Nutrient Uptake and Dry Matter Accumulation by Intensively Managed Pigeon Peas Grown on a Corozal Clay, An Ultisol[1,2]

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ABSTRACT

Pigeon peas grown on a typical Ultisol of the humid mountain region of Puerto Rico and fertilized with 450 kg/ha of 10-10-10 took up an average of 216, 12, 168, 54 and 19 kg/ha of N, P, K, Ca and Mg, respectively, over a planting-to-harvest season of 147 days. Total dry matter production and yield of mature-green pods were 12,340 and 8,104 kg/ha, respectively. Computations based on nutrient uptake, available nutrients in the soil, capacity of pigeon peas to fix atmospheric N, and losses of fertilizer nutrients showed that to support near optimum yields of pigeon peas, applications of 296, 32, 211, and 30 kg/ha of N, P_2O_5, K_2O and MgO, respectively, are required. These amounts are roughly equivalent to those of the nutrients in 2,000 kg/ha of 15-2-10-2 commercial fertilizer. The fertilizer should be applied in two equal portions 3 and 10 weeks after planting.

INTRODUCTION

Pigeon peas (*Cajanus cajan* (L.) Millsp.) are a leguminous shrub widely used for human food throughout the tropics. They flower during short days and can produce beans containing 20–22% protein from November to April.

This plant is generally considered to grow well and to produce acceptable yields even on soils of low fertility with fairly low rainfall. Fertilizer experiments conducted by Landrau and Samuels (5) and Pietri et al. (9) with pigeon peas growing on a Coto clay (Tropeptic Haplorthox) and a Yauco clay (Typic Calciustolls) showed no yield response to changes in the levels of N, P, K, Ca and Mg. Badillo-Feliciano et al. (2) found no response in yield to foliar applications of N, P and micronutrients to pigeon peas growing on a Coto clay.

Lugo-López and Abrams (6) explained the high yield of pigeon peas (7,800 kg/ha of green pods and seed) grown on a poor, unfertilized soil in Puerto Rico by calculating that the crop was capable of removing from the soil only 60, 15, 20, 20 and 10 kg/ha of N, P, K, Ca and Mg, respectively, during a growing season. Dalab (3) in Trinidad, reported that total N, P, K, Ca and Mg contained in pigeon peas yielding 5, 280

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[2] This paper covers work carried out cooperatively between the Agricultural Research Service, USDA, and the Agricultural Experiment Station, University of Puerto Rico, Río Piedras, P.R.

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kg/ha of green pods and peas were 198, 17, 53, 43 and 31 kg/ha, respectively.

The present study determined at 2-week intervals the nutrient content and dry matter production of pigeon peas grown at three fertilizer levels over a 5-month period on a typical Ultisol in the humid mountain region of Puerto Rico.

MATERIALS AND METHODS

The experiment was carried out from July 10 to December 4, 1980, at the Corozal Substation located in the north central part of the island, about 200 m above sea level. Total rainfall was 875 mm, and the average minimum and maximum temperature were 20.9° C and 31.0° C.

The soil is a Corozal clay (Aquic Tropudults) with a pH of 5.3. The soil contained 9 p/m of "available" P (Bray method) and 0.7, 8.3 and 1.6 meq of exchangeable K, Ca and Mg, respectively, per 100 g of soil.

The soil was plowed and harrowed twice and divided into 2.7 × 7.3 m plots surrounded by border rows and ditches. Seed of pigeon pea line 147, a determinate type developed by the University of Puerto Rico Agricultural Experiment Station, were sown every 30 cm in rows 90 cm apart.

Three fertilizer rates 0,450 and 900 kg/ha of 10-10-10 were tested in a randomized block experiment with 6 replications. The fertilizer was applied 2 weeks after the seed germinated. Soil, foliage and pod insects were controlled according to the recommendations of the Agricultural Experiment Station (4).

Seven weeks after planting, and every 2 weeks thereafter until 147 days after planting, two plants randomly chosen from each treatment and replication were uprooted, washed and divided into leaf blade and petioles, stems, and roots (only about 30% of which were recovered). The blossoms, immature pods and mature-green pods were also harvested.

Fresh and oven-dry weights of all plant parts were obtained. Dry samples of each part were chopped and ground, passed through a 20-mesh screen and analyzed for N, P, K, Ca, and Mg. Nitrogen was determined by the Kjeldahl macromethod, P colorimetrically, and K by flame photometry; and Ca and Mg by the Versenate method after digestion in nitric-perchloric acid.

RESULTS AND DISCUSSION

The yields of mature-green pods and peas produced during the 147-day growing period for plots receiving 0, 450, and 900 kg of fertilizer were 6,931, 8,103 and 8,040 kg/ha, respectively. The two highest yields were not significantly different, but they were higher (5% probability level, Duncan's multiple range test) than the yield for the unfertilized plots.

Since the medium fertilizer rate appears to have been near optimum for pigeon peas under the conditions of this experiment, the discussions that follow is based on that rate only.

Total dry matter production increased with age, reaching 12,340 kg/ha (table 1 and figure 1). Dry matter of the stems and roots also increased steadily with age, whereas that of the leaves increased with age until about 105 days after planting, and declined steadily thereafter. The loss of leaves is attributed to age and damage by the rust *Uromyces dolicholi* Arth., which attacked the plants about 15 days before flowering. The plants started flowering about 100 days after planting, and dry matter of the blossoms—and later of the green pods and peas—increased thereafter with age of the plants.

Uptakes of N, K and Ca by the pigeon peas increased throughout the crop season, although very slowly for Ca (table 2, figure 2). Phosphorus

TABLE 1.—*Actual dry matter production (kg/ha) in the various parts of the pigeon pea plant at different ages*

Days after planting	Leaves	Stems	Roots	Blossoms	Hulls	Peas	Total
49	363	267	81	—	—	—	711
63	961	873	373	—	—	—	2,207
77	2,193	1,646	737	—	—	—	4,576
91	2,708	4,639	1,099	—	—	—	8,446
105	2,315	6,461	1,470	38	—	—	10,284
119	1,960	7,232	1,695	500	—	—	11,387
133	1,474	7,012	1,772	—	1,146	936	12,340
147	1,225	6,226	1,420	—	1,286	1,928	12,085

and Mg uptakes were very low and did not increase beyond about 105 days after planting.

By the end of 147 days, total N, P, K, Ca and Mg uptakes for near optimum pigeon pea yields were 216, 12, 168, 54, and 19 kg/ha, respectively (table 2). Except for P, these nutrient contents were two to eight times the quantities estimated by Lugo-López and Abrams (6) for high yielding pigeon peas grown on soils of low fertility with reduced rainfall. Except for K, which was much higher in this experiment, the nutrient contents are in close agreement with those found by Dalab (3) for pigeon peas grown on a Fluventic Eutropepts with supplementary irrigation.

Total uptake of nutrients expressed in terms of their forms in commercial fertilizer was 216, 27, 202, and 32 kg/ha of N, P_2O_5, K_2O and MgO, respectively (table 3).

From these data and the considerations discussed below, we estimated

the fertilizer requirements of pigeon peas grown on Ultisols in Puerto Rico. Long term experiments conducted by Abruña et al. (1) and Vicente-Chandler et al. (11) with tropical grasses growing on Ultisols and Oxisols showed that these soils can supply about 0.22 kg/ha of both N and K_2O, and 0.05 kg/ha of MgO daily, or a total of 33 kg/ha of N and K_2O, and 8 kg/ha of MgO over a 147-day growing period for pigeon peas. Recent

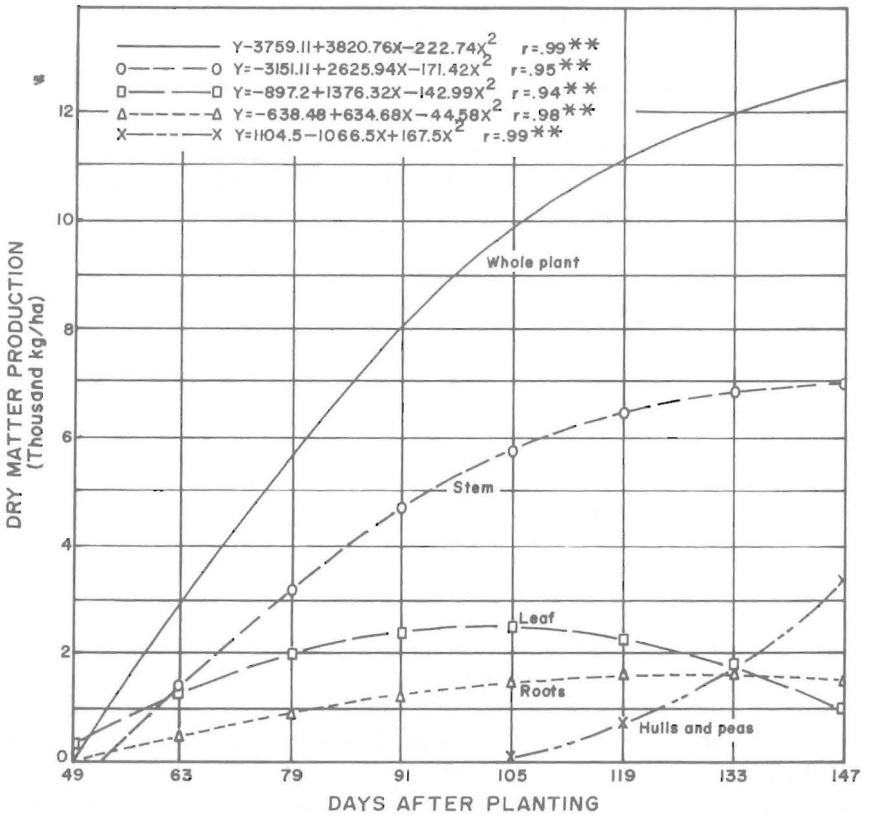

FIG. 1.—Rates of growth by intensively managed pigeon peas grown on a Corozal clay, an Ultisol.

studies with pigeon peas and tropical grasses have shown that these crops have similar rooting depths.[4] Another source of N is atmospheric N, which bacteria in symbiosis with pigeon pea plants can fix. Oke (7) estimated that 14.5 mg of N is fixed daily by each plant. A field with 16,277 pigeon pea plants/ha can therefore fix 35 kg/ha of N over a period

[4] Unpublished data obtained by the authors.

of 147 days. For our estimate, we assumed that no P is provided by the soil.

On the basis of these considerations, optimum yields of pigeon peas should be obtained by applying 148, 27, 169 and 24 kg/ha of N, P_2O_5, K_2O and MgO, respectively (table 4). However, Vicente-Chandler et al. (11) reported that about 50% of N, 20% of P_2O_5 and 25% of K_2O and of MgO applied as fertilizer are lost. Our final estimate, therefore, is that pigeon peas planted in Ultisols should be fertilized with 296, 32, 211 and 30 kg/ha of N, P_2O_5, K_2O and MgO, respectively, if they are to produce near optimum yields. These amounts are roughly the amounts present in 2,000 kg/ha of a 15-2-10-2 commercial fertilizer. The fertilizer may be applied in two equal portions 3 and 10 weeks after planting.

Ultisols have sufficient Ca to provide for the needs of pigeon peas. Liming, however, is required to prevent exchangeable Al and Mn from

TABLE 2.—*Actual uptake of nutrients (kg/ha) by pigeon peas at different ages*

Days after planting	N	P	K	Ca	Mg
49	25.0	1.4	15.4	6.2	2.1
63	52.2	2.9	44.1	21.2	2.9
77	134.5	6.1	89.0	33.2	15.4
91	179.0	7.7	137.0	36.6	23.7
105	197.7	10.6	145.7	37.9	22.7
119	199.4	10.4	137.5	45.6	18.2
133	193.9	8.4	165.9	41.8	14.9
147	215.6	12.0	168.2	53.8	19.0

reaching toxic levels. Pigeon pea yields were severely reduced in a Corozal clay when Al saturation exceeded 35%.[5]

Large quantities of nutrients are removed from the field via the harvested mature-green pods and peas. Table 4 shows that 101, 3, 54, 6 and 3 kg/ha of N, P, K, Ca and Mg, respectively, were removed in the pods and peas in one harvest. Under proper management a second crop of pigeon peas with a similar yield can be grown consecutively, from December to April; hence, the amount of nutrients removed via the peas and pods could be doubled. After fertilization with another 450 kg/ha of 10-10-10 on December 29, 1980, the plots in this experiment produced another crop yielding 8,000 kg/ha of pods. Thus, a total of about 16,000 kg/ha of mature-green pods was produced over a planting-to-harvest period of 251 days (July 10, 1980, to March 18, 1981).

The large amount of nutrients that can be removed from the field in

[5] Unpublished data obtained by Abruña-Rodríguez et al.

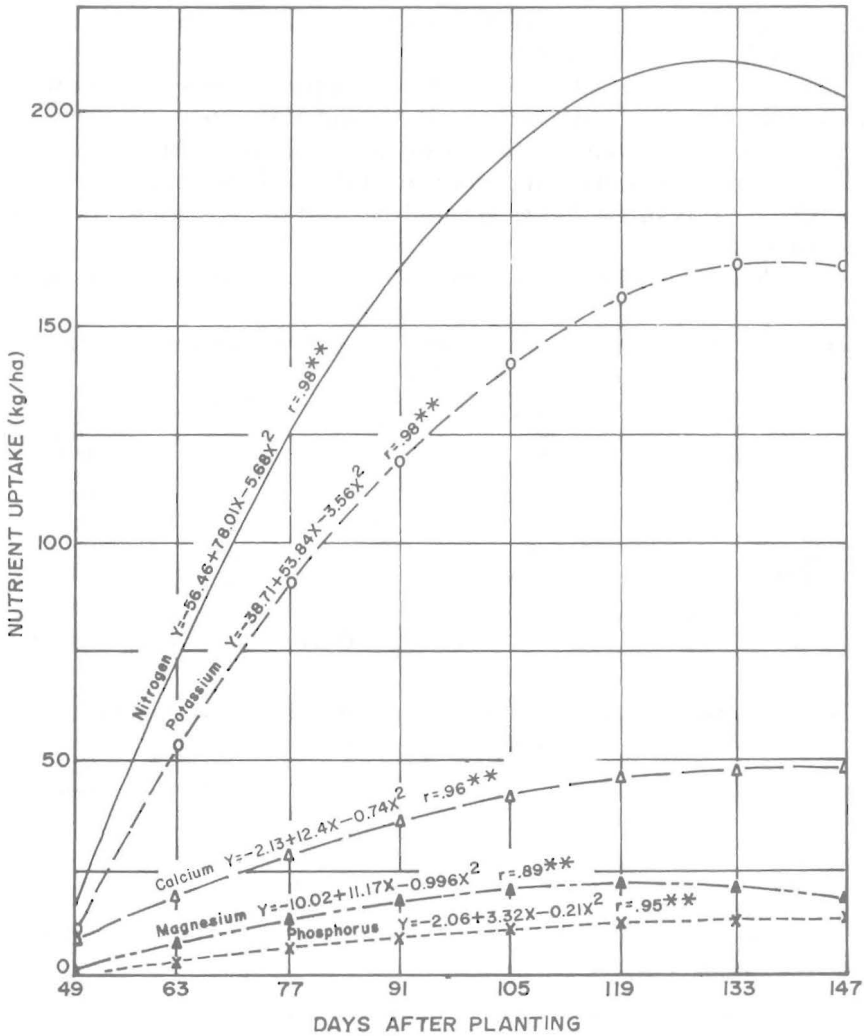

FIG. 2.—Rates of nutrient uptake by intensively managed pigeon peas grown on a Corozal clay, an Ultisol.

two heavy harvests may explain the drop in yield reported by farmers planting two successive crops of pigeon peas in the same field, especially one that, according to common practice, is not fertilized.

A total of 155, 9, 114 and 16 kg/ha of N, P, K, and Mg, respectively, were left in the field in 8,871 kg/ha of dry plant residues (table 4). Pérez-Escolar et al. (8) and Talleyrand et al. (10) reported no immediate effect

of N from various legume and corn residues on subsequent yield of corn grown on Ultisols and Oxisols.

The nutrient composition of the leaves of pigeon peas changed with age of the plant (table 5). Nitrogen, P, Ca and Mg contents were always higher in the leaf than in other plant parts. However, at harvest the mature-green pods and grain contained 3.67% of N. Nitrogen, P, K, Mg and Ca contents of the leaves generally tended to decrease with age of the plant.

Considering the high yields obtained, the lack of response to heavier

TABLE 3.—*Computation of the fertilizer required to support near optimum yields of pigeon peas (kg/ha)*

Nutrient	Total uptake by pigeon peas	Released by the soil[1]	Fixed by nodulation[2]	To be supplied from fertilizer	Fertilizer application required[3]
N	216	33	35	148	296
P_2O_5	27	0	0	27	32
K_2O	202	33	0	169	211
MgO	32	8	0	24	30

[1,2] See text for details.

[3] Assuming losses of 50% N, 20% P_2O_5 and 25% K_2O and MgO from fertilizer applied.

TABLE 4.—*Yields (kg/ha) of dry matter and nutrients in different parts of pigeon pea plants at harvest time*

Plant part	N	P	K	Ca	Mg	Dry matter
Roots	12	2	22	6	2	1,420
Leaves	48	2	19	12	4	1,225
Stems	55	5	73	30	10	6,226
Total plant residue	155	9	114	48	16	8,871
Mature-green pods	101	3	54	6	3	3,214
Total plant	216	12	168	54	19	12,085

fertilization, and the nutrient levels shown in table 5, the rate of fertilization would seem to have been close to optimum.

RESUMEN

Un experimento se llevó a cabo en un suelo Corozal arcilloso (Ultisol) para determinar el contenido de varios nutrimentos en la planta de gandul a intervalo de dos semanas, empezando 7 semanas después de la siembra y terminando con la cosecha 147 días más tarde.

A las plantas se les aplicó un fertilizante 10-10-10 a razón de 0, 450 y

900 kg/ha. El nivel medio de fertilización (450 kg/ha) resultó en rendimientos óptimos.

La extracción total de nitrógeno, potasio y calcio aumentó según las plantas se desarrollaban. El de fósforo y magnesio fue bajo todo el tiempo. Con raras excepciones el contenido de nutrimentos fue mayor en las hojas que en las otras partes de la planta.

La producción total de materia seca aumentó según las plantas desarrollaban. La de tallos y raíces, y después de la floración, la de las vainas aumentó con la madurez de la planta. La de las hojas disminuyó después de los 105 dias debido a senescencia y a los ataques de un hongo.

Las plantas llegaron en total a un máximo de 216, 12, 168, 54 y 19 kg/ha of N, P, K, Ca y Mg, respectivamente. La producción total de materia seca fue de 12,340 kg/ha y el rendimiento de gandul en vaina fue de 8,104 kg/ha.

TABLE 5.—*Content (%) of various nutrients in the leaves of pigeon pea at different ages*

Days after planting	N	P	K	Ca	Mg
49	5.41	.27	2.60	1.12	.40
63	4.14	.21	2.25	1.41	.16
77	4.70	.18	2.04	.92	.39
91	4.58	.18	1.94	.67	.33
105	4.65	.20	1.71	.55	.27
119	4.34	.12	1.59	.60	.16
133	3.86	.09	1.53	.70	.18
147	3.95	.15	1.57	.93	.28

Cálculos basados en el contenido de nutrimentos del gandul, la disponibilidad de nutrimentos en los suelos Ultisols, la capacidad biológica del gandul en simbiosis con bacterias fijadoras del intrógeno atmosférico y las pérdidas de nutrimentos aplicados como abono, demuestran que para obtener rendimientos óptimos de gandul en estos suelos es recomendable aplicar 296, 32, 211 y 30 kg/ha de N, P_2O_5, K_2O y MgO, respectivamente, equivalentes a alrededor de 2,000 kg/ha de un fertilizante 15-2-10-2. Este abono debe aplicarse en dos partes iguales 3 y 10 semanas después de la siembra.

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