EFFECTS OF FERTILIZATION UPON THE GROWTH AND MINERAL UPTAKE OF SORGHUM SEEDLINGS ON COMPOSTED LATERITIC SOIL

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INTRODUCTION

The lateritic soil on Ta-tu-shan in central Taiwan is deficient in both nitrogen and phosphorus (12) , and corn plants grown on it have shown significant responses to a combination of the two elements in fertilizers (1). Organic matter improves the soil by influencing its physical properties as well as increasing the availability of nutrients (5, 10). Easily replaceable cations are provided along with nitrogen, phosphorus and sulfur held in organic forms. Such increase in nutrients in soil will greatly stimulate crop growth. Compost is one of the sources of soil orangic matter. The addition of compost to lateritic soils increased profoundly the production of crops as reported by Orchard and Darby (7). The present paper reveals the effects of compost addition and fertilization on the growth and mineral uptake of sorghum seedlings on the lateritic soil on Ta-tu-shan.

METHODS

Soil for pot cultures in the experiment was collected from the denuded land located near the east side of a Taiwan acacia grove on the campus of Tunghai University. One part of compost was mixed thoroughly with two parts of the soil for the experiments. The compost used was made with grasses grown on the lateritic soil on the University campus.

Pot cultures with sorghum (*Andropogon sorghum*, Brot.) seedlings were made out of doors on Ta-tu-shan. Six-inch pots were used, with two seedlings per pot in quadruplicate. In these tests 2200 grams of composted soil were weighed into a pot and then fertilized with various treatments as shown in Table 2. The fertilizers used were ammonium nitrate, ammonium phosphate, potassium phosphate, potassium nitrate and potassium chloride as the sources of nitrogen, phosphorus, and potassium. The designations N_0, N_1, N_2, N_3 and N_4 indicate that the soil received nitrogen at the rate of nil, 100, 200, 300, and 400 pounds per acre respectively; P_0, P_1, P_2, P_3, and P_4, at the rate of nil, 100, 200, 300, and 400 pounds P_2O_5 per acre respectively; K_0, K_1, K_2, K_3, and K_4, at the rate of nil, 100, 200, 300 and 400 pounds K_2O per acre respectively.

Sorghum seeds were sown on March 24, 1961 and the seedlings were harvested on

May 15, 1961. During the growing period the plants were watered with distilled water once or twice a day depending upon the moisture condition of the soils. At the time of harvest the seedlings were individually separated at the ground line and were then dried to a constant weight in an oven at 70°C. The shoots and roots from each treatment in quadruplicate were mixed and then ground in a Wiley mill through a 40 mesh screen. The plant tissue was analyzed for nitrogen, phosphorus, potassium, calcium and magnesium.

Total nitrogen was determined by the Kjeldahl method modified from Winkler (9); the ammonia was distilled into boric acid solution and then titrated with standard hydrochloric acid solution. The samples of plant tissue used for phosphorus, potassium, calcium and magnesium determinations were prepared by the usual dry ashing method. Magnesium and phosphorus were determined by a modification of the molybdi-vanadate method of Murray and Ashley (6). Magnesium was precipitated as magnesium ammonium phosphate and then estimated by comparing with phosphate standards on a colorimeter; for phosphate the ash solution was used directly. Potassium was precipitated as the cobaltinitrite and titrated with standard permanganate (2); calcium was precipitated as calcium oxalate, and the oxalate titrated with permanganate in hot sulfuric acid solution (4).

The composted soil was analyzed for soil texture, soil reaction, organic matter, total nitrogen, available phosphorus, cation exchange capacity and exchangeable potassium, calcium and magnesium. Soil texture was determined by the Bouyoucos hydrometer method (9). Soil reaction was measured by glass electrode with a soil-water ratio of 1:1. Organic matter of the soil was determined by the potassium dichromate method. Total nitrogen was determined as described above for plant tissue. Available phosphorus was extracted with dilute sulfuric acid (11) and then estimated by comparing with phosphorus standards on a colorimeter. Cation exchange capacity was determined by a method modified from Peech et al. (8). The leachate was evaporated to dryness, treated with concentrated nitric acid and hydrochloric acid, and dried again. The residue was then heated at 390°C. to oxidize organic matter, dissolved with 0.1 N HNO_3, and subjected to the same method used in analysis of the plant tissue for potassium, calcium and magnesium elements.

RESULTS AND DISSCUSSION

1. The effect of compost on soil improvement.

The soils physical and chemical properites were modified after treated with compost. Table 1 shows a comparison of the texture, soil reaction, organic matter and chemical composition of the composted lateritic soil with those of the lateritic soil without compost addition.

Table 1

The physical and chemical properties of the lateritic soils

Soil sample	Soil texture				pH	Air dry moisture content	Organic matter	Total N	Available P	Cation exchange capacity	Exchangeable K	Exchangeable Ca	Exchangeable Mg
	Name	sand	silt	clay									
		%*	%	%		%	%	%	lb./A	m.e**	m. e.	m. e.	m. e.
Soil (without compost addition)	sandy loam	64.9	21.9	13.2	4.5	0.64	0.84	0.053	1.30	—	0.231	0.60	—
Composted soil	Clay loam	36.3	35.9	27.8	5.8	2.71	4.43	0.284	123.2	16.05	1.086	11.94	2.90

* % of oven dry soil

** m. e. per 100 grams oven dry soil

The soil improving effect of compost in this experiment was very striking. The acidity was decreased as the base content of the composted soil increased. The organic matter, total nitrogen, available phosphorus and exchangeable calcium, potassium and magnesium of the soil were increased by compost addition. The organic matter, total nitrogen and exchangeable potassium levels of the composted soil were about five times higher, the calcium content twenty times greater, and the available phosphorus amount one hundred times higher than those of the soil without added compost. Such increments in nutrients made the composted soil more productive than the soil without compost addition.

2. Effects of fertilization on the growth and dry weight of sorghum seedlings.

The growth and dry weight of sorghum plants can best be shown in Figure 1 and Table 2. Seedlings with all fertilizer treatments showed a slight increase in dry weights. On the basis of increased dry weight, the seedlings with $N_1P_1K_2$, $N_1P_1K_3$ and $N_1P_1K_4$ treatments developed better than those with other treatments. Their dry weight indexes of the shoot are 151, 136 and 128 respectively; while their dry weight indexes of the roots are 124, 130 and 139 respectively. The control plants had more extensive root development and yielded greater dry weight than most of the fertilized plants. Other factors being equal, a tendency existed toward decreasing dry weights of the shoots but increasing dry weights of the roots with increasing nitrogen, phosphorus, or potassium fertilizer amounts in the composted lateritic soil.

Soil fertility varies greatly with different kinds of soil. The effects of fertilization on the growth sorghum seedlings on the composted lateritic soil of Taiwan are therefore not consistent with those reported by Iljin (3) for the same species in Venezuela. In his experiments, the fertilized sorghum plants on lateritic soil of Venezuela showed no response to NK treatment, but the dry yield increased greatly when treated with NP. Comparing the yield of NPK with those of NP treatment, it seemed that the addition of potassium give little effect on the growth of sorghum plants in his experiments.

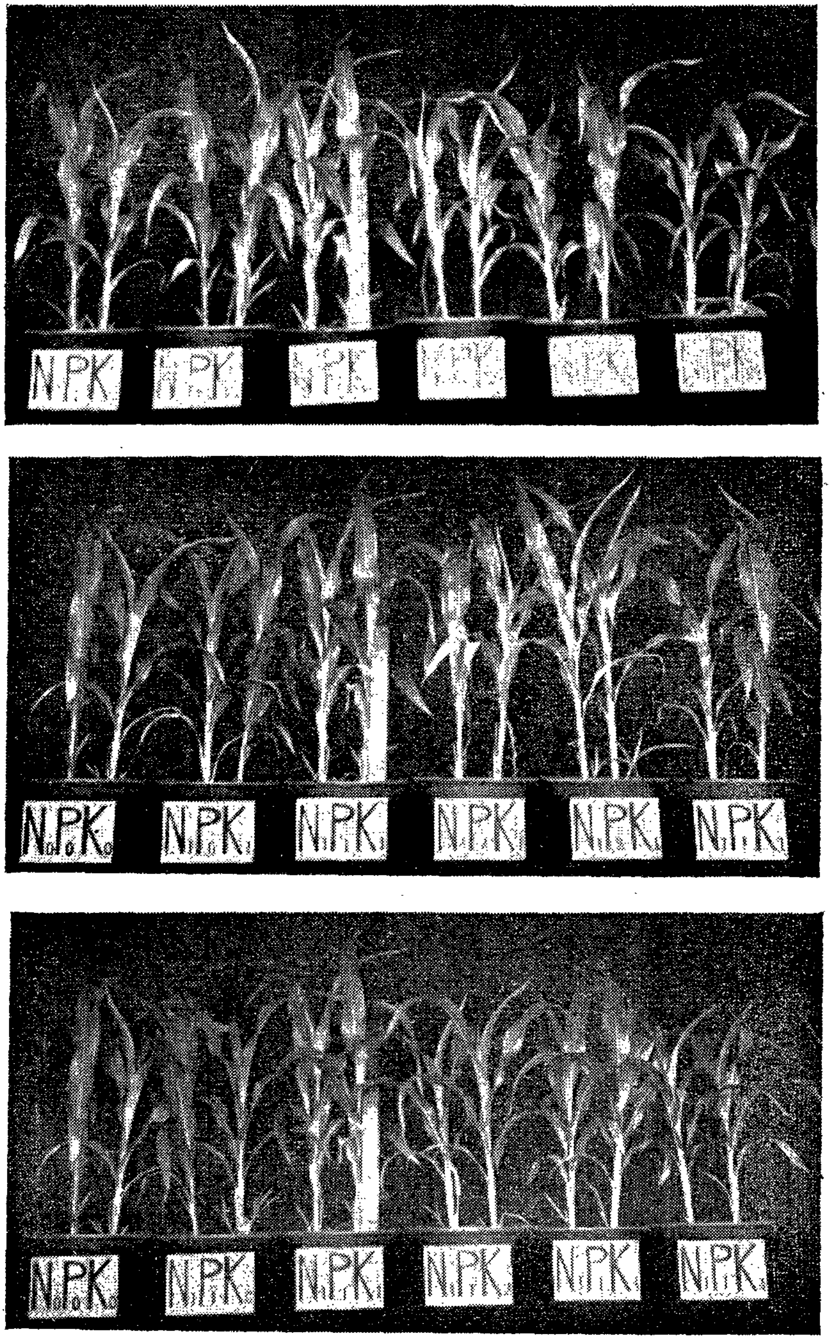

Fig. 1 A comparison of the growth of sorghum seedlings with various treatments on the composted lateritic soil (Left to right, top, $N_0P_0K_0$, $N_0P_1K_1$, $N_1P_1K_1$, $N_2P_1K_1$, $N_3P_1K_1$, and $N_4P_1K_1$; medium, $N_0P_0K_0$, $N_1P_0K_1$, $N_1P_1K_1$, $N_1P_2K_1$, $N_1P_3K_1$, and $N_1P_4K_1$; bottom, $N_0P_0K_0$, $N_1P_1K_0$, $N_1P_1K_1$, $N_1P_1K_2$, $N_1P_1K_3$ and $N_1P_1K_4$.

Table 2

Dry weight, Chemical composition and uptake of the sorghum seedlings

Treatment	Average dry weight per seedling (gm.)			Dry weight index of the shoot	Dry weight index of the roots	Chemical composition: N%*		P %		K %		Ca %		Mg %		Chemical uptake per average seedling: N mg			P mg			K mg			Ca mg			Mg mg		
	Shoot	Roots	Total			Shoot	Roots	Shoot	Roots	Shoot	Roots	Shoot	Roots	Shoot	Roots	Shoot	Roots	Total	Shoot	Roots	Total	Shoot	Roots	Total	Shoot	Roots	Total	Shoot	Roots	Total
$N_0P_0K_0$	4.01	3.85	7.86	100	100	1.23	1.10	0.212	0.163	2.89	1.28	0.508	0.594	0.198	0.374	49.3	42.4	91.7	8.5	6.3	14.8	115.9	49.3	165.2	20.4	22.9	43.3	7.9	14.4	22.3
$N_0P_1K_1$	4.54	4.63	9.17	113	120	1.22	1.25	0.212	0.155	3.08	1.22	0.476	0.911	0.198	0.317	55.4	57.9	113.3	9.6	7.2	16.8	139.8	56.5	196.3	21.6	42.2	63.8	9.0	14.7	23.7
$N_1P_0K_1$	4.77	2.01	6.78	119	52	1.53	1.23	0.212	0.175	3.40	1.75	0.522	0.528	0.215	0.223	73.0	24.7	97.7	10.1	3.5	13.6	162.2	35.2	197.4	24.9	10.6	35.5	10.3	4.5	14.8
$N_1P_1K_0$	4.93	2.14	7.07	123	56	1.88	1.30	0.237	0.201	2.96	1.41	0.582	0.639	0.215	0.223	92.7	27.8	120.5	11.7	4.3	16.0	145.9	30.2	176.1	28.7	13.7	42.4	10.6	4.8	15.4
$N_1P_1K_1$	4.50	1.80	6.30	112	47	1.22	0.92	0.269	0.245	3.00	2.18	0.493	0.378	0.210	0.307	54.9	16.6	71.5	12.1	4.4	16.5	135.0	39.2	174.2	22.2	6.8	29.0	9.5	5.5	15.0
$N_2P_1K_1$	5.10	2.25	7.35	127	59	1.13	0.90	0.237	0.237	2.99	1.51	0.468	0.364	0.182	0.287	57.6	20.3	77.9	12.1	5.3	17.4	153.5	40.0	193.5	23.9	8.2	32.1	9.3	6.5	15.8
$N_3P_1K_1$	4.40	2.30	6.70	110	60	1.62	1.18	0.261	0.209	3.37	1.57	0.611	0.500	0.198	0.307	71.3	27.1	98.4	11.5	4.8	16.3	148.3	36.1	184.4	26.9	11.5	38.4	8.7	7.1	15.8
$N_4P_1K_1$	4.27	3.42	7.69	106	89	3.24	1.52	0.261	0.176	3.64	1.11	0.743	1.058	0.312	0.277	138.4	52.0	190.4	11.2	6.0	17.2	155.4	38.0	193.4	31.7	36.2	67.9	13.3	9.5	22.8
$N_1P_2K_1$	4.85	2.67	7.52	121	70	1.07	0.96	0.228	0.255	2.85	1.88	0.476	0.411	0.151	0.297	51.8	25.6	77.4	11.1	6.8	17.9	138.2	50.2	188.4	23.1	11.0	34.1	7.3	7.9	15.2
$N_1P_3K_1$	4.61	2.73	7.34	115	71	1.02	1.10	0.277	0.173	3.32	1.92	0.514	0.755	0.159	0.174	47.0	30.0	77.0	12.8	4.7	17.5	153.1	52.4	205.5	23.7	20.6	44.3	7.3	4.8	12.1
$N_1P_4K_1$	4.23	2.92	7.15	106	76	1.17	1.04	0.228	0.189	2.96	2.87	0.497	0.486	0.182	0.248	49.5	30.4	79.9	9.6	5.5	15.1	125.2	83.8	219.0	21.0	14.2	35.2	7.7	7.2	14.9
$N_1P_1K_2$	6.05	4.75	10.80	151	124	1.29	1.28	0.189	0.228	3.31	1.36	0.483	0.847	0.138	0.298	78.1	62.4	140.5	11.4	10.8	22.2	200.3	64.6	264.9	29.2	40.2	69.4	8.4	14.2	22.6
$N_1P_1K_3$	5.45	5.02	10.47	136	130	1.43	1.20	0.189	0.209	2.89	2.23	0.528	0.745	0.143	0.210	77.9	60.2	138.1	10.3	10.5	20.8	157.5	111.6	269.1	28.8	37.4	66.2	7.8	10.5	18.3
$N_1P_1K_4$	5.15	5.35	10.50	128	139	1.51	1.35	0.189	0.155	3.07	1.84	0.558	1.133	0.154	0.182	77.8	72.2	150.0	9.7	8.3	18.0	158.1	98.4	256.5	28.7	60.6	89.3	7.9	9.7	17.6

* % of oven dry tissue.

In a previous report (1) corn seedlings grown on the lateritic soil of central Taiwan without compost treatment showed a significant response to $N_1P_1K_0$ but little response to potassium except in the treatment of $N_1P_2K_2$. As the soil was deficient in both nitrogen and phosphorus, the dry weights of corn seedlings depended upon the amounts of these two elements supplied by the fertilizers. However, sorghum plants grown on the same lateritic soil treated with compost showed a small response to $N_1P_1K_0$ treatment and maximum response to $N_1P_1K_2$ treatment in these experiments.

3. Chemical composition and uptake of the sorghum seedlings.

Table 2 shows the chemical composition and uptake of sorghum seedlings. The application of nitrogenous fertilizers increased the nitrogen content within the tissue. Nitrogen concentration in the shoots ranged from 1.02-3.24% of dry weight and the uptake from 47.0-138.4mg; in the roots from 0.90-1.52% and 24.7-72.2 mg. The application of phosphorus resulted in its concentration in the shoots from 0.189-0.269% and the average uptake per shoot from 8.5-12.8 mg; in the roots from 0.155-0.255%and 3.5-10.8 mg. The application of potassium fertilizers resulted in an accumulation of potassium within the shoot ranging from 2.85-3.64% and the amounts used from 155.9-200.3 mg; in the roots from 1.11-2.87% and 30.2-111.6 mg.

The application of elements to the soil affects (a) the content of such elements in the plant and (b) the utilization of other elements in the soil. In this experiment, an increase in nutritional elements within the plant may not be correlated with increased dry weight, for there is no intimate correlation between the accumulation of a certain element within plant tissue and the total amount of tissue produced. Comparing the chemical composition and uptake of sorghum seedlings for various treatments, the following relations may be established.

(1) Fertilization from addition of phosphorus and potassium (but without applying nitrogen) resulted in increasing greatly calcium concentration within the roots as compared with the control.

(2) The nitrogen and calcium percentages within both shoots and roots, and phosphorus and potassium in the shoots increased, but phosphorus and potassium in the roots decreased with increasing nitrogenous fertilizers in the composted lateritic soil.

(3) The potassium increased but magnesium decreased greatly in the roots with $N_1P_0K_1$ treatment as compared with the control plants.

(4) The potassium, calcium and magnesium concentrations within the roots increased with increasing phosphorus amounts in the composted lateritic soil.

(5) Comparing with the control plants, the seedlings treated with $N_1P_1K_0$ had higher nitrogen in the shoots but lower magnesium in the roots.

(6) The nitrogen and calcium within both shoots and roots, and magnesium in the shoots increased but phosphorus and magnesium in the roots decreased with increasing potassium levels in the composted lateritic soil.

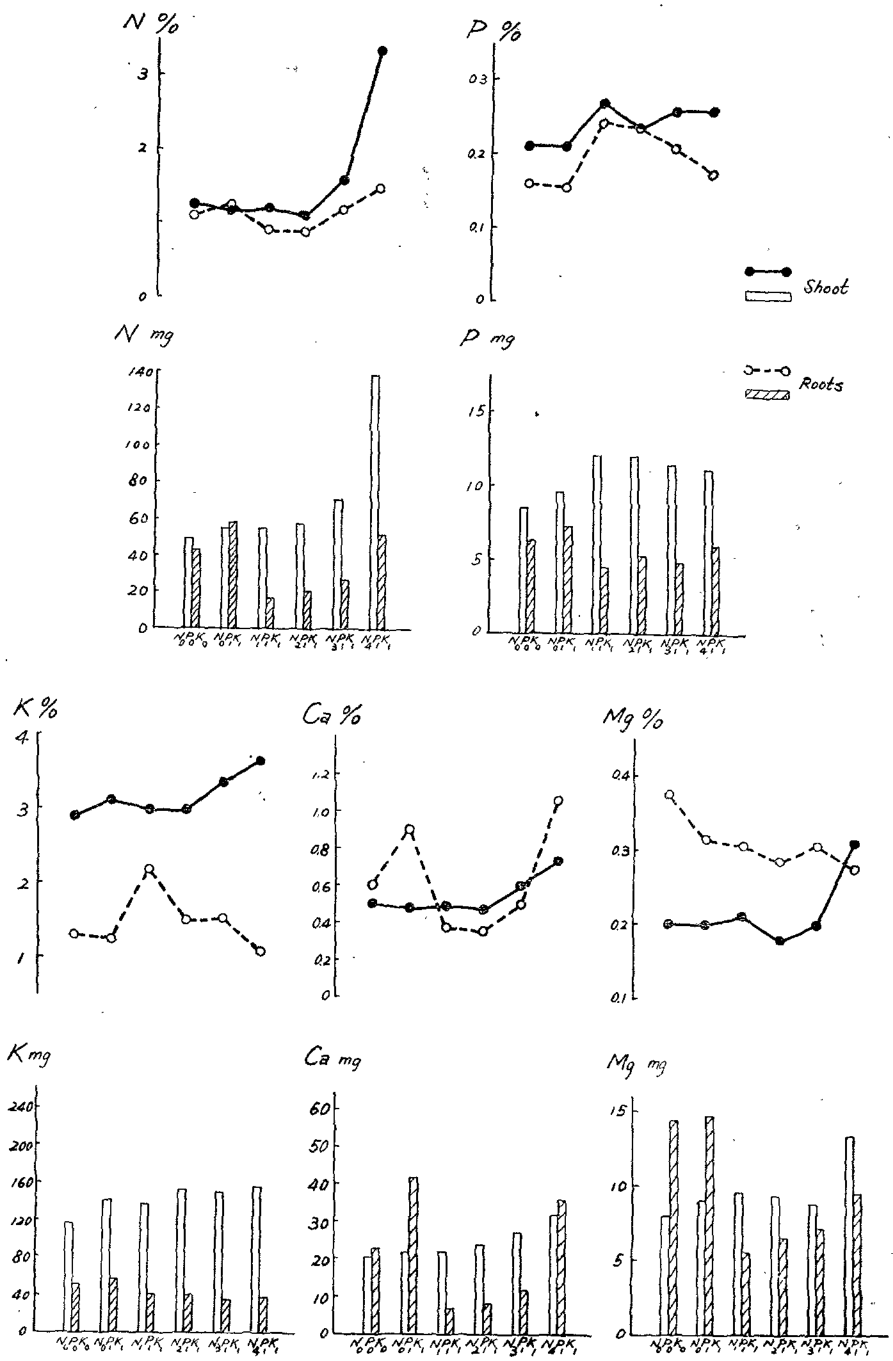

Fig. 2 A comparison of nutrient concentration and uptake of the shoots with those of the roots of the sorghum seedlings, left to right: $N_0P_0K_0$, $N_0P_1K_1$, $N_1P_1K_1$, $N_2P_1K_1$, $N_3P_1K_1$, and $N_4P_1K_1$, (% of oven dry weight and mg. per average shoot or roots).

The corn seedlings grown on the same lateritic soil without compost addition showed an increasing phosphorus content with decreasing nitrogen, potassium, and

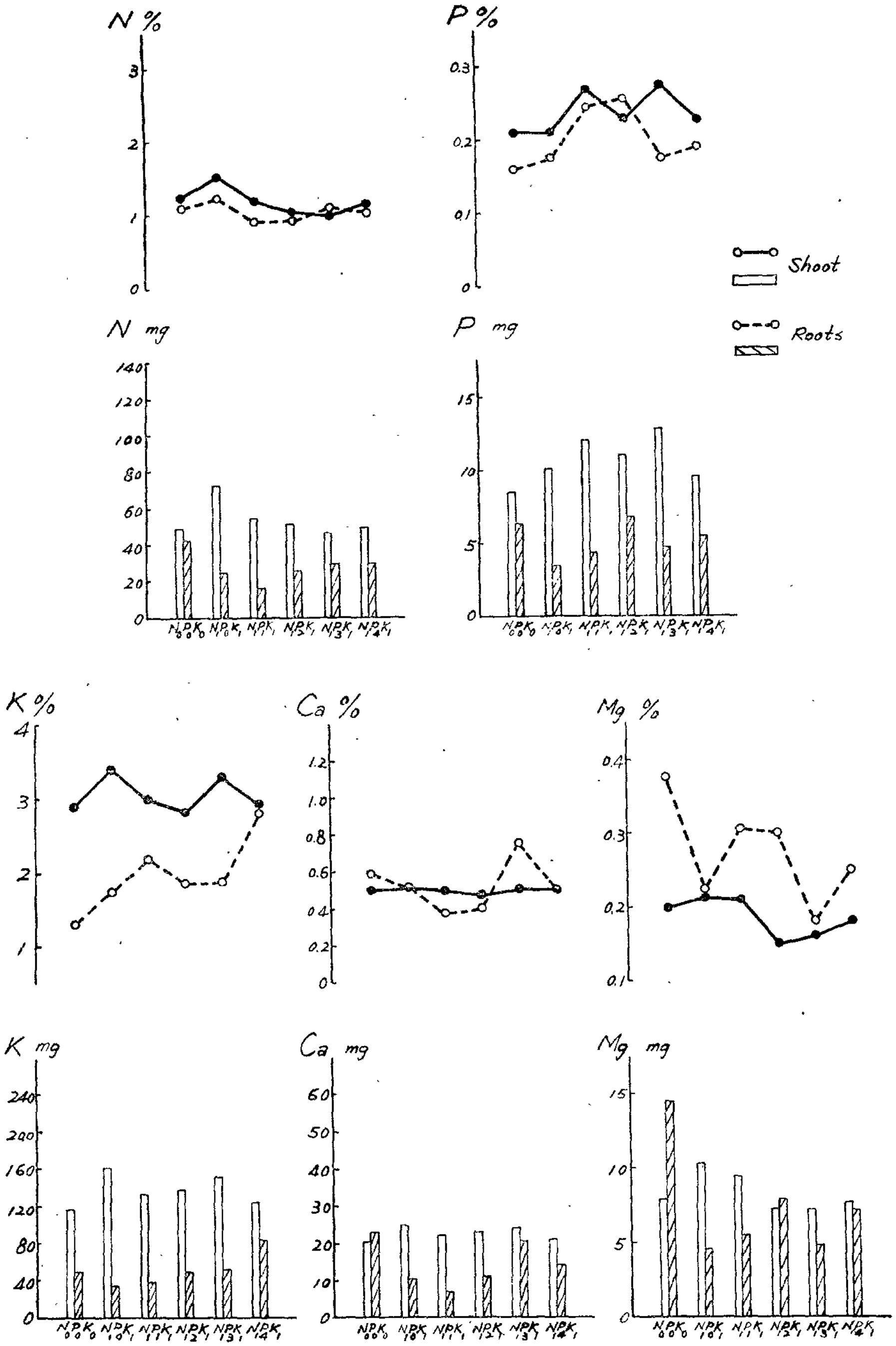

Fig. 3 A comparison of nutrient concentration and uptake of the shoots with those of the roots of the sorghum seedlings, left to right: $N_0P_0K_0$, $N_1P_0K_1$, $N_1P_1K_1$, $N_1P_2K_1$, $N_1P_3K_1$, and $N_1P_4K_1$ (% of oven dry weight and mg. per average shoots or roots).

calcium percentages within the shoots (1). The corn seedlings with $N_1P_0K_1$ treatment also had much greater nitrogen and potassium contents but lesser phosphorus percentage

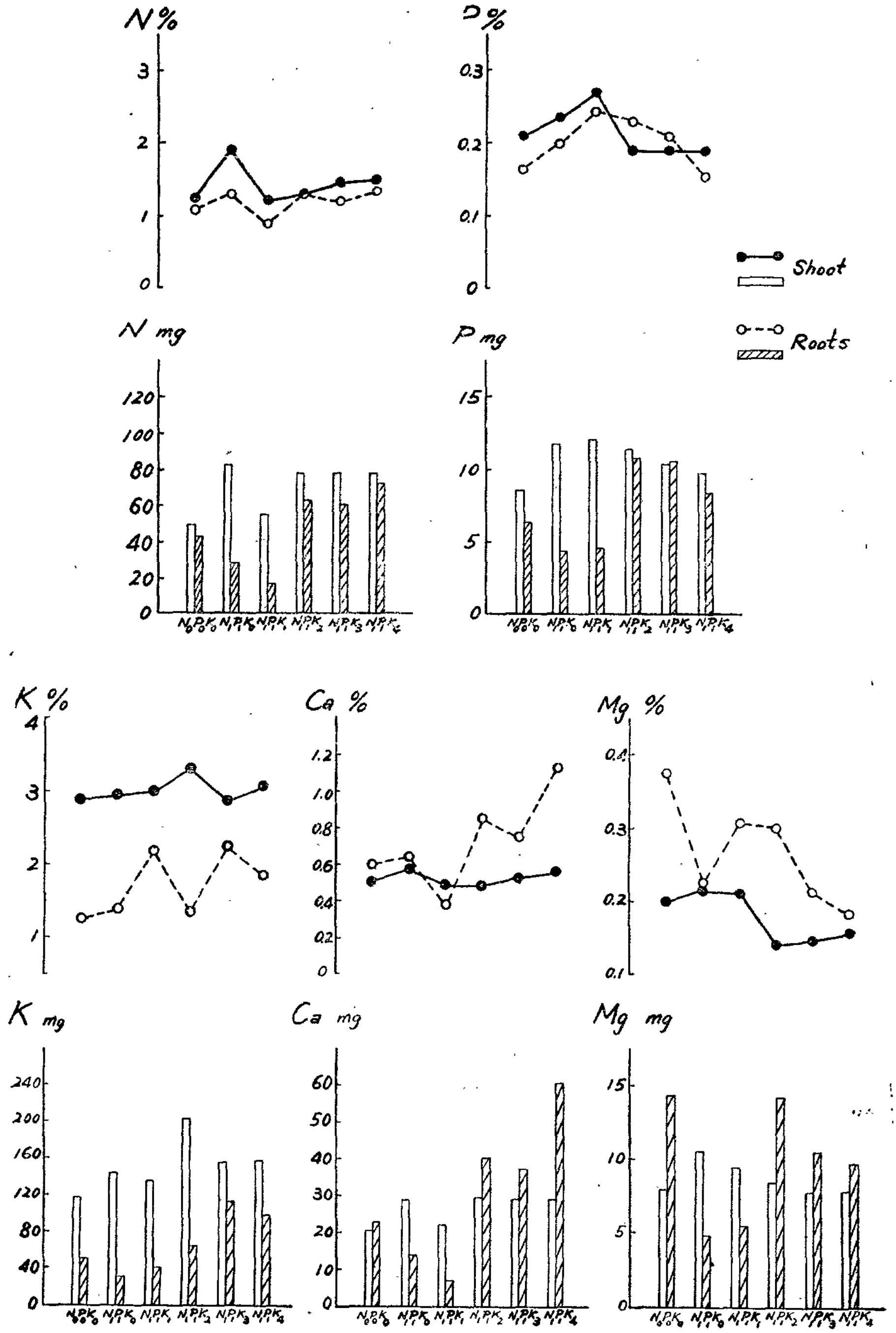

Fig. 4 A comparison of nutrient concentration and uptake of the shoots with those of the roots of the sorghum seedlings, left to right: $N_0P_0K_0$, $N_1P_1K_0$, $N_1P_1K_1$, $N_1P_1K_2$, $N_1P_1K_3$, and $N_1P_1K_4$ (% of oven dry weight and mg. per average shoots or roots).

within the shoot. Such relations, however, were not found in this study.

A comparison of nutrient concentration and uptake of the shoot with those of the roots is presented in Figures 2, 3 and 4. In general, the nitrogen, phosphorus and potassium levels were higher within the shoots than those within the roots. The magnesium percentages in the roots were greater than those in the shoots, whereas the magnesium uptake fluctuated in both shoots and roots.

SUMMARY

Sorghum seedlings were grown on composted lateritic soil with fertilization in pot cultures for observation of growth and mineral uptake. The composted lateritic soil was more productive than the same lateritic soil without compost addition.

On the basis of increased dry weight, the sorghum seedlings with $N_1P_1K_2$, $N_1P_1K_3$, and $N_1P_1K_4$ treatments developed better than those with other treatments. The control plants had more extensive root development and yielded greater dry weight than most of the fertilized plants.

The nitrogen, phosphorus and potassium levels, both percentages and milligrams, were higher within the shoot than those within the roots whereas the magnesium percentages were the reverse.

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堆肥及化學肥料與高粱幼苗生長及養分吸收量之關係

陳　賢　芳

本試驗目的，在觀察大肚山紅壤施用堆肥及化學肥料與高粱幼苗生長及養分吸收量之關係。大肚山紅壤之肥力，如全氮量及有效性磷均低，土壤反應呈强酸性。紅壤施用堆肥，提高土壤肥力甚多，如全氮量及交換性鉀素提高約五倍，交換性鈣素約廿倍，有效性磷約一百倍，增進土壤之生產力甚大。

紅壤施用堆肥，如再加施化學肥料，促進高粱幼苗之生長並不顯著。根據增加之乾重量，高粱幼苗以生長在 $N_1P_1K_2$, $N_1P_1K_3$ 及 $N_1P_1K_4$ 等三種處理所得之乾重量較大，其苗部乾重指數各爲 151,136, 及 128。

文中曾論及加施化學肥料後高粱幼苗化學成分之相互關係，並比較各種處理之幼苗苗根兩部分之養分濃度及含量。一般而言，幼苗苗部之氮，磷及鉀素之濃度及含量均較根部者爲高，鎂素之濃度以根部者較高，至於苗根兩部之鎂素含量與鈣素濃度及含量則均變動不定。