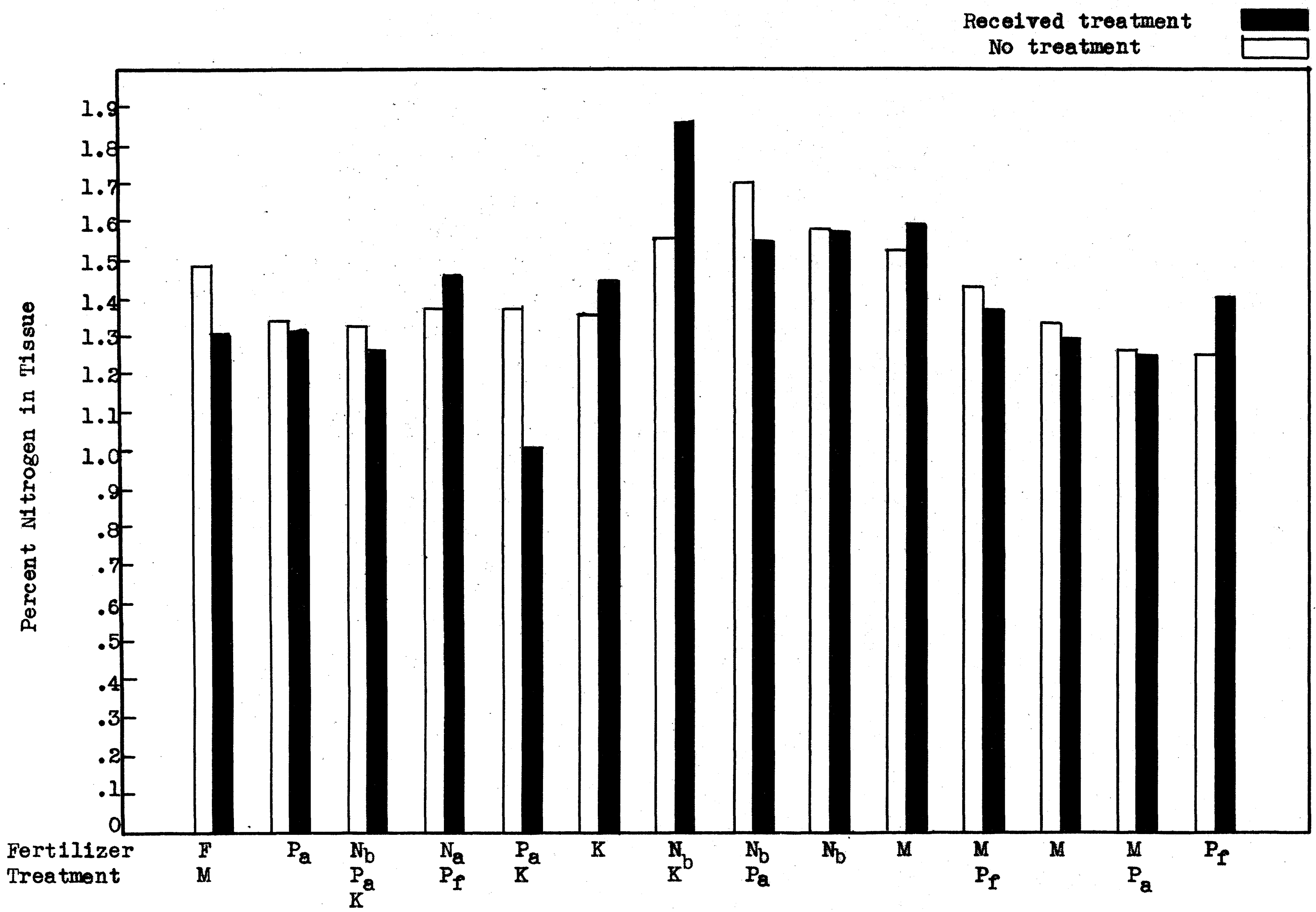

Fig. 2.- Nitrogen content of tissue of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Plants gathered August 29, 1928.

Table 2.- Nitrogen content of tissue of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered September 28, 1928.

Plat Nos.	Treatment	Sample No.	Per-cent Nitrogen	Ave. per-cent Nitrogen	Total yield grain & stover in lbs. 1928
$1A_1$	Continuous Corn, no treatment	1	1.3446		
		2	1.3661	1.3553	80.5
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons manure once in four years	1	1.2735		
		2	1.2711	1.2723	185.0
$2D_1$	No treatment	1	1.2724		
		2	1.2783	1.2753	168.0
$2D_2$	70 lbs. P_2O_5 from acid phosphate annually	1	1.2772		
		2	1.2182	1.2477	208.5
$3D_1$	No treatment	1	1.3738		
		2	1.3352	1.3545	219.0
$3D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	1.3362		
		2	1.3777	1.3569	259.5
$4D_1$	Check, no treatment	1	1.4985		
		2	1.4910	1.4947	204.0
$4D_2$	40 lbs. N. from sul. of ammonia annually, 70 lbs. P_2O_5 from floats annually	1	1.4769		
		2	1.4746	1.4757	216.2
$5D_1$	No treatment	1	1.2714		
		2	1.2706	1.2710	235.5
$5D_2$	70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	1.2283		
		2	1.2144	1.2213	256.0
$6D_1$	No treatment	1	1.3739		
		2	1.3491	1.3615	198.0
$6D_2$	100 lbs. K_2O from mur. of potash annually	1	1.4147		
		2	1.3874	1.4010	318.5
7D1	No treatment	1	1.3653		
		2	1.3495	1.3574	170.5

Table 2 continued.

Plat Nos.	Treatment	Sample No.	Per-cent Nitrogen	Ave.per-cent Nitrogen	Total Yield grain & stover in lbs. 1928
$7D_2$	40 lbs. N. from dried blood annually, 100 lbs. K_2O from mur. of potash annually	1 2	1.4233 1.4315	1.4274	310.5
$8D_1$	No treatment	1 2	1.4200 1.4374	1.4287	124.5
$8D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phosphate annually	1 2	1.4008 1.4597	1.4302	145.5
$9D_1$	No treatment	1 2	1.4158 1.4028	1.4093	100.5
$9D_2$	40 lbs. N. from dried blood annually	1 2	1.4732 1.4899	1.4815	102.5
$10D_1$	No treatment	1 2	1.3730 1.3665	1.3697	186.2
$10D_2$	16 tons manure once in four years before corn.	1 2	1.3758 1.3626	1.3692	452.0
$11D_1$	No treatment	1 2	1.4205 1.3962	1.4083	129.0
$11D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annually	1 2	1.4202 1.4261	1.4231	441.2
$12D_1$	No treatment	1 2	1.2427 1.2281	1.2354	252.5
$12D_2$	Four tons manure annually	1 2	1.3946 1.3710	1.3828	475.0
$13D_1$	No treatment	1 2	1.3224 1.2932	1.3678	206.5
$13D_2$	16 tons manure once in four	1 2			

Table 2 continued.

Plat Nos.	Treatment	Sample No.	Per-cent Nitrogen	Ave.per-cent Nitrogen	Total yield in grain & stover, lbs.1928
	years before corn, 70 lbs.	1	1.3638		
	P_2O_5 from acid phosphate annually	2	1.3582	1.3610	385.5
$14D_1$	No treatment	1	1.3064		
		2	112996	1.3030	168.0
$14D_2$	70 lbs. P_2O_5 from floats	1	1.3244		
	annually	2	1.3556	1.3300	205.0

The data in the above table were furnished by the Agronomy department.

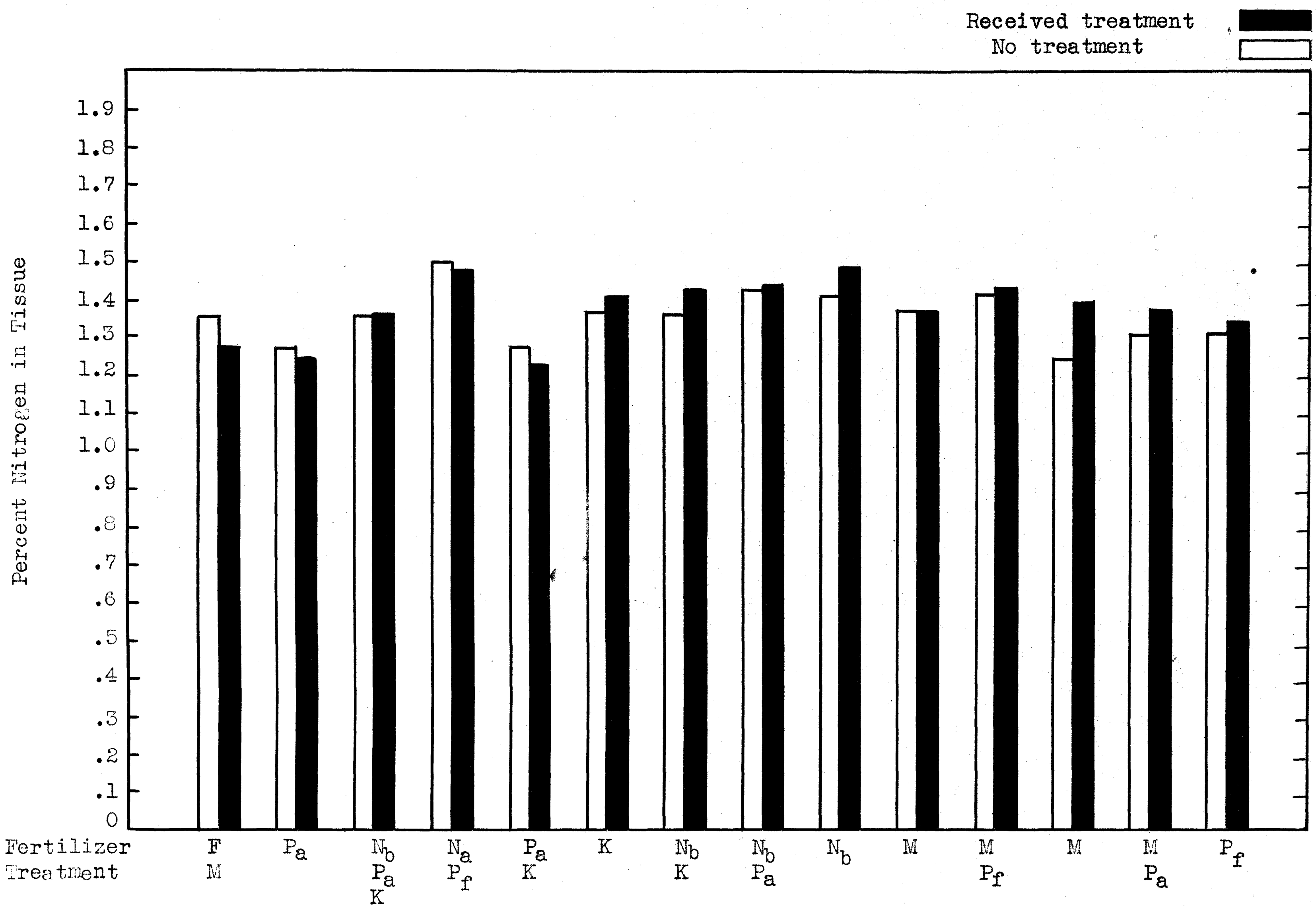

Fig. 3.- Nitrogen content of tissue of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Plants gathered September 28, 1928.

Table 3.- Nitrogen content of tissue fo corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 30, 1929.

Plat Nos.	Treatment	Sample No.	Per-cent Nitrogen	Ave.per-cent Nitrogen	Total yield grain & stover in lbs. 1929
$1A_1$	Continuous corn, no treatment	1	1.334		
		2	1.355	1.344	127.0
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons	1	.985		
	manure once in four years	2	.927	.955	252.5
$2C_1$	No treatment	1	1.500		
		2	1.497	1.498	382.0
$2C_2$	70 lbs. P_2O_5 from acid	1	1.509		
	phosphate annually	2	1.595	1.552	395.5
$3C_1$	No treatment	1	1.556		
		2	1.558	1.557	349.0
$3C_2$	40 lbs. N. from dried blood	1	1.548		
	annually, 70 lbs. P_2O_5 from acid phosphate annually, 100 lbs. K_2O from mur. of potash annually	2	1.571	1.555	363.0
$4C_1$	Check, no treatment	1	1.484		
		2	1.484	1.484	365.5
$4C_2$	40 lbs. N. from sul. of ammonia	1	1.623		
	annually, 70 lbs. P_2O_5 from floats annually	2	1.643	1.633	314.0
		1	1.425		
$5C_1$	No treatment	2	1.448		319.5
		3	1.465	1.446	
$5C_2$	70 lbs. P_2O_5 from acid phos. annually	1	1.519		
	100 lbs. K_2O from mur. of potash annually	2	1.505	1.517	454.5
$6C_1$	No treatment	1	1.506		
		2	1.499	1.502	315.0
$6C_2$	100 lbs. K_2O from mur. of potash	1	1.517		
	annually	2	1.453		
		3	1.513	1.471	404.0

Table 3 continued.

Plat Nos.	Treatment	Sample No.	Percent Nitrogen	Ave.per-cent Nitrogen	Total yield grain & stover in lbs. 1928
$7C_1$	No treatment	1	1.495		
		2	1.475	1.485	311.5
$7C_2$	40 lbs. N. from dried blood annually, 100 lbs. K_2O from mur. of potash annually	1	1.485		
		2	1.507	1.496	401.0
$8C_1$	No treatment	1	1.420		
		2	1.416	1.419	325.0
$8C_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually	1	1.662		
		2	1.665	1.665	207.0
$9C_1$	No treatment	1	1.435		
		2	1.423	1.429	199.5
$9C_2$	40 lbs. N. from dried blood annually	1	1.655		
		2	1.685	1.675	143.0
$10C_1$	No treatment	1	1.641		
		2	1.685	1.663	229.0
$10C_2$	16 tons manure once in four years before corn	1	1.510		
		2	1.559	1.534	473.5
$11C_1$	No treatment	1	1.446		
		2	1.440		
		3	1.489	1.458	190.5
$11C_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annually	1	1.449		
		2	1.452	1.450	428.0
$12C_1$	No treatment	1	1.539		
		2	1.499	1.519	316.5
$12C_2$	Four tons manure annually	1	1.342		
		2	1.333	1.337	454.5

Table 3 continued.

Plat Nos.	Treatment	Sample No.	Percent Nitrogen	Ave. percent Nitrogen	Total yield grain & stover in lbs. 1928
$13C_1$	No treatment	1	1.439		
		2	1.456	1.447	264.0
$13C_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from acid phosphate annually	1	1.442		
		2	1.437	1.439	424.0
$14C_1$	No treatment	1	1.423		
		2	1.424	1.423	227.5
$14C_2$	70 lbs. P_2O_5 from floats annually	1	1.506		
		2	1.512		
		3	1.569	1.543	256.0

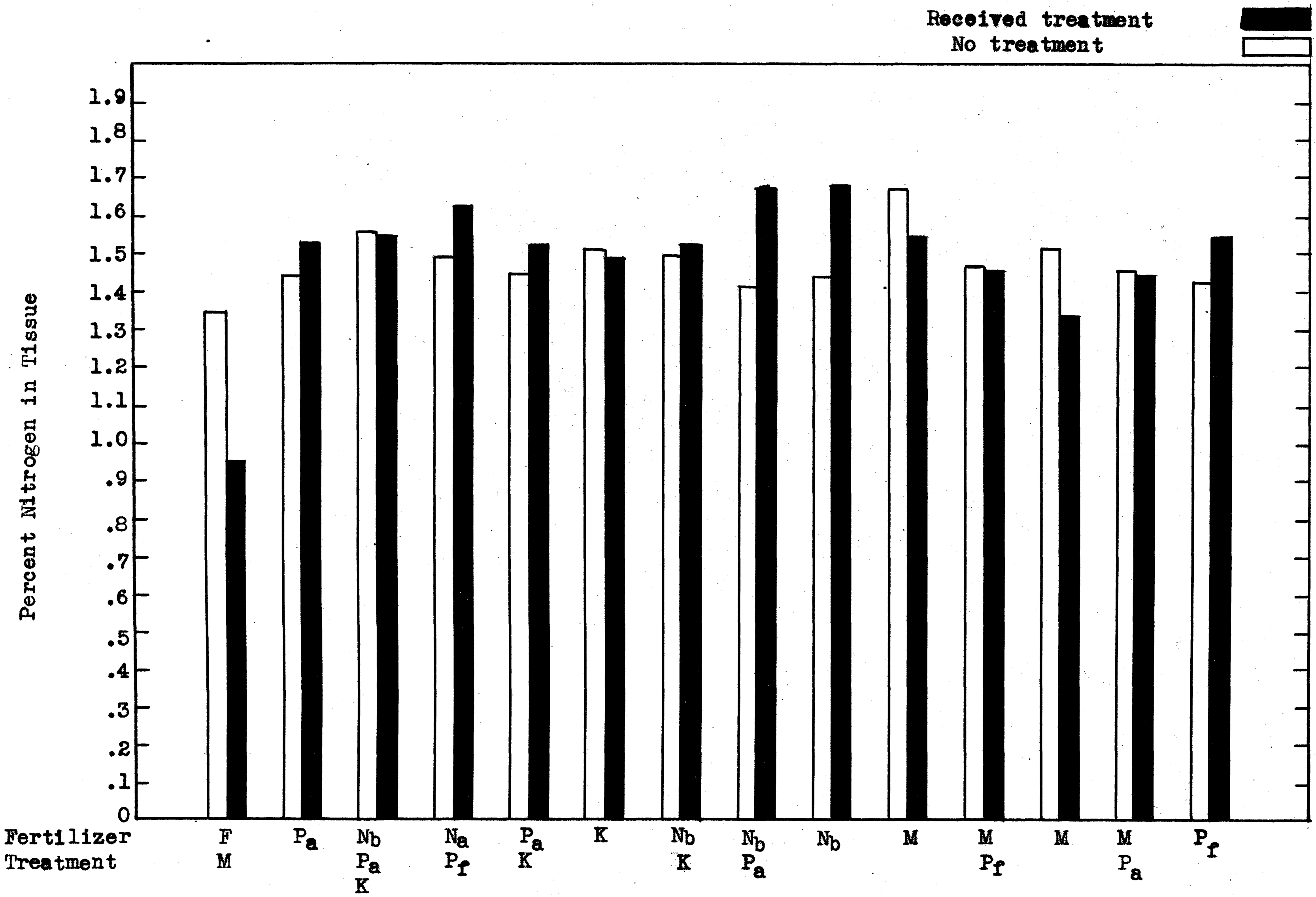

Fig. 4 .- Nitrogen content of tissue of corn plants grown on the Rotation with Fertilizer Continuous Corn plat at Blacksburg, Virginia. Plants gathered August 30, 1929.

Nitrate-nitrogen in Juice - Since plants take up most of their nitrogen in the form of nitrates, it was decided to limit the preliminary work to the nitrate form. Considerable difficulty was experienced in the beginning in decolorizing the juice samples for the colorimetric phenoldisulphonic acid determination of nitrates. The improved procedure finally adopted was not available in 1928 and hence the nitrate results obtained during the first year are not considered to be worthy of presentation. The 1929 results are given in table 4 and figure 5.

It is clear from table 4 and figure 5 that the nitrate-nitrogen content of the juice samples from the different plats varied a great deal. The continuous corn plat contained but twenty parts of nitrate to a million of juice, while the fertilized half of plat 13 yielded a juice containing 1110 ppm. concentrations ranging from one extreme to the other were obtained (Fig. 5).

With respect to nitrogen fertilization, the nitrate concentrations show a rather poor degree of correlation. This is perhaps due to the fact that with the exception of plats $1A_1$ and $1A_2$ (continuous corn), the nitrate concentrations are very high in the juice from all plats. The season of 1929 was very favorable for nitrification and nitrates were formed in abundance in the soil. The fact that clover preceded the corn crop strengthens this possibility. The nitrate concentrations of the juice indicate that only two plats were suffering from a lack of nitrates, the remaining plats yielding juices containing sufficient nitrates, regardless of nitrogen fertilization. The nitrate concentrations of the juices, therefore, are probably in close agreement with the nitrogen situations in the soil, even though they do not show good correlation with the application or non-application of nitrogenous fertilizers. The limited data at hand indicate that the nitrate concent of the expressed juice of corn plants may be used as a guide to nitrogen deficiencies and sufficiencies.

It is not surprising perhaps that the nitrate contents do not show a closer relation to nitrogen fertilization. The formation of nitrates in the soil is dependent on environmental conditions being favorable for nitricification, a biochemical process which converts organic forms of nitrogen in inorganic forms. If conditions are not favorable for this process, nitrate production is limited and the soil will contain few nitrates regardless of whether organic nitrogenous fertilizers were applied. On the other hand, if conditions are very favorable for nitrification, rotated soils, such as used in this investigation, will show large quantities of nitrates irrespective of fertilizer practices. Under these conditions, nitrates in the juice would show no correlation with fertilizer practice, but would be in perfect accord with nitrate concentrations in the soil. Under average conditions, however, where nitrates would be made available in considerable quantities on fertilized plats, but only sparingly on unfertilized plats, the composition of the plant juice

Table 4.- Nitrate nitrogen concentrations in the juices and total nitrogen in the tissues of corn plants grown on the Continuous Corn plat and the Rotation with Fertilizer plats at Blacksburg, Virginia. Juices extracted August 30, 1929.

Plat Nos.	Treatment	NO_3 in P.P.M.	Percent Nitrogen in T.	Total yield grain & stover in lbs. 1929
$1A_1$	Continuous Corn, no treatment	20	1.344	127.0
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons manure once in four years.	24	.955	252.5
$2D_1$	No treatment	160	1.498	382.0
$2D_2$	70 lbs. P_2O_5 from acid phosphate annually	149	1.552	395.5
$3D_1$	No treatment	177	1.557	349.0
$3D_2$	40 lbs. N. from dried blood annually 70 lbs. P_2O_5 from acid phos. annually 100 lbs. K_2O from mur. of potash annually	200	1.555	363.0
$4D_1$	Check, no treatment	165	1.434	365.5
$4D_2$	40 lbs. N. from sul. of ammonia annually 70 lbs. P_2O_5 from floats annually	220	1.633	314.0
$5D_1$	No treatment	476	1.446	319.5
$5D_2$	70 lbs. P_2O_5 from acid phos. annually 100 lbs. K_2O from mur. of potash annually	250	1.517	454.5
$6D_1$	No treatment	278	1.502	315.0
$6D_2$	100 lbs. K_2O from mur. of potash annually	370	1.471	404.0
$7D_1$	No treatment	556	1.485	311.5
$7D_2$	40 lbs. N. from dried blood annually 100 lbs. K_2O from mur. of potash annually	714	1.496	401.0
$8D_1$	No treatment	228	1.418	325.0
$8D_2$	40 lbs. N. from dried blood annually 70 lbs. P_2O_5 from acid phosphate annually	322	1.665	207.0

Table 4 continued.

Plat Nos.	Treatment	NO_3 in P.P.M.	Percent nitrogen in tissue	Total yield grain & stover in lbs. 1929
$9D_1$	No treatment	148	1.429	199.5
$9D_2$	40 lbs. N. from dried blood annually	220	1.675	143.0
$10D_1$	No treatment	250	1.663	229.0
$10D_2$	16 tons manure once in four years before corn	1000	1.534	473.5
$11D_1$	No treatment	312	1.458	190.5
$11D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annually	714	1.450	428.0
$12D_1$	No treatment	303	1.519	316.5
$12D_2$	Four tons manure annually	768	1.337	454.5
$13D_1$	No treatment	312	1.447	264.0
$13D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from acid phosphate annually	1110	1.439	424.0
$14D_1$	No treatment	137	1.423	227.5
$14D_2$	70 lbs. P_2O_5 from floats annually	626	1.543	256.0

The data on the plant juices were furnished by the Agronomy department.

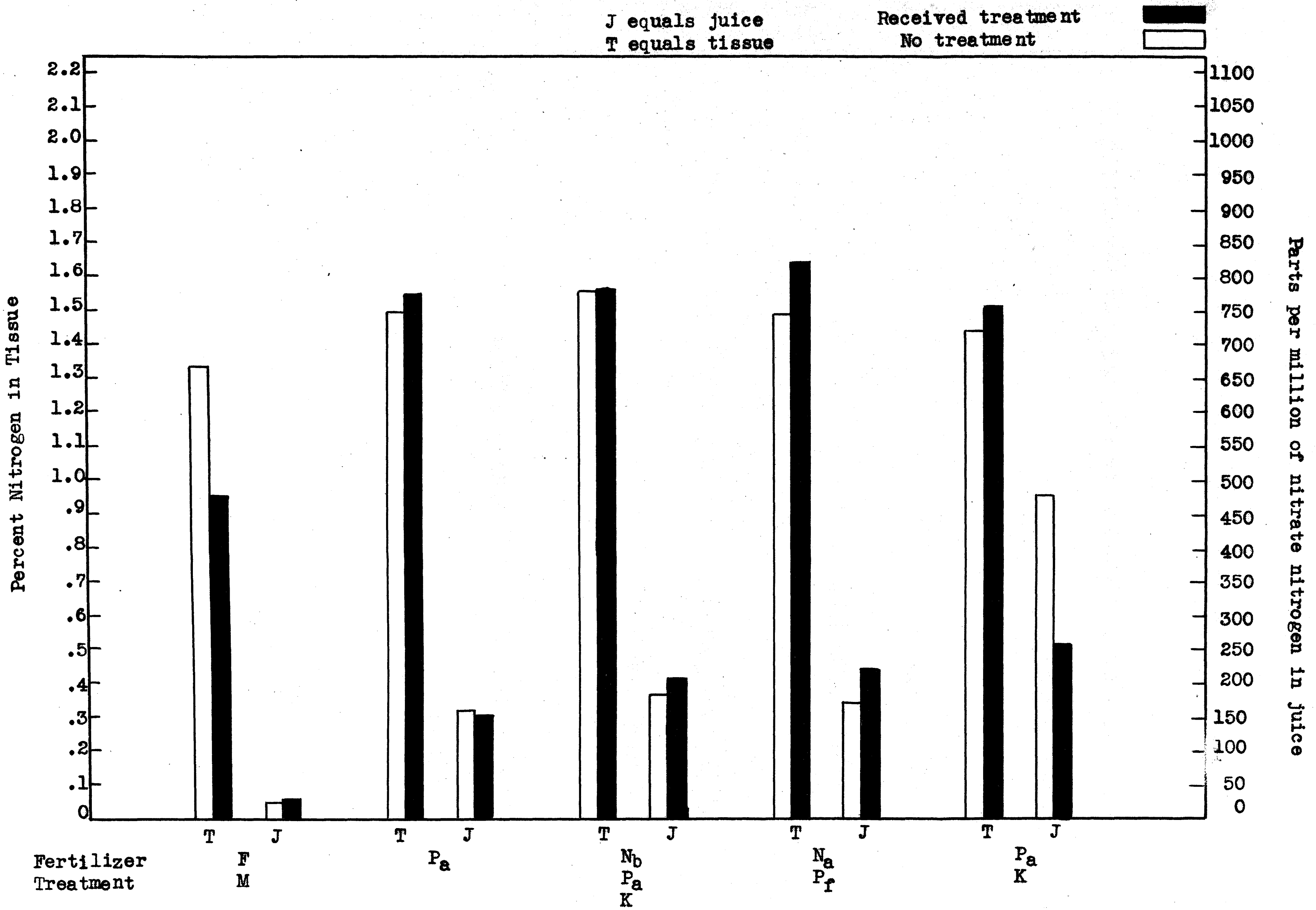

Fig. 5.- Nitrate nitrogen in juices and total nitrogen in tissues of corn plants on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 30, 1929.

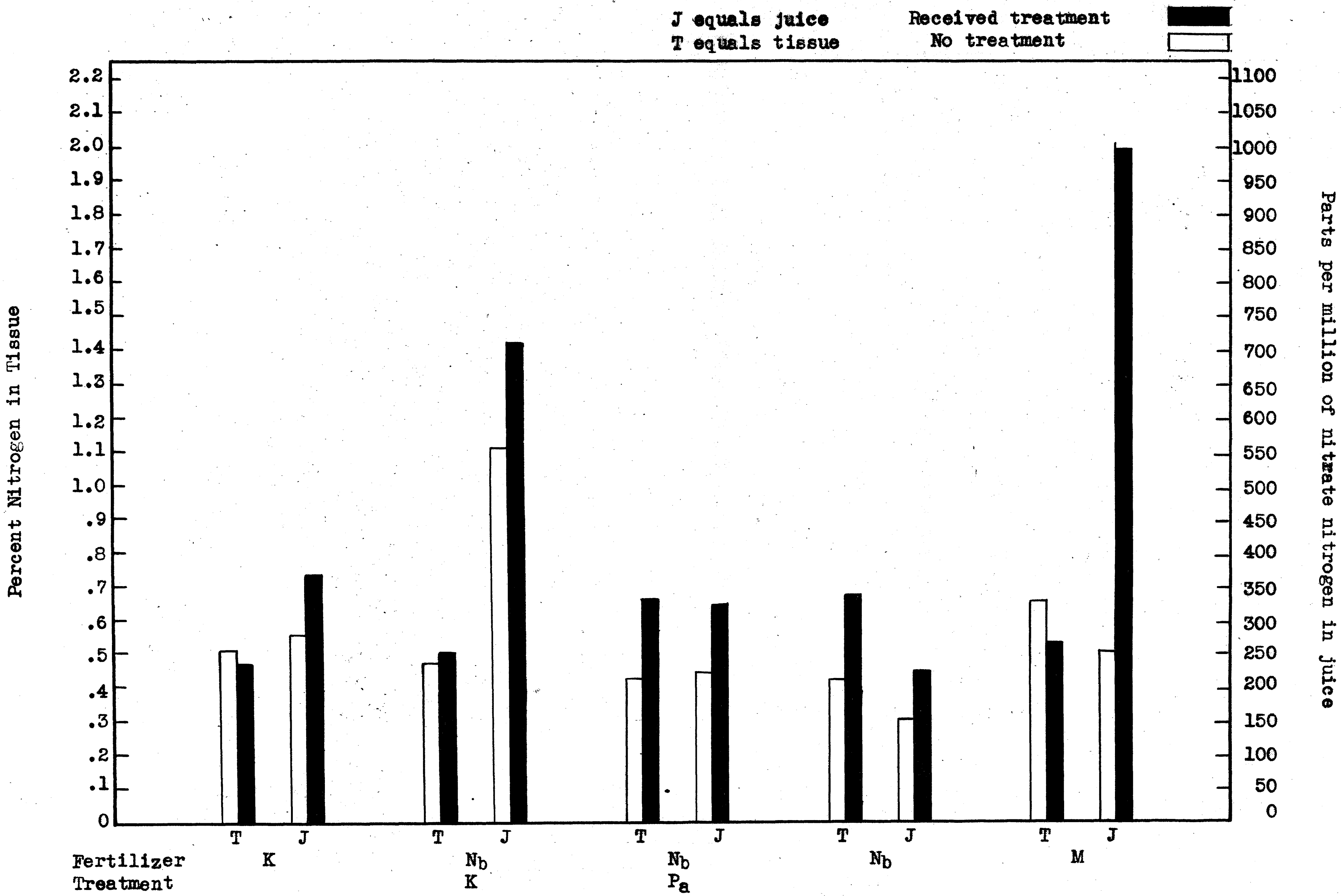

Fig. 5 .- Nitrate-nitrogen in juices and total nitrogen in tissue of corn plants on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 30, 1929.

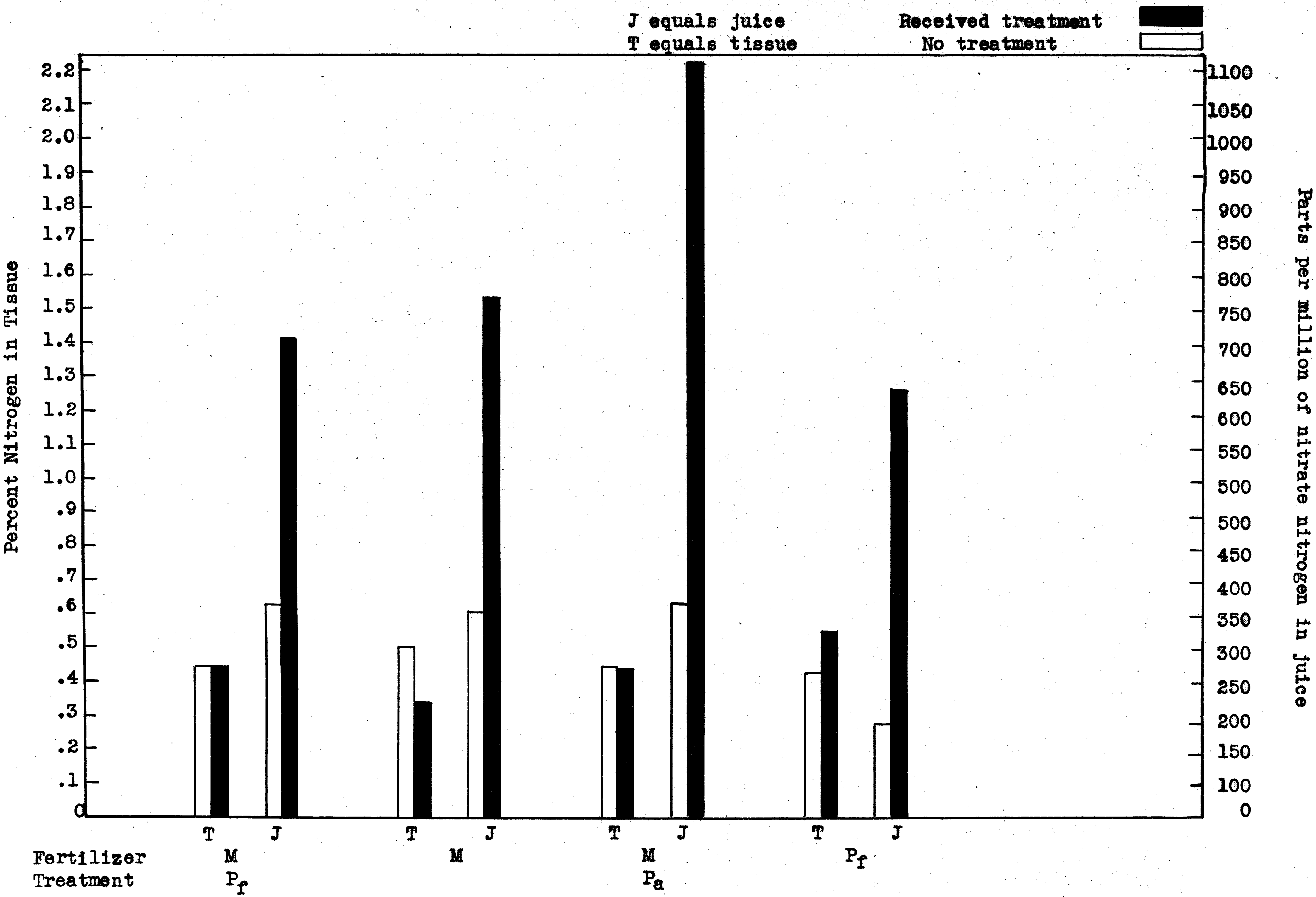

Fig. 5 .- Nitrate nitrogen in juices and total nitrogen in tissues of corn plants on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 30, 1929.

would show good correlation with fertilizer practices.

<u>Relation between Nitrogen in Juice and in Tissue</u> - It is evident in Figure 5 that the nitrogen content is higher in the juices from plats that received manure and the one that received nitrogen from dried blood and potassium as compared to the nitrogen content of the tissue from those plats. The reverse is true of the first five plats which received floats and manure; acid phosphate; nitrogen from dried blood, acid phosphate and potassium; nitrogen from ammonium sulfate and floats; acid phosphate and potassium, respectively. The manure plats are very productive; thus the nutrients that are stored in the tissue is scattered throughout the large quantity of grain and stover that is produced. It is logical that the fertile plats gives up a larger quantity of nitrogen than do the unprodictive plats, yet due to the larger amounts of tissue produced on the fertile plats, the concentrations of nitrogen in the tissues are lower.

Work done by Cook (2) at Michigan shows the total nitrogen content of the dried tissue to vary directly with the amount of nitrate in the juice. His work further indicates that the state of fertility of the soil had more effect than soil type on the nitrate content of the juice and the total nitrogen content of the tissue of the small grains. These results from Michigan do not agree with the data presented in this paper. The low coefficient of correlation of

$-.22\pm.12$ indicates very little relation between the nitrogen content of the juices of all plats and the nitrogen content of the corresponding tissues. It will be noted, however, that the Michigan station used small grains for their work, while corn was used in the investigation reported here.

Total phosphorus in Tissue - The tissue samples of all three sampling dates were analyzed for total phosphorus. The results obtained are presented in Tables 5, 7 and 9 and Figures 6, 7 and 8. There was considerable variation in the phosphorus content. The August samples 1928 ranged from .4185 percent in plat $2D_2$ (fertilized with acid phosphate) to .8810 percent in plat $4D_2$ (floats and sulfate of ammonia). The average concentration of the tissue from the treated plats was .0754 percent higher than the average of the untreated plats. The average for the treated was .6966 percent, while the untreated was .6212 percent. The samples gathered in September 1928 showed even a wider range. Plat $13D_1$ (no treatment) contained .4700 percent P_2O_5, while plat $9D_2$ (dried blood) contained .963 percent P_2O_5. The correlation between the phosphorus content and the fertilizer treatment is slightly better in the September samples than those gathered in August. The average concentration for the untreated plats is .6444 percent, while that of the treated ends is .7605 percent. The treated ends not only had an average of .1161 percent more phosphorus than the untreated ends, but produced 108.47 pounds of grain and stover per plat more than the untreated plats. The data

Table 5.- Phosphorus pentoxide content of tissue of corn plant grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 29, 1928.

Plat Nos.	Treatment	Sample No.	Per-cent P_2O_5	Ave. per-cent P_2O_5	Total yield grain & stover in lbs. 1929.
$1A_1$	Continuous Corn, no treatment	1	.577		
		2	.577	.5775	80.5
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons manure once in four years	1	.752		
		2	.795		
		3	.762	.7690	185.0
$2D_1$	No treatment	1	.565		
		2	.554	.5590	168.0
$2D_2$	70 lbs. P_2O_5 from acid phosphate annually	1	.405		
		2	.443		
		3	.401	.4185	208.5
$3D_1$	No treatment	1	.642		
		2	.593		
		3	.604	.6130	219.0
$3D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos, annually, 100 lbs. K_2O from mur. of potash annually	1	.659		
		2	.659	.6590	259.5
$4D_1$	Check, no treatment	1	.583		
		2	.570		
		3	.559	.5700	204.0
$4D_2$	40 lbs. N. from sul. of ammonia annually, 70 lbs. P_2O_5 from floats annually	1	.871		
		2	.892	.8810	216.2
$5D_1$	No treatment	1	.583	.5770	235.5
		2	.572		
$5D_2$	70 lbs. P_2O_5 from acid phosphate annually, 100 lbs. K_2O from mur. of potash annually	1	.803		
		2	.807		
		3	.807	.8050	256.0
$6D_1$	No treatment	1	.533		
		2	.548		
		3	.537	.5393	198.5

#2

Plat Nos.	Treatment	Sample No.	Per-cent P_2O_5	Ave. per-cent P_2O_5	Total yield grain & stover in lbs. 1929
$6D_2$	100 lbs. K_2O from mur. of potash, annually.	1	.593		
		2	.593		
		3	.572		
		4	.593	.5877	318.5
$7D_1$	No treatment	1	.738		
		2	.728	.7330	170.5
$7D_2$	40 lbs. N from dried blood, annually. 100 lbs. K_2O from mur. of potash, annually	1	.540		
		2	.529		
		3	.554		
		4	.586	.5525	310.5
$8D_1$	No treatment	1	.728		
		2	.738		
		3	.793		
		4	.783	.7605	124.5
$8D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid pho., annually.	1	.866		
		2	.852	.8590	145.5
$9D_1$	No treatment	1	.707		
		2	.707		
		3	.719		
		4	.730	.7157	100.5
$9D_2$	40 lbs. N. from dried blood, annually.	1	.813		
		2	.787		
		3	.837		
		4	.837	.8235	102.5
$10D_1$	No treatment	1	.656		
		2	.689	.6725	186.2
$10D_2$	16 tons manure once in four yrs. before corn	1	.839		
		2	.818		
		3	.856		
		4	.835	.8370	452.0
$11D_1$	No treatment	1	.725		
		2	.704		
		3	.693	.7073	129.0

Plat Nos.	Treatment	Sample No.	Per-cent P_2O_5	Ave.per-cent P_2O_5	Total yield grain & stover in lbs. 1929.
$11D_2$	16 tons manure once in 4 yrs. before corn. 70 lbs. P_2O_5 from floats, annually.	1	.678		
		2	.678		
		3	.708		
		4	.702	.6915	441.2
$12D_1$	No treatment	1	.535		
		2	.504	.5195	252.5
$12D_2$	Four tons manure annually	1	.648		
		2	.687	.6675	475.0
$13D_1$	No treatment	1	.492		
		2	.459	.4755	206.5
$13D_2$	16 tons manure once in four years before corn. 70 lbs. P_2O_5 from acid phos., annually.	1	.621		
		2	.628	.6245	385.5
$14D_1$	No treatment	1	.677		
		2	.677	.6770	168.0
$14D_2$	70 lbs. P_2O_5 from floats, annually	1	.554		
		2	.577		
		3	.598	.5763	205.0

Table 6.- Phosphorus pentoxide content of juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Juices extracted August 29, 1928.

Plat Nos.	Treatment	Sample No.	Mgm. P_2O_5 per cc	Ave. Mgm. P_2O_5 per cc	Total yield grain & stover in lbs. 1928
$1A_1$	Continuous Corn, no treatment	1	----		
		2	.121		
		3	.144		
		4	.199		
		5	.158		
		6	.172	.159	80.5
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons manure once in four years	1	.140		
		2	.115	.128	185.0
$2D_1$	No treatment	1	.220		
		2	.144		
		3	.172		
		4	.227	.191	168.0
$2D_2$	70 lbs. P_2O_5 from acid phosphate annually	1	.371		
		2	.350	.361	208.5
$3D_1$	No treatment	1	.124		
		2	.106	.115	219.0
$3D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos, annually, 100 lbs. K_2O from mur. of potash annually	1	.236		
		2	.226	.231	259.5
$4D_1$	Check, no treatment	1	.098		
		2	.103	.101	204.0
$4D_2$	40 lbs. N. from sul. of ammonia annually, 70 lbs. P_2O_5 from floats annually	1	.237		
		2	.181	.209	216.2
$5D_1$	No treatment	1	.162		
		2	.159	.161	235.5
$5D_2$	70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	.252		
		2	.246	.249	256.0
$6D_1$	No treatment	1	.136		
		2	.139	.138	198.2
$6D_2$	100 lbs. K_2O from mur. of potash annually	1	----		
		2	.114		
		3	.096		
		4	.089	.150	318.5

Table 6 continued.

Plat Nos.	Treatment	Sample No.	Mgm. P_2O_5 per cc	Ave.Mgm. P_2O_5 per cc	Total yield grain & stover in lbs. 1928
$7D_1$	No treatment	1	.083		
		2	.165		
		3	.076		
		4	.069	.098	170.5
$7D_2$	40 lbs. N. from dried blood annually, 100 lbs. K_2O from mur. of potash annually	1	.137		
		2	.096	.116	310.5
$8D_1$	No treatment	1	.186		
		2	.172	.179	124.5
$8D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phosphate annually	1	.364		
		2	.357	.360	145.5
$9D_1$	No treatment	1	.124		
		2	----		
		3	.124		
		4	.131	.126	100.5
$9D_2$	40 lbs. N. from dried blood annually	1	.213		
		2	.220	.216	102.5
$10D_1$	No treatment	1	.124		
		2	.172	.136	186.2
		3	.131		
		4	.117		
$10D_2$	16 tons manure once in four years before corn.	1	.268		
		2	.227	.247	452.0
$11D_1$	No treatment	1	.124		
		2	.103	.113	129.0
$11D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annually	1	.261		
		2	.227	.244	441.2
$12D_1$	No treatment	1	.103		
		2	.110	.106	252.5
$12D_2$	Four tons manure annually	1	.254		
		2	.261	.257	475.0

Table 6 continued.

Plat Nos.	Treatment	Sample No.	Mgm. P_2O_5 per cc	Ave. Mgm. P_2O_5 per cc	Total yield grain & stover in lbs. 1928
$13D_1$	No treatment	1	.083		
		2	.076	.079	206.5
$13D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from acid phosphate annually	1	----		
		2	----	----	385.5
$14D_1$	No treatment	1	.069		
		2	.096	.083	168.0
$14D_2$	70 lbs. P_2O_5 from floats annually	1	.117		
		2	.103	.110	205.0

The data on the plant juices were furnished by the Agronomy department.

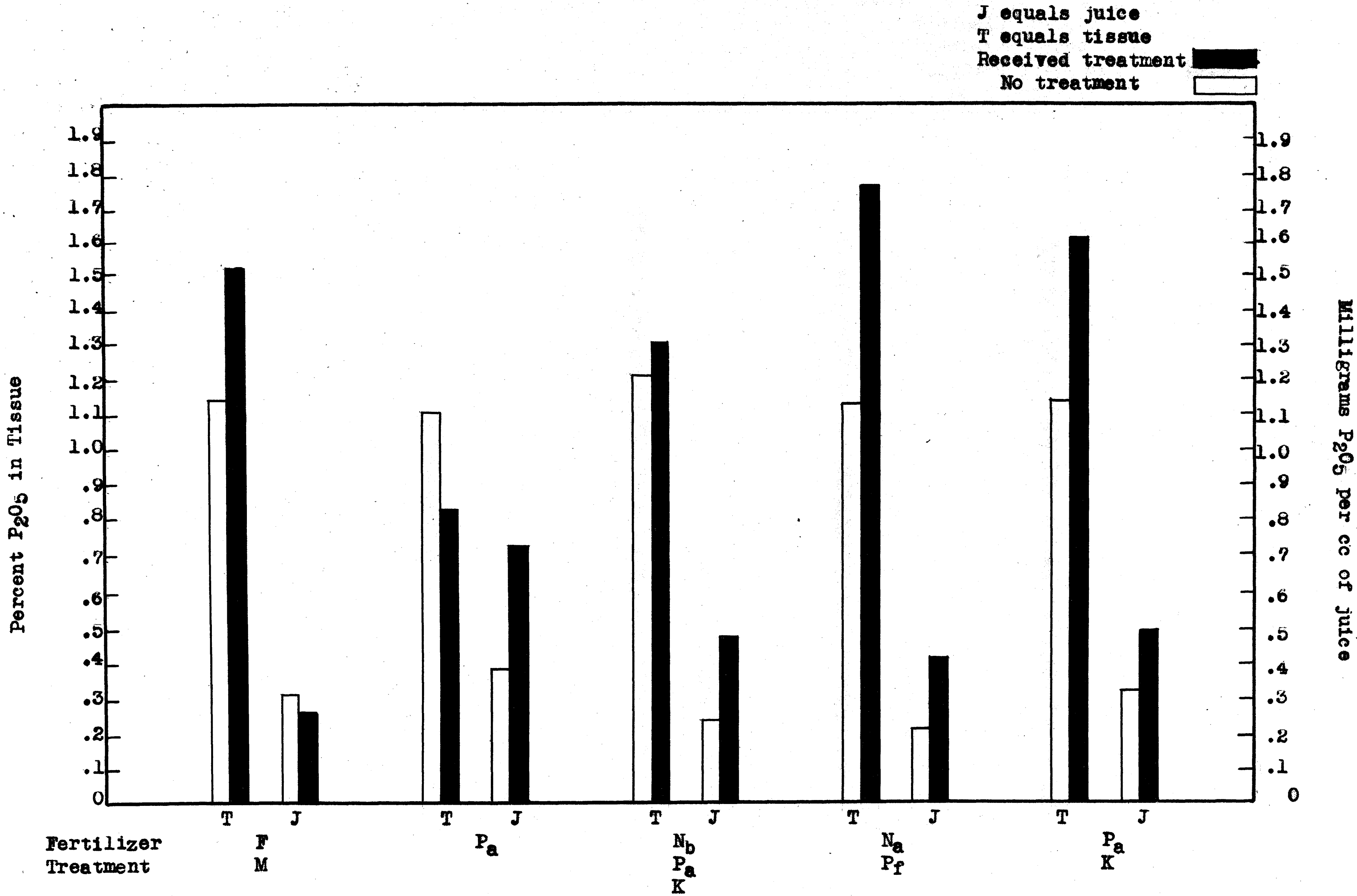

Fig. 6 .- Phosphorus content of tissue and juices of corn plats grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 29, 1928.

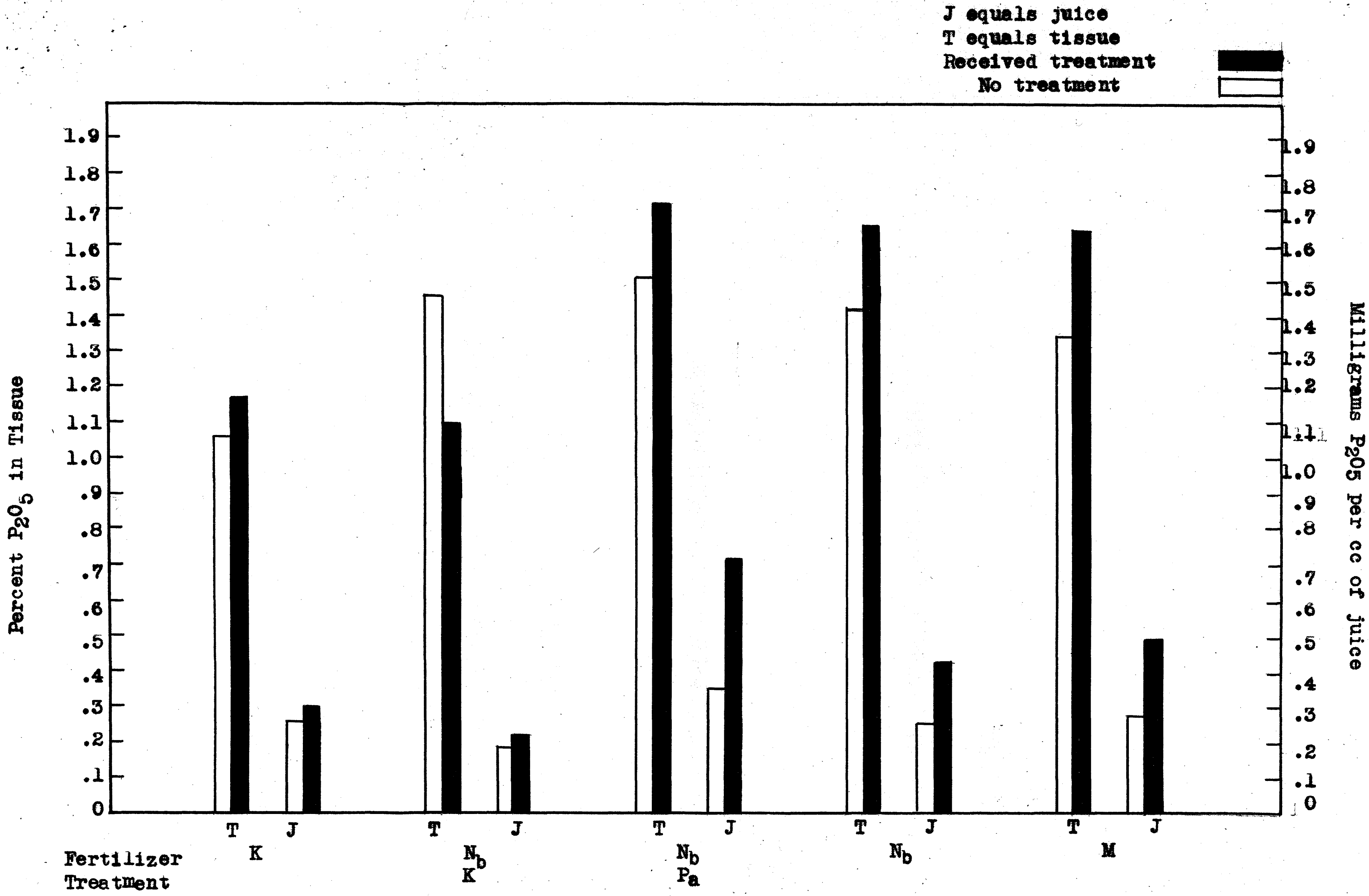

Fig. 6 .- Phosphorus content of tissue and juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 29, 1928.

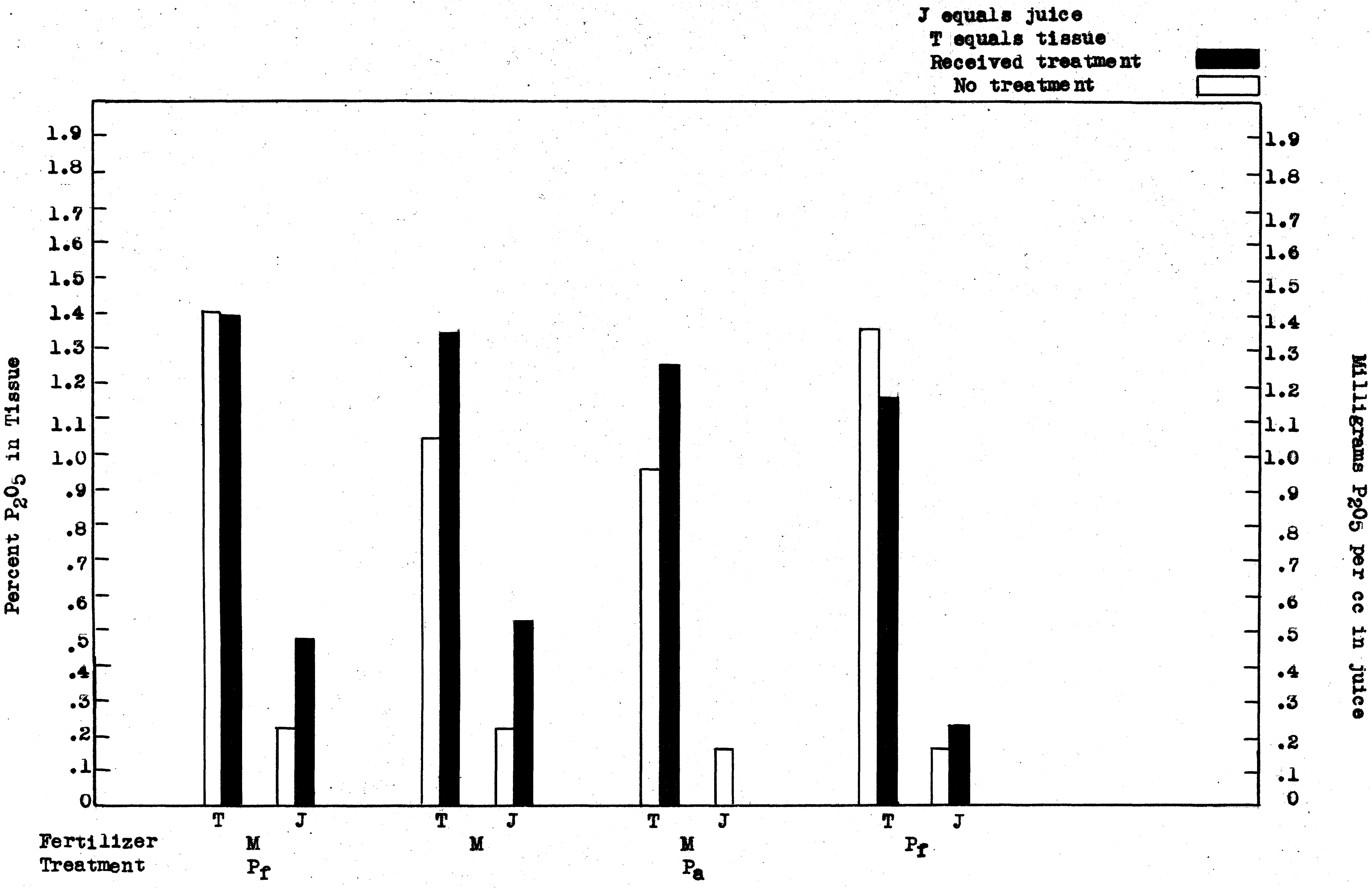

Fig. 6 .- Phosphorus content of tissue and juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 29, 1928.

also show an increase in phosphorus in the tissue from August to September. This would indicate that when the ears reach maturity there is an accumulation of phosphorus not only in the sap of the plant, but in the tissue also.

The samples gathered in August 1929 show an increase in phosphorus both in the treated and untreated plats. The average concentration in the treated ends is .858 percent P_2O_5, while the untreated ends show .845 percent. There was considerable variation even in the treated ends. The highest being 1.089 percent in plat $9D_2$, while the lowest was .512 percent in plat $8D_2$. Both extremes are treated plats while the untreated plats are intermediate.

Total Phosphorus in Juice - The juice samples of all three sampling dates were analyzed for total phosphorus. The results obtained are presented in Table 6, 8 and 10 and in Figures 6, 7 and 8.

These data show a remarkable correlation between the phosphorus content of the juices and phosphatic fertilization. On the first sampling date, August 29, 1928, the plats receiving no phosphatic fertilizers yielded juices containing less than .20 mgm. P_2O_5 per cc of juice. With but two exceptions, all plats to which phosphorus was applied gave juices with a phosphorus content above .20 mgm. P_2O_5 per cc. The samples collected on September 28, 1928 show an even better correlation between the phosphorus content of the juice samples and fertilizer treatment. Plats receiving no phosphatic fertilizers showed

Table 7.- Phosphorus pentoxide content of tissue of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered September 28, 1928.

Plat Nos.	Treatment	Sample No.	Per-cent P_2O_5	Ave.per-cent P_2O_5	Total yield grain & stover in lbs. 1928
$1A_1$	Continuous Corn, no treatment	1	.565		
		2	.537		
		3	.542		
		4	.552		
		5	.565	.5502	80.5
$1A_2$	Continuous Corn, 219 lbs. Floats annually, 16 tons manure once in four years	1	.607		
		2	.641		
		3	.619	.6223	185.0
$2D_1$	No treatment	1	.559		
		2	.577		
		3	.581	.5723	168.0
$2D_2$	70 lbs. P_2O_5 from acid phosphate annually	1	.615		
		2	.581		
		3	.610	.6020	208.5
$3D_1$	No treatment	1	.853		
		2	.868		
		3	.874	.8650	219.0
$3D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	.859		
		2	.824	.8415	259.5
$4D_1$	Check, no treatment	1	.635		
		2	.602	.6185	204.0
$4D_2$	40 lbs. N. from sul. of ammonia annually, 70 lbs. P_2O_5 from floats annually	1	.668		
		2	.654	.6610	216.2
$5D_1$	No treatment	1	.541		
		2	.554		
		3	.583	.5590	235.5
$5D_2$	70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from murl of potash annually	1	.828		
		2	.834	.8310	256.0

Table 7 continued.

Plat Nos.	Treatment	Sample No.	Per-cent P_2O_5	Ave.per-cent P_2O_5	Total yield grain & stover in lbs. 1928
$6D_1$	No treatment	1	.524		
		2	.587	.5555	198.2
$6D_2$	100 lbs. K_2O from mur. of potash annually	1	.528		
		2	.528	.5280	318.5
$7D_1$	No treatment	1	.487		
		2	.487	.4870	170.5
$7D_2$	40 lbs. N. from dried blood annually, 100 lbs. K_2O from mur. of potash annually	1	.570		
		2	.618	.5940	310.5
$8D_1$	No treatment	1	.641		
		2	.620	.6305	124.5
$8D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually	1	.857		
		2	.858	.8575	145.5
$9D_1$	No treatment	1	.667		
		2	.721	.6940	100.5
$9D_2$	40 lbs. N. from dried blood annually	1	.947		
		2	.979	.9630	102.5
$10D_1$	No treatment	1	.908		
		2	.888	.8980	186.2
$10D_2$	16 tons manure once in four years before corn	1	.883		
		2	.923		
		3	.923	.9087	452.0
$11D_1$	No treatment	1	.856		
		2	.856	.8560	441.2
$11D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annually	1	.703		
		2	.682	.6923	252.5

Table 7 continued.

Plat Nos.	Treatment	Sample No.	Per cent P_2O_5	Ave. per-cent P_2O_5	Total yield grain & stover in lbs. 1928
$12D_1$	No treatment	1	.703		
		2	.682	.6923	252.5
$12D_2$	Four tons manure annually	1	.762		
		2	.719	.7405	475.0
$13D_1$	No treatment	1	.464		
		2	.478	.4700	206.5
$13D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from acid phos annually	1	.771		
		2	.776	.7735	385.5
$14D_1$	No treatment	1	.574		
		2	.598	.5860	168.0
$14D_2$	70 lbs. P_2O_5 from floats annually	1	.858		
		2	.879	.8685	205.0

Table 8.- Phosphorus pentoxide content of juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Juices extracted September 28, 1928.

Plat Nos.	Treatment	Sample No.	Mgm. P_2O_5 per cc.	Ave.	Total yield grain & stover in lbs. 1928.
$1A_1$	Continuous Corn, no treatment	1	.1787		
		2	.1718	.1753	80.5
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons manure ince on four years	1	.2234		
		2	.2199	.2217	185.0
$2D_1$	No treatment	1	.1443		
		2	.1306	.1375	168.0
$2D_2$	70 lbs. P_2O_5 from acid phosphate annually	1	.5292		
		2	.5155	.5224	208.5
$3D_1$	No treatment	1	.1787		
		2	.1924	.1856	219.0
$3D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	.7216		
		2	.7148	.7182	259.5
$4D_1$	No treatment	1	.3024		
		2	.2887	.2956	204.0
$4D_2$	40 lbs. N. from sul. of ammonia annually, 70 lbs. P_2O_5 from floats annually	1	.3780		
		2	.3230	.3505	216.2
$5D_1$	No treatment	1	.1443		
		2	.1375	.1409	235.5
$5D_2$	70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	.9484		
		2	.9553	.9519	256.0
$6D_1$	No treatment	1	.1718		
		2	.1649	.1684	198.2
$6D_2$	100 lbs. K_2O from mur. of potash annually	1	.2749		
		2	.2887	.2818	318.5
$7D_1$	No treatment	1	.1512		
		2	.1375	.1444	170.5

Table 8 continued.

Plat Nos.	Treatment	Sample No.	Mgm. P_2O_5 per cc.	Ave.	Total yield grain & stover in lbs. 1928.
$7D_2$	40 lbs. N. from dried blood annually, 100 lbs. K_2O from mur. of potash annually	1 2	.2749 .3093	.2921	310.5
$8D_1$	No treatment	1 2	.2749 .2680	.2715	124.5
$8D_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phosphate annually	1 2	.5017 .5155	.5086	145.5
$9D_1$	No treatment	1 2	.2818 .2749	.2784	100.5
$9D_2$	40 lbs. N. from dried blod annaully	1 2	.2680 .2749	.2715	102.5
$10D_1$	No treatment	1 2	.1581 .1718	.1650	186.2
$10D_2$	16 tons manure once in four years before corn	1 2	.4467 .4330	.4399	452.0
$11D_1$	No treatment	1 2	.2818 .2680	.2749	129.0
$11D_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annaully	1 2	.3436 .3505	.3471	441.2
$12D_1$	No treatment	1 2	.2612 .2474	.2543	252.5
$12D_2$	Four tons manure annually	1 2	.4742 .4605	.4674	475.0
$13D_1$	No treatment	1 2	.0687 .0687	.0687	206.5
$13D_2$	16 tons manure once in four	1 2	.4605 .4811	.4708	385.5

Table 8 continued.

Plat Nos.	Treatment	Sample No.	Mgm. P_2O_5 per cc.	Ave.	Total yield grain & stover in lbs. 1928.
	years before corn, 70 lbs. P_2O_5 from acid phosphate annually				
$14D_1$	No treatment	1	.1168		
		2	.1100	.1134	168.0
$14D_2$	70 lbs. P_2O_5 from floats annually	1	.3780		
		2	.3436	.3608	205.0

The data on the plant juices were furnished by the Agronomy Department.

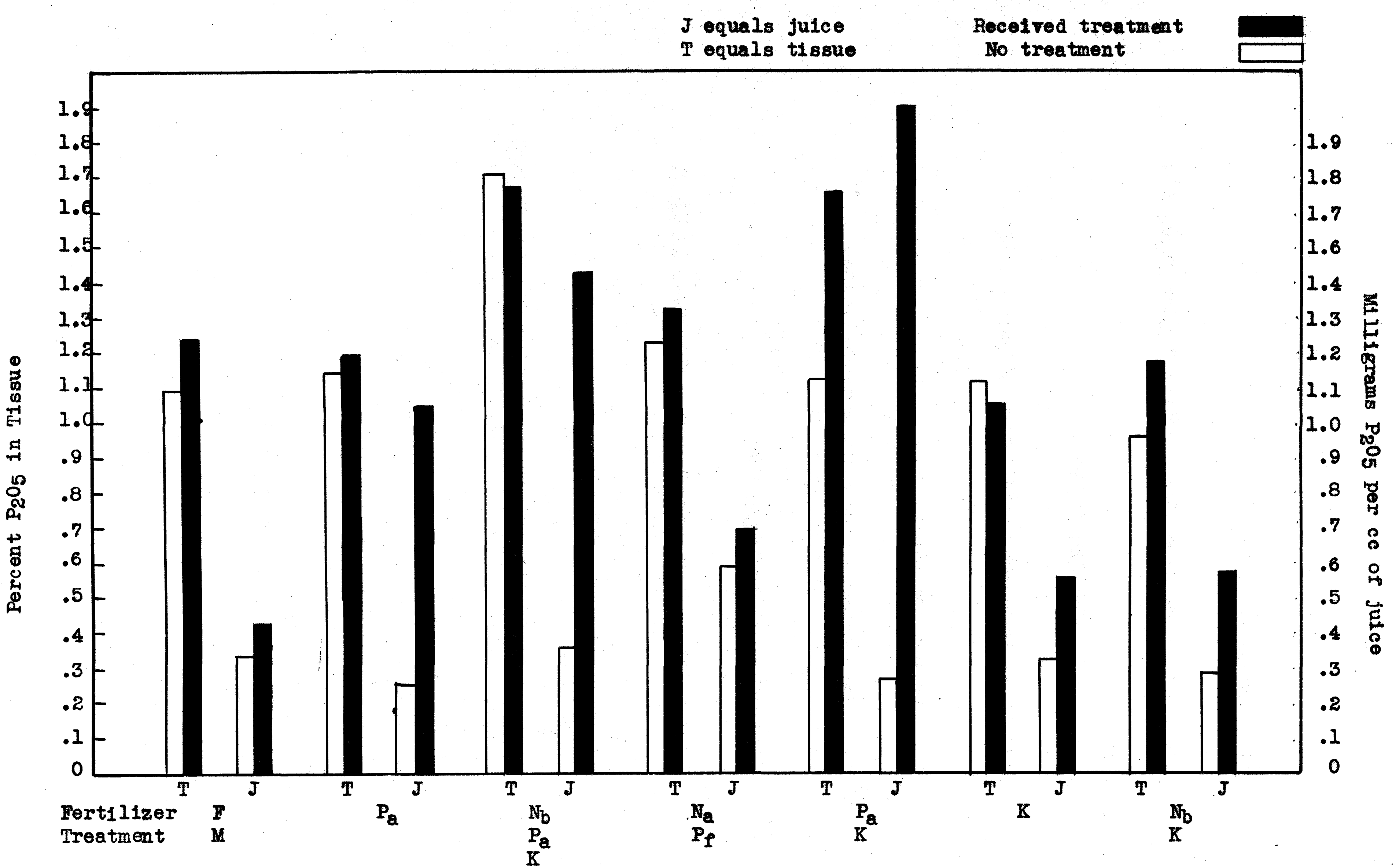

Fig. 7 .- Phosphorus content of tissue and juices of corn plants grown on the Rotation with Fertilizer and the Continuous Corn plats at Blacksburg, Virginia. Samples gathered September 28, 1928.

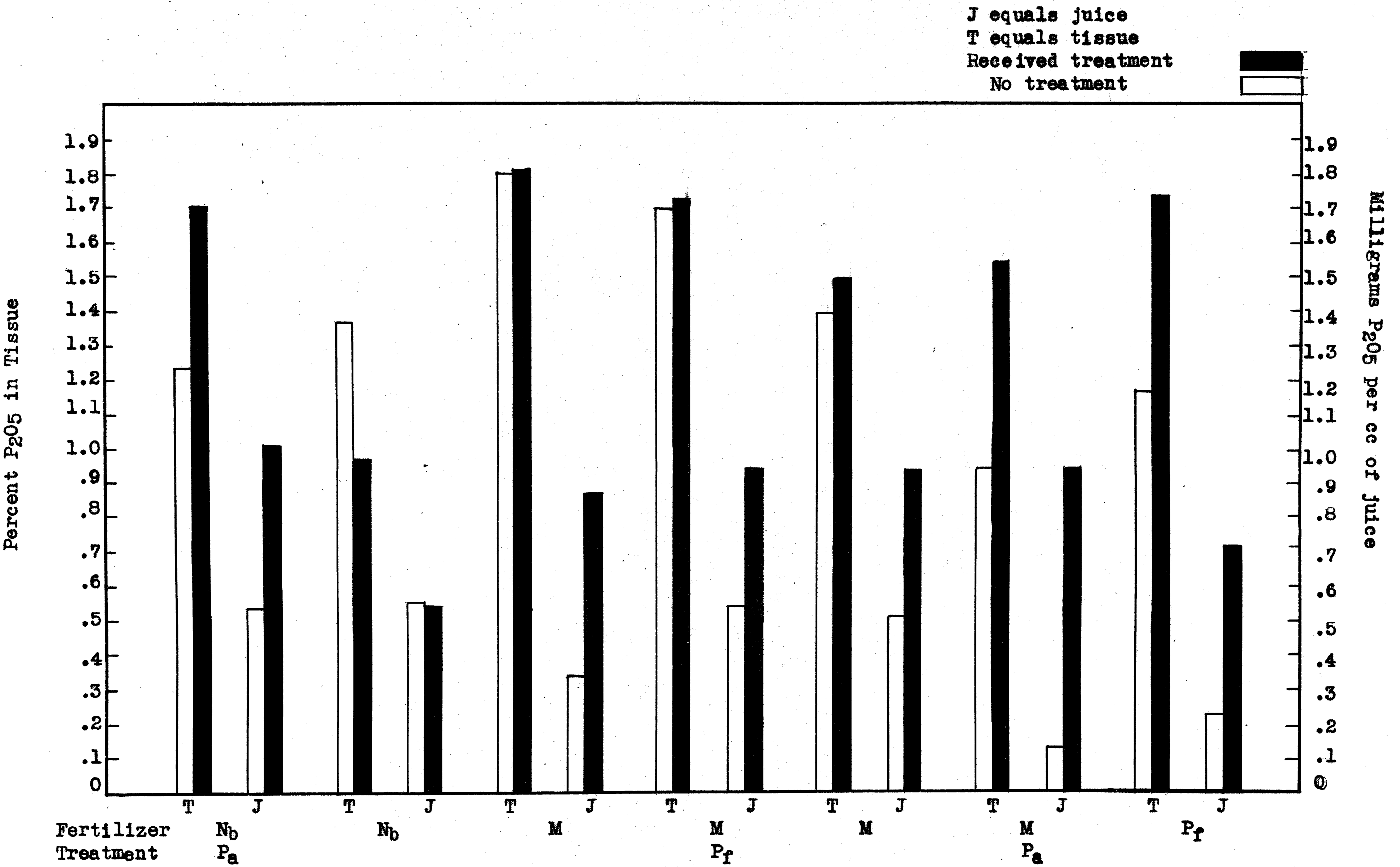

Fig. 7 .- Phosphorus content of tissue and juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered September 28, 1928.

less than .30 mgm. P_2O_5 per cc of juice. The plats receiving raw rock phosphate, a relatively unavailable source of phosphorus, yielded juices containing between .30 and .40 mgm. per cc. All plats receiving superphosphate, which is a relatively available source of phosphorus, gave up more than .40 mgm. of P_2O_5 for every cc of juice. The results for 1929 harmonize well with those of 1928 with but one or two exceptions. The plats receiving phosphorus yielded juices of higher phosphorus content than the plats receiving no phosphorus. It appears, therefore, that the phosphorus content of the expressed juice of corn plants may be used as a reliable guide to the application of phosphorus containing fertilizers. The results thus far obtained indicate that, in general, when the phosphorus content of the juice goes below .20 mgm P_2O_5 per cc during the month of August, applications of phosphate will be profitable if no other element is acting as a limiting factor. If the sap contains more than .25 mgm per cc the soil is not deficient in phosphorus.

Table 7 also brings out the effect of age of the corn plant on the phosphorus content of its juice. The juices expressed on September 28, 1928, contained nearly twice as much phosphorus as those obtained from the same plats a month earlier. Furthermore, the samples taken on August 30, 1929, show about the same phosphorus content as those gathered a year earlier, and therefore, are much lower in phosphorus than the September samples of 1928. These statements are of interest in relation to the condition of the plants on the various sampling dates. On August 29, 1928, the ears were fully developed, but had undergone little, if any, maturation. A month later the ears and leaves were fully mature, but the stalks still contained considerable juice. The difference in phosphorus contents on the different dates as pointed out above may be explained by the differential demand for phosphorus by the plant during the earing and maturation periods. During August, when the ears are developing rapidly, the demand for phosphorus is high and the assimilative processes keep the phosphorus content of the juice at a relatively low level. As the plant approaches maturity the demand for phosphorus becomes less and less, assimilative processes decrease in activity, and with a subsequent lag in the cessation of absorption, phosphorus accumulates in the juice during the maturation period. This occurs regardless of the previous fertilizer treatment. There was considerable variation even in the treated ends. The highest being 1.089 percent in plat $9D_2$, while the lowest was .512 percent in plat $8D_2$. Both extremes are treated plats while the untreated plats are intermediate.

Phosphorus in Tissue and Juice - Figures 6, 7 and 8 show the phosphorus content in the juice and in the tissue. The charts are arranged in such a way that the difference between the phosphorus content of the juice and tissue can be seen and also the effect of the various fertilizer treatments upon the phosphorus content of both

Table 9.- Phosphorus pentoxide content of tissue of corn plants grown on the Rotation with Fertilizer and Continous Corn plats at Blacksburg, Virginia. Samples gathered August 30, 1929.

Plat Nos.	Treatment	Sample No.	Per-cent P_2O_5	Ave.per-cent P_2O_5	Total yield grain & stover in lbs. 1929
$1A_1$	Continuous Corn, no treatment	1	.916		
		2	.933	.924	127.0
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons manure once in four years	1	.753		
		2	.691	.722	252.5
$2C_1$	No treatment	1	.956		
		2	.983	.969	382.0
$2C_2$	70 lbs. P_2O_5 from acid phosphate annually	1	.955		
		2	.921	.938	395.5
$3C_1$	No treatment	1	.795		
		2	.789	.792	349.0
$3C_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	.977		
		2	.995	.986	363.0
$4C_1$	No treatment, check	1	1.080		
		2	1.055		
		3	1.081	1.072	365.5
$4C_2$	40 lbs. N. from sul. of ammonia annually, 70 lbs. P_2O_5 from floats annually	1	.856		
		2	.866	.861	314.0
$5C_1$	No treatment	1	.911		
		2	.900	.905	319.5
$5C_2$	70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	1	.913		
		2	.904	.908	454.5
$6C_1$	No treatment	1	.878		
		2	.902	.890	315.0
$6C_2$	100 lbs. K_2O from mur. of potash annually	1	.900		
		2	.908	.904	404.0

Table 9 continued.

Plat Nos.	Treatment	Sample No.	Per-cent P_2O_5	Ave. per-cent P_2O_5	Total yield grain & stover in lbs. 1929
$7C_1$	No treatment	1	.997		
		2	.916	.956	311.5
$7C_2$	40 lbs. N. from dried blood annually, 100 lbs. K_2O from mur. of potash annually	1	1.015		
		2	.993	1.004	401.0
$8C_1$	No treatment	1	.654		
		2	.683	.668	325.0
$8C_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phosphate annually	1	.539		
		2	.486	.512	207.0
$9C_1$	No treatment	1	.954		
		2	.913	.933	199.5
$9C_2$	40 lbs. N. from dried blood annually	1	1.017		
		2	1.153	1.089	143.0
$10C_1$	No treatment	1	.930		
		2	.940	.935	229.0
$10C_2$	16 tons manure once in four years before corn.	1	.932		
		2	.974	.953	473.5
$11C_1$	No treatment	1	.977		
		2	.903	.940	190.5
$11C_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annually	1	.864		
		2	.850	.857	428.0
$12C_1$	No treatment	1	.628		
		2	.628	.628	316.5
$12C_2$	Four tons manure annually	1	.951		
		2	.945	.948	454.5
$13C_1$	No treatment	1	.599		
		2	.610	.604	264.0
$13C_2$	16 tons manure once in four years before corn, 70 lbs.	1	.643		
		2	.664	.653	424.0

Table 9 continued.

Plat Nos.	Treatment	Sample No.	Per-cent P_2O_5	Ave.per-cent P_2O_5	Total yield grain & stover in lbs. 1929
$14C_1$	No treatment	1	.622		
		2	.611	.616	227.5
$14C_2$	70 lbs. P_2O_5 from floats annually	1	.679		
		2	.679	.679	256.0

Table 10.- Phosphorus pentoxide content of juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Juices extracted August 30, 1929.

Plat Nos.	Treatment	Milligram P_2O_5 per cc of juice	Total yield grain & stover in lbs. 1929
$1A_1$	Continuous Corn, no treatment	.327	127.0
$1A_2$	Continuous Corn, 219 lbs. floats annually, 16 tons manure once in four years	.340	252.5
$2C_1$	No treatment	.267	382.0
$2C_2$	70 lbs. P_2O_5 from acid phosphate annually	.405	395.5
$3C_1$	No treatment	.147	349.0
$3C_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	.345	363.0
$4C_1$	Check, no treatment	.100	365.5
$4C_2$	40 lbs. N. from sul. of ammonia annually, 70 lbs. P_2O_5 from floats annually	.187	314.0
$5C_1$	No treatment	.090	319.5
$5C_2$	70 lbs. P_2O_5 from acid phos. annually, 100 lbs. K_2O from mur. of potash annually	.225	454.5
$6C_1$	No treatment	.090	315.0
$6C_2$	100 lbs. K_2O from mur. of potash annually	.107	404.0
$7C_1$	No treatment	.077	311.5
$7C_2$	40 lbs. N. from dried blood annually, 100 lbs. K_2O from mur. of potash annually	.125	401.0

Table 10 continued.

Plat Nos.	Treatment	Milligrams P_2O_5 per cc of juice	Total yield grain & stover in lbs. 1929
$8C_1$	No treatment	.115	143.0
$8C_2$	40 lbs. N. from dried blood annually, 70 lbs. P_2O_5 from acid phosphate annually	.257	229.0
$9C_1$	No treatment	.120	473.5
$9C_2$	40 lbs. N. from dried blood annually	.185	190.5
$10C_1$	No treatment	.128	428.0
$10C_2$	16 tons manure once in four years before corn.	.315	316.5
$11C_1$	No treatment	.185	454.5
$11C_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from floats annually	.325	264.0
12C1	No treatment	.175	424.0
$12C_2$	Four tons mamure annaully	.328	227.5
$13C_1$	No treatment	.177	256.0
$13C_2$	16 tons manure once in four years before corn, 70 lbs. P_2O_5 from acid phosphate annually	.585	325.0
14C1	No treatment	.148	207.0
$14C_2$	70 lbs. P_2O_5 from floats annually	.325	199.5

The data on the plant juices were furnished by the Agronomy department.

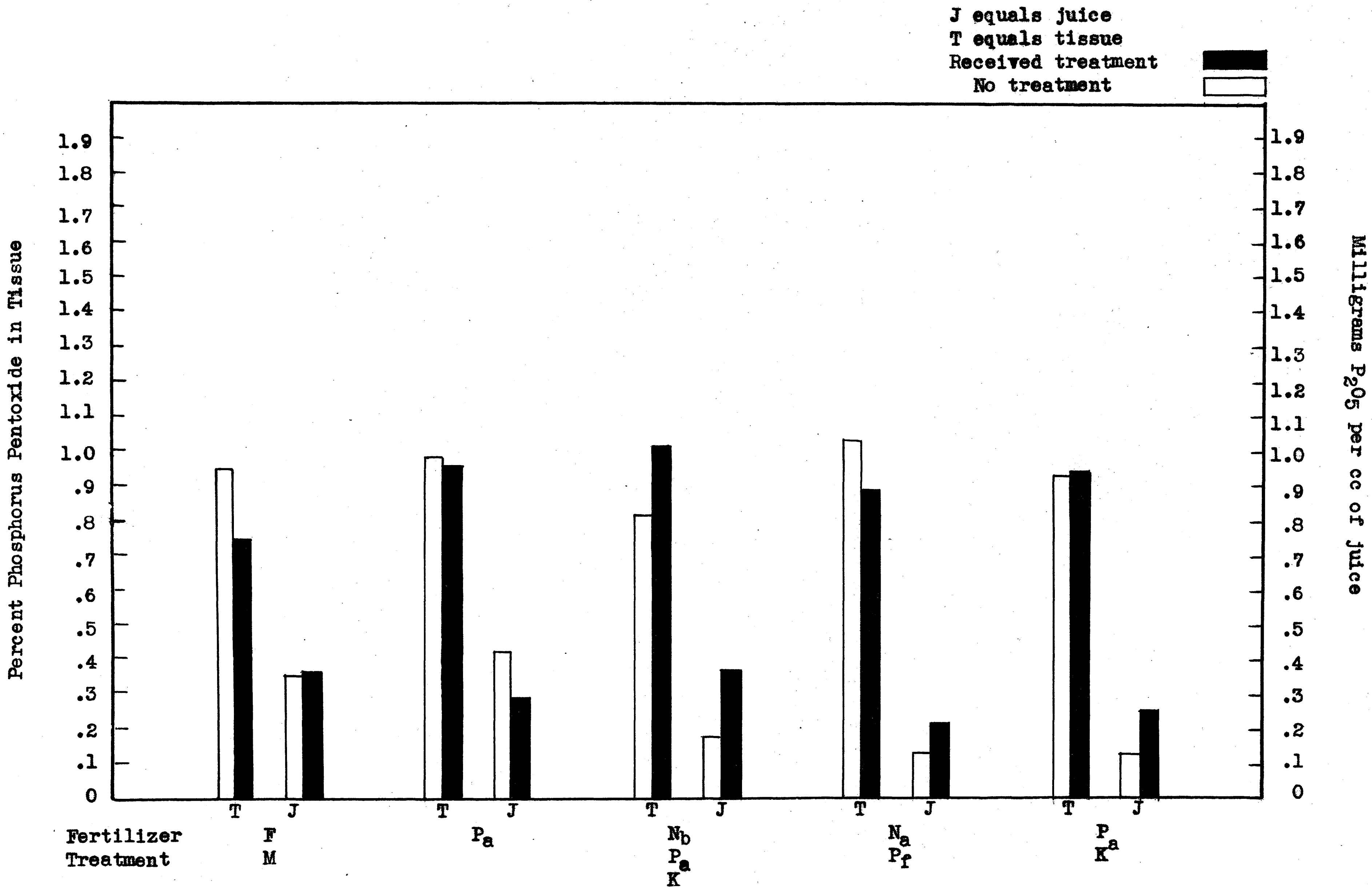

Fig. 8 .- Phosphorus content of tissue and juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 30, 1929.

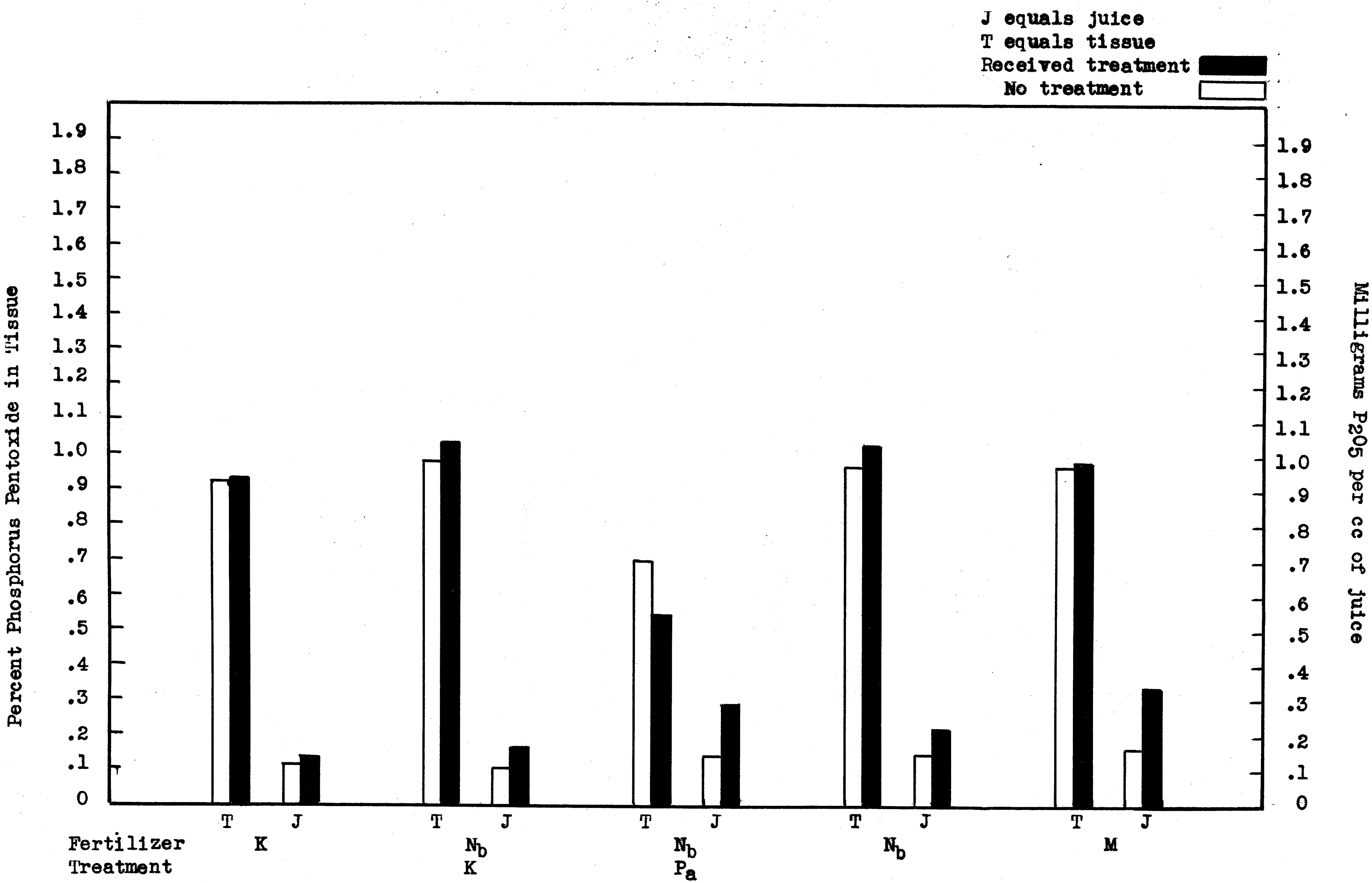

Fig. 8 .- Phosphorus content of tissue and juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 30, 1929.

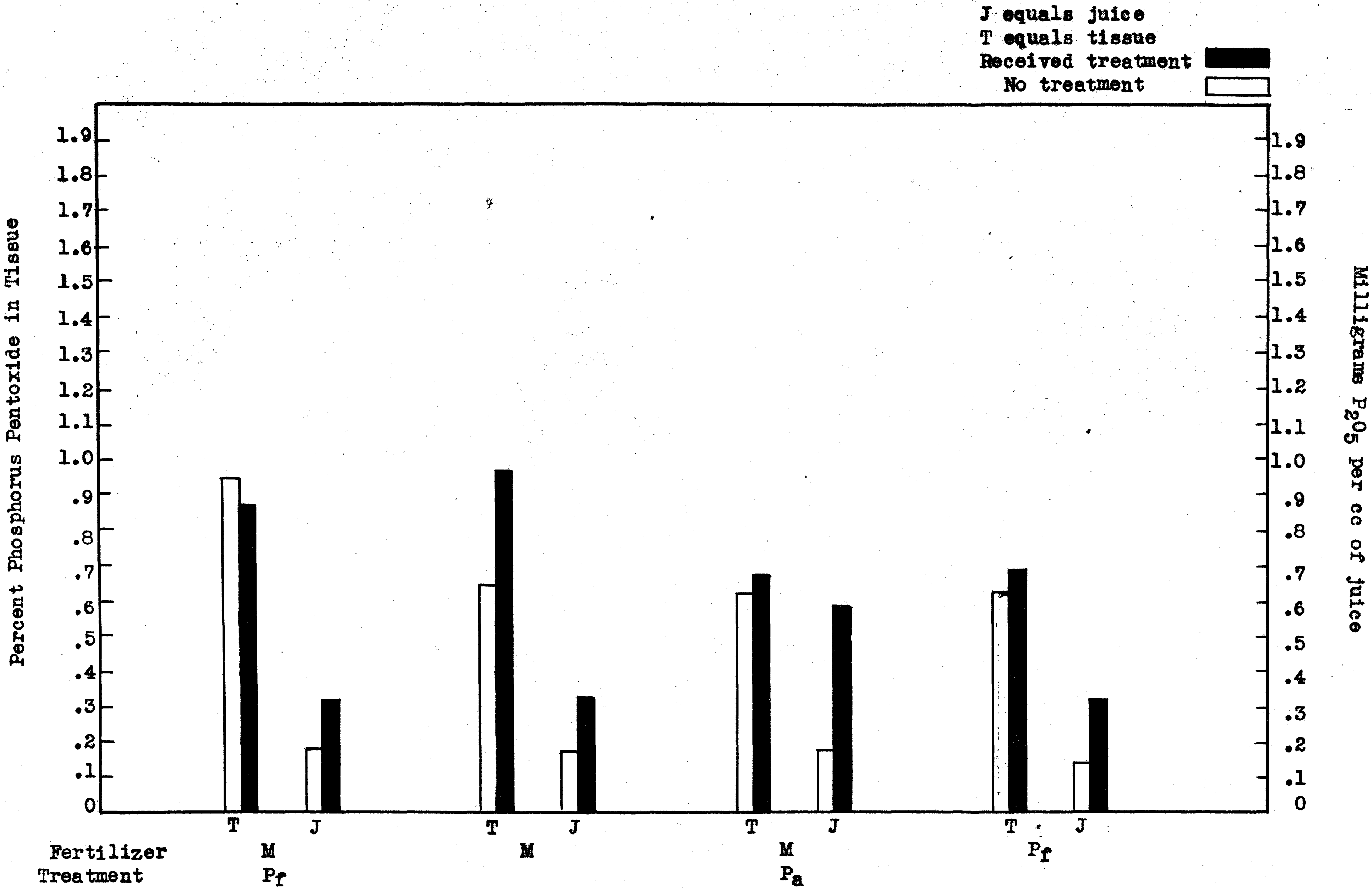

Fig. 8 .- Phosphorus content of tissue and juices of corn plants grown on the Rotation with Fertilizer and Continuous Corn plats at Blacksburg, Virginia. Samples gathered August 30, 1929.

the juices and tissues. The tissue is expressed in percent, and the juices in milligrams per cubic centermeter of juice, but still a comparison can easily be made. The correlation between the juices and the tissue is too low to be significant. In the samples gathered in August 1928 the correlation is .278 ± .12. In the samples gathered a month later, the correlation is decreased to.189 ± .082. The samples gathered in August 30, 1929 also indicate by a correlation of .20 ± .12 that there is very little relation between the phosphorus content of the juice and that of the tissue.

Summary and Conclusions

1. The nitrogen content of tissue of corn plants does not follow the nitrogen fertilization.

2. The nitrate content of the juice is a good indicator of nitrogen needs in spite of the fact that it may not show a relation to the application of organic nitrogenous fertilizers.

3. The total nitrogen content of the tissue shows practically no correlation with the nitrate nitrogen content of the juice.

4. The total nitrogen content of the tissue shows practically no correlation with the total yield of grain and stover.

5. There appears to be little correlation between the phosphorus content of corn tissue and phosphatic fertilization.

6. The phosphorus content of corn tissue increases with the age of the plant and probably reaches its maximum concentration at maturity.

7. The total phosphorus content of the juice is closely related to phosphorus fertilization. Applications of either superphosphate or farm manure increased the total phosphorus content from two to five times that contained in juices coming from plats receiving no phosphorus. Rock phosphate was less effective in increasing the phosphorus content than either superphosphate or manure.

8. There is an accumulation of phosphorus in the juice

during September due to the lessened demand after the ear has reached maturity.

9. There is little correlation between the phosphorus content of the tissue and the concentration of the juices.

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