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IRRIGATION-FERTILITY STUDIES WITH CARAOTA

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INTRODUCTION

Caratoa, or black bean as it is called elsewhere, is a basic food in the diet of the Venezuelan people. It is preferred over other bean types. It is so dominant that other beans are given such names as caraota blanco (white bean) and caratoa rosado (pink bean). In most other Spanish speaking countries, the general word used for "bean" is "frijole", not caraota.

Traditionally, caraota has been planted at the end of the rainy season (October up to January depending on location). Frequently, however, heavy rains occur at least once or twice in this period and often cause severe damage to the crop. Caraota is susceptible to several fungus diseases. Wet surface soil and high humidity with the warm climate of Los Llanos is a perfect environment for serious damage from fungal attacks. Later planting in the dry season to avoid these unpredictable storms and high humidity requires irrigation to supply adequate water. Recent development of large irrigation districts makes possible caraota growth completely within the mostly non-rainy period, which is 90 to 120 days long.

LITERATURE REVIEW

Until the past few years few fertility or irrigation studies have been done with caraota in Venezuela (Barrios, et al. 1970). Average yields in Venezuela have been between 400 and 600 Kg/ha in recent years (Barrios, 1966, and Pérez, 1969b). Reasons for such low yields include (1) the severe problem of fungal diseases, (2) irregularity of rainfall, (3) non-use of fertilizers, (4) low plant densities, (5) low quality seed used, (6) planting on poorly adapted soils, and (7) generally poor management such as inadequate spraying for weed and insect control.

Disease and Insect Problems

The region of this study is Los Llanos, The Plains, of central Venezuela. The area exists at an elevation of about 150 meters and a latitude of 9° to 10° north. The area is tropical with high humidity (seldom is the daily humidity below 50%; usually over 75%) and slight daily temperature variation (25-34°C; usually 27-30°C). Such conditions are excellent for growth of fungus. Attempts to grow caraota in the rainy season (May through August) have been complete failures. Attempts to use the drier end of the rainy season (October through December) have resulted in erratic results. Drier years often had good yields. A year with a wet November, as example, was a failure. Generally only plantings in November or later have been satisfactory.

Other problems of disease or insect nature are controlled by recommended spraying and variety selection. A list of diseases and their season of incidence is given by Barrios (1966).

Fertility Needs

Caraota is a legume but still responds to added fertilizer, particulary nitrogen. There are many areas where studies done do not show response to

added nitrogen (Tapia, 1965; Miyasaka et al., 1964, 1965 after Barrios, 1970; Vieira et al., 1966). The reasons for these conditions are often not given in the reports. However, it is easy to suggest conditions under which response would not be evident: (1) using a fertile soil previously well fertilized for other crops such as corn, (2) growing a crop without adequate water, either low rainfall or inadequate irrigation, (3) irregular densities and growth producing inconsistent yields and (4) using new land recently out of brush or forest. Therefore, the relative response expected of caratoa to fertilizer must depend on many conditions in addition to the levels of fertilizer added.

Nitrogen. Examples of responses of caraota to fertilizer nitrogen are as variable as the studies with no response. Yglesias (1962) got noticeable yield responses in Costa Rica to levels of 50 and 100Kg/ha of nitrogen. Craspén Medina (1963) obtained increases from a low level of 20Kg/ha of nitrogen with added phosphorus also. Miyasaka et al. (after Barrios, 1970) presented a number of papers in which response to levels up to 60Kg/ha of N was reported for some studies. Other studies had no response. In Nicaragua and three other countries of Central America, Lizarraga (1966) recommended the general use of 45Kg N/ha. In most of these reports, little detail of the soil use or previous history was given.

In some instances, response to nitrogen occurred at some levels but not much at higher levels. Pessoa and Herandnez (1968) claimed 75% yield increases with 50 to 70Kg N/ha but only 7% increase with 100 Kg N/ha. Barrios (1970) in studies with 7 soil sites and 10 experiments in Venezuela had many treatments with added N respond well; others had no response or were less than the check. Many treatment yield inconsistencies are reported such as the one for Campo Experimental C.I.A. (Barrios et al., 1970) as follows:

N	P_2O_5	K_2O	Kg/ha yield	% of Control Plot
60	100	0	948	84
60	100	70	1505	134
60	200	0	1048	93
40	100	70	1177	105
80	100	70	1175	105

The 60-100-70 treatment was much greater than the same one with either more or less nitrogen added. Although tendencies exist to suggest a response to nitrogen, there are numerous inconsistencies in the individual data.

Phosphorus. Response of caraota to phosphorus depends on soil reserves of phosphorus, previous fertilizing history and to growth conditions of the crop. Numerous studies in various countries have illustrated growth responses. Yglesias (1962) claimed the largest yield increases and enlarged seed and better plant vigor from phosphorus additions. Miyasaka et al. (1966a - 1966f after Barrios et al. 1970) claimed more general increases in yields from phosphorus additions than from nitrogen additions. The effects were more marked in soils previously unfertilized. Vieira et al. (1966) also observed more response to additions of phosphorus than to additions of nitrogen. Lizarraga (1966) recommended phosphorus doses of 39Kg P/ha for caraota in four Central American countries.

Data of Barrios (1970) in 7 Venezuelan soils and 10 experiments illustrate sites that respond and sites that don't. Unfortunately, the response is not closely related to the phosphorus test values given for these soils. The data have enough inconsistent values to make general conclusions of response to phosphorus uncertain. Barrios also claimed reduced yields in some experiments as a result of added phosphorus. No reasons were suggested. The data do not clearly illustrate that such reductions do in fact occur and such an effect would be difficult to understand.

Other elements. The need by caraota for other nutrient elements has not been investigated much in tropical America. Potassium has been used by many investigators who have included it in combinations with nitrogen and phosphorus trials Nearly all studies have resulted in "no effect" or slight effect as a result of added potassium. It is certainly probable that some soils low in exchangeable potassium could produce appreciable yield increases as a result of added potassium.

No literature on needs of other elements was available. Various studies in other climates on different kinds of beans have proven the existence of areas deficient in sulfur, in iron and in zinc. Other deficiences are less often reported.

Density of Planting

The Consejo de Bienstar Rural (CBR) of Venezuela (Anonymous, 1967) listed planting density as one reason for low average caraota yields. It did not specify whether these low yields resulted from densities too large or too small. Pérez Pérez (1969a) studied densities as affected by inter-row spacing and different row widths. Irrigation was by sprinkler. He concluded that row spacings of 30cm, 40cm, and 50cm resulted in higher yields than wider spacings. This is logical because ground canopy cover by the beans can cover the land surface with row widths of about 40cm. Increasingly wider spacings do not effectively use the land areas and such wide spacing leaves increasingly more land without plant cover. Spacings within rows were from 5cm to 20cm between plants. Generally 5cm and 10cm distances resulted in better yields than wider distances. However, clearcut conclusions are difficult to make on the data of Pérez Pérez because of experimental variation. For example:

Distance x Density	Population/ha	Yield, Kg/ha
Four highest yielding treatments		
50cm x 5cm	400,000	3,185
30cm x 5cm	666,700	3,000
30cm x 20cm	166,500	2,807
60cm x 5cm	334,000	2,367
Four lowest yielding treatments		
80cm x 15cm	182,500	1,235
70cm x 15cm	94,500	1,087
60cm x 15cm	110,000	900
60cm x 20cm	83,500	809

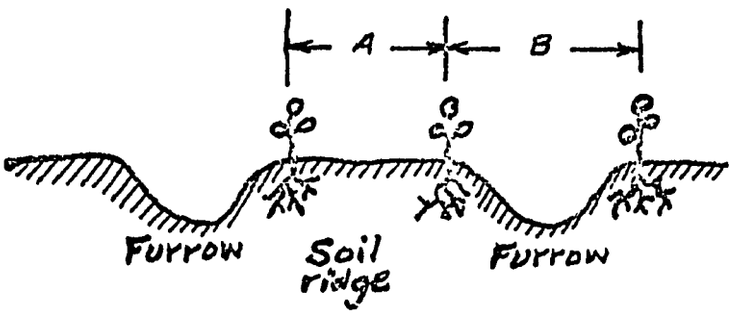
The 4 highest yielding varieties had row widths of 30, 30, 50 and 60cm, and one within-row spacing of 20cm between plants.

The caraota will develop a larger bush when less competition exists. Therefore, within some limits the plant will compensate for thinner stands. On this basis, distance between rows (the further distance between plants) should influence yield more than distance between plants within the row. The between-row distance was varied from 30cm to 80cm; the within-row distance varied from 5cm to 20cm.

Other investigators have suggested various densities. Montalvo (1961) in Peru said yields increased with density increases up to a population of 300,000 plants per hectarea. Camacho et al. (1968) in Columbia claimed

220,000 plants per hectarea were best for his area of study. In Mexico Cárdenas (1961) got maximum yields on fertilized land with a density of 332,000 plants per hectarea.

One major problem in the use of narrow rows (such as 30 or 40cm between rows) is the shallow furrow and narrow, peaked ridge that results. Seeding is difficult because the machine must trail perfectly. Also the irrigation water often will break over the small ridges. More practical furrows need to be 60 cm or more apart. To meet this limitation, the idea of planting double rows on one ridge top was tried. One study by Ortega and Barrios (1968) compared distances of 50cm and 60cm for "B" in the diagram and



20, 25, and 30cm values for "A". Yields reported were low (946 to 800 Kg/ha) and without clearcut indications of which spacings are best. Because of the distances convenient to wheel spacings on most tractors, these investigators recommended the use of spacings A = 30cm and B = 60cm. Yields were 18% greater than with the use of simple 1 row furrows with 60cm spacing between furrow centers (= A plus B distances with one row of plants). Within rows they used 10cm between plants. Their recommendations result in a density of about 220,000 plants per hectarea.

Pérez Pérez (1969b) also studied mechanized planting of caraota in double row systems. His test results illustrated more mechanical problems than it did test results of yields. Attempts to leave wide spacings between the paired rows of plants caused seed to be poorly planted because of

wandering of the seeder into the ridge slope or the furrow. They recommended distance "A" be 40cm and distance "B" be 60cm. He suggested populations of 400,000 plants per hectarea, a high figure. In the report, no yield figures or data were available to be studied.

Irrigation

Caraota are heavily attacked by root diseases and pathogenic organisms in wet fields. Therefore, caraota growth during the dry season will need controlled irrigation. An excellent general review of irrigation of beans is the article by Robins et al. (1967). According to these writers, "Field beans [in the United States] have been studied extensively and, in the absence of diseases, clearcut recommendations are possible for this crop."

Beans have a central taproot system with branching secondary roots. The root system is moderately shallow and not very proliferous (seldom penetrating more than about 1.6-1.8m even in excellent soils; more often penetration is within 60cm (2 feet).

Beans are sensitive (show symptoms) to depletion of high amounts of the available water. Yet, they are able to withstand considerable moisture stress without yield reductions of seed (Howe and Rhoades, 1961; Robins and Domingo, 1956). The statement by Robins et al. (1967) is, "Visible stress symptoms evidenced by foliar color change and wilting for periods up to 5 days or more reduce vegetative growth but do not significantly reduce seed yield." However, they caution that the shallow, sparse root system may still require frequent irrigations. They recommend water furrow depths be kept less than 3 inches deep to reduce surface soil wetting which is a good condition to increase pathogenic diseases.

The recommendation by Robins et al. (1967) for irrigation of beans is, "Irrigation scheduling for field beans can best be based on visual stress symptoms... It is recommended that irrigation water by applied within 3 to 5 days following this color change [from light to dark green] on coarse-textured or shallow (<60cm or 2 ft.) soils and within 5 to 8 days following the color change on deeper, medium-or fine-textured soils." After vegetative growth has developed, irrigation intervals suggested are 5-7 days for coarse-textured soils and 15-25 days for deeper, fine textured soils.

A study by Barrios (1966) in Venezuela included weekly irrigations for 10 weeks plus a preplant wetting. His average yield was a high 1,981 Kg/ha compared to 1,067 for growth only with rainfall (planted in August, or September, Maracay). His conclusions for growth under irrigation were: (1) the growth cycle was prolonged 10 days; (2) yields were increased 85%; and (3) plant populations were kept 32 to 45% higher (less disease).

Varieties and Their Characteristics

Considerable testing of varieties of caraota has been done in Venezuela. Fortunately, the commercial varieties recommended still test quite high when compared with other newly tested varieties. The two most used are Cubagua and Coche. Some general caraota characteristics are given by Barrios (1969) and Ortega (1969). A typical description of commercial caraota in Venezuela is given by Barrios and Ortega (1968) in their description of the variety "Coche". The plant is erect with most pods along the principal stem. Its cycle from germination to harvest is 75 days. It defoliates completely by harvest time. Average seed size is small (20 grams per 100 seeds).

Yield data are variable, depending on soil characteristics, the fertilizer used and whether rain or irrigation is employed. Barrios and Ortega (1968) had yields on 4 sites and during 4 years as follows:

	Nonirrigated	Irrigated
Coche	700-2073Kg/ha	1942-2305Kg/ha
Cubagua	578-1809Kg/ha	1691-2136Kg/ha

Ortega (1969) had slightly different results:

	Nonirrigated (Kg/ha)	Irrigated (Kg/ha)
Cubagua	1,740	2,441
Coche	1,651	2,259
Ven. 44-1	1,880	2,597

A third variety, Ven 4401, is included in the table above because it was used in an early pilot study and will be mentioned in the "results" section.

Production Costs

The costs of producing caraota are estimated in various publications in Venezuela. The Ministry of Agriculture and Livestock (M.A.C.) has published a guide for costs for the area of this study (Anonymous, 1967). They gave average yields for 1961 to 1966 as follows:

Barinas	472 to 630Kg/ha	
Portuguesa	329 to 433Kg/ha	(one was 607)
Cojedes (near Acarigua)	342 to 464Kg/ha	

Estimates of MAC were:

	Bolívars	U.S. Dollars
Production of 1 hectarea of seed, with irrigation	730	162
Cost for seed, fertilizer, planting	200	45
Land preparation	120	27
Chemicals (herbicides, insecticides, etc)	140	31

Water for irrigation	100	22
Water distribution	50	11
Harvest costs	120	27

Production costs are reduced whenever any of these costs are reduced. Costs without fertilizer were in many cases Bs550 ($120) and in Portuguesa State were listed at a low Bs325-390 ($72-87).

METHODS AND MATERIALS

A gift of caraota seed from the Central National de Investigaciones Agropecuarias (CNIA), Palmira, Columbia, was obtained in 1969 with other seeds requested. The limited quantity of each of the 34 varieties and other work in progress limited the time and size of the study.

Plots were 5m long and 4 plant rows wide. Beans were seeded 2 rows per furrow ridge. Furrows were 60 cm apart; seeded rows on the ridge were 20-25cm apart. Number of planted seeds per plot ranged from 77 to 83. All were fertilized with 50Kg N/ha, 80Kg P/ha and 30Kg K/ha using ammonium sulfate, treble superphosphate and potassium sulfate.

Planting was October 20, 1969. Some reseeding was done November 14, a little late. Growth and condition inventories were made November 11 and December 3. Irrigation by sprinkler was needed October 26 to insure germination and December 3, during a longer drying period. Harvest was January 14 for early maturing and January 19 for later varieties. Hand weeding and insecticides were applied as needed.

The seed used in the 1970-71 studies was variety Cubagua, certified quality by MAC-CIA, dated June 1970, with the following data: Germination 80%, Purity -- 98%, varietal purity -- 98%. Planting density was intended

to be 350,000 plants per hectarea, with excess seeding followed by thinning after germination. Double rows per furrow ridge were separated by 25cm; furrow centers were 90cm apart.

Land areas in 4 locations not planted to any other intensively grown crop for the previous year were selected in the 3 irrigation districts Guanare, Bocono (Sabaneta), and Las Majaguas. The sites had the following history as known to the senior author prior to planting caraota about December 1970:

Las Majaguas (Cojedes) - Previously in unsatisfactory pasture planting trials; recently plowed and borders leveled; very low in incorporated plant residues.

Guanare - Uniformly-fertilized, tall-growing cotton plowed under in February 1970; weed (grass) crop of low density grew during the rainy season (May-August).

Parcela 90 - Cropped once to corn in July 1969, variable fertilizer; plowed out of dense grass regrowth in October 1970; eliminated heavily grassed borders in November 1970.

Sabaneta - Cropped to unfertilized corn July 1969; leveled in April 1970; mostly clean cultivated until planted to caraota.

Land preparation included early plowing at all stations except Guanare. Just before planting, the land was disced and furrowed. Furrowing at 90cm centers also included a trailing V-board to form a convex ridge cross-section. Unless rainfall occurs, such a precaution is unneccessary. However, a flat ridge top is preferred over a concave surface, as could occur using narrow and shallow furrowing shovels without a following V-board or levelling bar.

Fertilization included 3 levels of P and 2 levels of N as shown in the scheme following:

Phosphorus Levels	Nitrogen levels		
	0	40Kg N/ha,	80Kg N/ha
0	F0[a]	F4	F8
30 Kg P/ha	F1	F5	F9
60 Kg P/ha	F2	F6	F10
90 Kg P/ha	F3	F7	F11

[a]Code symbol for the fertilizer treatment
All except F0 also contained 15 Kg K/ha

Fertilizer carriers used were ammonium sulfate (1.4% H_2O, 21% N), treble superphosphate (3.4% H_2O, 19.8% P), and potassium sulfate (1.2% H_2O, 44.5% K). For the larger "bottom-of-the field" lots in Majaguas and Sabaneta, diammonium phosphate (4.5% H_2O, 16% N, 20.1% P) was used as the phosphate source and part of the nitrogen. This change was made because a shortage of superphosphate in Venezuela at this time made it impossible to get enough to use on the total area.

Fertilizer was measured per lot (8m x 3.6m) by containers previously calibrated by weighing and marked for that volume. Care was used to select containers for each measurement such that the container was tall and slender and would be nearly full when the amount was correctly measured. This eliminated some measuring error that would occur using containers of large diameter but shallow. Checks of five weights of measured quantities by the senior author agreed within 3% of predicted weights. However, field work likely had errors in some infrequent instances of nearly 10%. Most fertilizer applications were measured personnally or were closely supervised in the field by the senior author and are believed to be within about 5% error.

To apply the fertilizer, very shallow furrows were marked which would

later be below the center of the ridge in the final planting. Fertilizer measured and mixed per lot was divided into 4 equal portions (each lot had 4 ridges of 2 plant rows each) and one portion distributed in each of the 8m-long furrows. The furrower then covered this fertilizer by performing a common furrowing operation burying the fertilizer row centered between the new, permanent furrows at a depth of 10cm to 15cm. The fertilizer bands each served two plant rows and would be a couple of inches below and 10cm to 15cm to the one side of the planted seed (centered between the plant rows). A band closer to seed on each planted row would have been more efficient and helped the plant at an earlier growth stage. Time and equipment consideration determined the use of this method.

This operation requires careful attention to tractor position so that the fertilizer is still centered between furrows after several passes of the furrower covering the fertilizer. In Las Majaguas, considerable "off-centered" covering occurred in two ridges each of blocks 3 and 4. If one leaves a buffer strip (one meter wide) unplanted each 8 or 12 ridges, this solves the refurrowing problem and keeps small uniform spacing errors from growing progressively worse with each equipment pass, as could occur with 20 to 30 rows consecutively furrowed.

Planting was done with a Ford two-row corn seeder off-centered on the tractor such that a down-pass seeded one side of each of 2 ridges and the up-pass seeded the other sides of those same ridges leaving the two seeded rows on a given ridge about 25cm apart. A seeding rate of about 550,000 seeds/ha was planted to allow for the 80% germination and allow a slight margin for plant death from various causes. Within two weeks of germination, thinning to 350,000 plants/ha was to have been completed. This 350,000 plants/ha density for double rows on 90 cm furrow centers is 15.8 plants/m.

Irrigation was done immediately following planting. Only the Guanare plot had been pre-irrigated, but it also was irrigated following planting. Within three days of irrigation, herbicide(2Kg/ha of LAZO and 1Kg/ha of LOROX was recommended) was applied by back-mounted sprays. The Guanare trial was sprayed by a tractor-mounted sprayer. A major exception to the use of the recommended herbicide mixture was the use of CORTORAN as the herbicide in Parcela 90. An interested party strongly recommended we use this chemical. As a compromise in the interest of information we decided to apply CORTORAN on Parcela 90 and the recommended material in Guanare. Later, we were informed that the chemical in mind was not CORTORAN but a different one. The results will be discussed in later sections.

Irrigation was furrow irrigation using siphons for water control. An irrigation block was 4 ridges wide and approximately 125 m long. A reservoir at the top of each irrigation block was used to reduce canal water level fluctuation and to simplify water measurement. Only the water delivered by siphons from the main canal to the reservoir was measured. Smaller siphons from the reservoirs to individual furrows did not have their flow monitored. However, advance time in the furrows in each irrigation block were generally very close. Drainage measurements were taken to the extent that equipment (Parshall flumes) permitted. Only during a few irrigations was drainage of all blocks measured.

Irrigation schemes were intended to maintain adequate moisture uniformly rather than to apply a given amount of water. Two watering patterns were used. Ir was to irrigate on a regular time interval. In Majaguas it was each 8 days; in Guanare and Sabaneta it was each 7 days. The other irrigation pattern, Is, was to irrigate within 3 days of the time when drying was evident as indicated by a darkening green color and the leaf "wilt". In

hot afternoons, these symptoms are more common (though transient) than in less sunny days.

The amount of water to be added was not rigidly set. It was suggested to add 4cm net irrigation weekly after the first four weeks to Ir blocks. During the first month, irrigation was altered depending on the apparent moisture condition of the soil. For Is blocks, a use of 6mm per day was assumed for the actively growing crop (after first 3 weeks) and a number of days times 6mm = needed net irrigation.

This procedure suggests using for irrigation demand approximate values of the pan evaporation whereas the evapotranspiration factors at maximum water need suggest only 0.90 of the pan evaporation value. However, non-uniform application of water and visual observations of the soils indicated that these values did not seem to be excessive irrigations except within the first 3 or 4 weeks.

The actual change in evaporation (average values for each month from past year's data) were used to alter the values given earlier. For example, the weekly evaporation less for Guanare was as follows: December -- 4.0cm, January -- 4.2cm, February -- 5.0cm.

Preventive chemical sprays were used to control insects (D.D.T. and PERFEKTION) and to help reduce pathogenic organisms (DIPTEREX plus MANZATE).

Harvest was done by hand. Of each lot, the center 4 plant rows 7m long were collected as the "treatment." Each outside ridge (2 plant rows each times 7m long) was harvested separately as "border row" to compare border effects between adjacent lots. These border rows are also checks on "treatment" yield values. Seed was shelled and then weighed on an analytical balance (precision was 0.01 gram).

The experimental plot layouts are given in Tables 1 and 2. Lot details and fertilizer treatment are listed in figure 1. Characteristics of the soils at the 4 locations are given in Table 3. Considerable soil variation occurred in the Los Majaguas and Sabaneta station. In Sabaneta particularly the upper 4 to 5 lots in most blocks was considerably more sandy than lower portions of the field. Portions of the upper part could be felt when wet without much staining of the hand from clay. It would at the finest be sandy loam texture in that upper portion of the plots.

Table 1. Fertilizer treatment and irrigation block layout for caraota Sabaneta and Las Majaguas, 1970-71. Ir = irrigation at a constant set time interval (weekly in early growth; each 8 days in later growth). Is = irrigation within 2 or 3 days of visual symptoms of lack of water such as darker green foliage or incipient wilting in the hot afternoon. Sabaneta had only 8 blocks, rather than the 10 as shown for Las Majaguas. Also, fertilizer randomization varied some from this design. For details see Fig. 1.

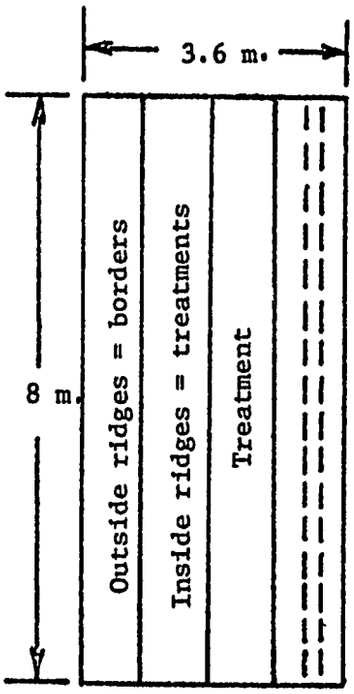
Is	Ir	Ir	Is	Ir
F10	F3	F7	F2	F10
F2	F5	F10	F4	F2
F0	F6	F8	F9	F0
F8	F9	F1	F8	F8
F11	F4	F0	F6	F11
F7	F11	F4	F11	F7
F9	F1	F6	F1	F9
F1	F0	F2	F5	F1
F4	F7	F11	F3	F4
F6	F10	F3	F0	F6
F5	F8	F5	F7	F5
F3	F2	F9	F10	F3
F10	F10	F10	F10	F10

Is	Is	Ir	Is	Ir
F3	F10	F2	F6	F7
F5	F2	F4	F5	F10
F6	F0	F9	F3	F8
F9	F8	F8	F9	F1
F4	F11	F6	F4	F0
F11	F7	F11	F11	F4
F1	F9	F1	F1	F6
F0	F1	F5	F0	F2
F7	F4	F3	F7	F11
F10	F6	F0	F10	F3
F8	F5	F7	F8	F5
F2	F3	F10	F2	F9
F10	F10	F10	F10	F10

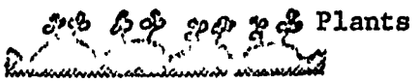
Table 2. Fertilizer treatment and irrigation block layout for caraota in Parcela 90 and Guanare, 1970-71. Ir = irrigation at a constant set time interval (weekly in early weeks; each 7 days in later growth). Is = irrigation within 2 or 3 days of visual symptoms of lack of water such as darter green foliage or incipient wilting in the hot afternoon. F0 - no fertilizer, F1-F3 = increasing amounts of phosphorus, and F4-F11 = various mixtures of nitrogen and phosphorus.

Ir	Ir	Is	Ir	Is	Ir	Is	Is
F10	F3	F7	F2	F3	F10	F2	F3
F2	F5	F10 reg.	F4	F5	F2	F4	F5
F0	F6	F8	F9	F6	F0	F9	F6
F8	F9	F1	F8	F9	F8	F8	F9
F11	F4	F0	F6	F4	F11	F6	F4
F7	F11	F4	F11	F11	F7	F11	F11
F9	F1	F6	F1	F1	F9	F1	F1
F1	F0	F10 error	F5	F0	F1	F5	F0
F4	F7	F2	F3	F7	F4	F3	F7
F6	F10	F11	F0	F10	F6	F0	F10
F5	F8	F3	F7	F8	F5	F7	F8
F3	F2	F5	F10	F2	F3	F10	F2
F10	F10	F10	F10	F10	F10	F10	F10

	Kg. N per ha.			
	0	40	80	
0	F0	F4	F8	All but F0 also +15 Kg. K
30	F1	F5	F9	
60	F2	F6	F10	
90	F3	F7	F11	



Top View



Cross-section

Lot Details

1. Double rows approximately 25-30 cm. apart on each ridge. Furrows 90 cm. apart.

2. Fertilizer applied in center of ridge at about 10-12 cm. deep.

3. Cubagua variety at density of 350,000 plants/Ha. after thinning or spot reseeding.

4. Irrigation water measured for whole block one lot wide, but added to each furrow separately by siphons.

5. Two irrigation patterns:
   Ir - Regular periodic: weekly
   Is - Irrigated within 3 days only when symtoms appear (dark color, moderate wilt in hot hours of day).

Figure 1. Fertilizer scheme and lot details for caraota experiments, 1970-71, in Los Llanos in Porteguesa State, Venezuela.

Table 3. Some soil characteristics of the four soils used in field studies. Fields in Sabaneta and in Las Majaguas had the greatest in-field variation in properties.

Soil Characteristic		Guanare	Parcela 90	Sabaneta	Las Majaguas
Texture of surface 20 cm.	% Sand	13	32	45*	28
	% Silt	46	37	40	38
	% Clay	41	31	15*	34
	Class	si. clay	c. loam	loam	c. loam
Soil Reaction (pH), 1:2		7.1	5.8	6.4	5.9
Oxidizable organic matter %		3.9	2.9	2.5*	4.7
Available P ppm	Bray - Kurty	55	--	7*	Trace
	Olsen	95	--	--	--
Exchangeable K, me/100g.		0.65	--	0.32	0.18
Moisture constants	Field capacity	29	23	18*	31
	Wilting point	17	12	9*	18

* Varied from 27% for sand to 49%, clay content varied similarly from 13% to 30%. All data quite variable. Some non-sampled areas were more sandy.

RESULTS AND DISCUSSION

Varieties Study - 1969

The results of the varieties trials are summarizied in Table 4. The most popular and recommended variety grown in Venezuela is Cubagua and the two plots of this in the experiment rank 2 and 7 among the 36 plots. The top yielding variety, Venezuela 36, was not further identified by the supplier.

Several varieties would seem not well adapted to this climate for October planting (but may do better in mid-December planting). In order from poorest to slightly better varieties I would list Guatemala 591, Guatemala 113, Guatemala 123, Guatemala 367, Guatemala 51, Guatemala 109, Guatemala 67, Guatemala 43 and Guatemala 400. Most of these had high disease incidence and were generally prostrate in form. In contrast, some plants -- ICA-Tuf, Mexico 120-1, and Preto Caruao -- had no plants with obvious infections on December 3. Although I-4 had 2 plants infected it looked the best of all plots -- tall, green and vigorous. The top yielder, Venequela 36, was also rated on December 3 as having "excellent growth" and few plants infected.

Other factors altered yields. Poor germination or early plant losses were noted for Venezuela 45, I-110, Breto Brilhante, I-113, and Cubagua. It is interesting that the Cubagua with a note about "low survival" also finally ranked No. 2 in yield. Unfortunately the numbers of plants harvested was not counted.

From the observations and data collected, the following conclusions seem justified to the writer:

1. The currently popular variety used in Portuguesa State, Cubagua, is a top quality variety of those tested.

Table 4. Black bean (caraota) varieties study given by field position, Portuguesa State, Venezuela. Planted October 20, 1969. Densities low because of limited seed available. Top 10 in yield are in squares heavily lined.

26 Ven. 44-2 60/81 358	35† Guat. 400 63/83 67	24† Mex. 494 56/81 395	13 Ven. 43-2 43/80 865
10 ICA-HU 57/78 1094	23† Guat. 368 56/79 396	12† Black Tur. 31/78 977	1 Ven. 36 60/80 2465
29† Mex. 12-1 21/80 230	15 Mex. 11 53/78 842	5 Por. No. 1 63/78 1418	36* Guat. 113 59/80 (Trace)
14 Mex. 369-1 54/78 860	19† Ecu. 132 59/81 554	16† Guat. 43 72/78 684	17 Ven. 45 38/80 652
20 Turr. 2 71/82 508	25† Guat. 109 67/78 358	28 I-110 47/78 310	8 ICA-Tuf. 60/81 1208
31† Guat. 67 61/78 189	18* Guat. 51 70/79 645	34* Guat. 123 66/82 81	33† Breto Br. 24/80 86
21 Mex. 120-1 59/79 445	3 I-4 78/82 1965	9 I-113 60/78 1119	6 Ven. 44-1 53/79 1402
30* Guat. 367 70/82 205	22 Ven. 17 43/82 421	27† Mex. 456 50/77 345	4† Jamapa 57/82 1427
32* Guat. 591 68/82 152	11 Preto Car. 70/82 1073	7† Cubagua 55/80 1244	2 Cubagua 55/81 2358

* Over 50% disease or virus affected on December 3.
† About 20-50% disease or virus affected on December 3.

26 — Ranking on yield
Ven. 44.2 — Variety name
60/80 — Survival/planted
358 — Yield, Kg/ha

Survival on Nov. 11, 1969.

Abbreviations used

Br. = Brilhante
Car. = Caruaó
Ecu. = Ecuador
Guat. = Guatemala
Hu. = Huasanó
Mex. = Mexico
Por. = Porillo
Tur. = Turtle
Turr. = Turrialba
Ven. = Venezuela

Plot dimensions

1.2m x 5m = 6.0m^2
25 cm between 2-seed "hills"

Densities (plants/ha)

40/plot = 66,700
50/plot = 83,300
60/plot =100,000

Normal Data for Area

Planting density -300,000
Yields (good) - 1500 Kg/ha

2. Other top varieties in disease resistance and yield per plant include Venezuela 36, I-4, Jamapa and Porillo No. 1. Possibly Venezuela 44-1 should also be considered. Black turtle had considerable wilt problem although it had relatively high yield per plant. Examples of growth is shown in Photo 1 with 1-4 in the foreground.

Majaguas - 1970-71

The caraota study in Las Majaguas was supervised by R. W. Miller and Ing. Alfonso Bustillos. Direct field work was under these two men and the Perito Aldo Guilarte.

Caraota were planted November 26, 1970. In this year, the date was too early for a comparison of irrigation regimes because rainfall almost adequate for growth occurred throughout December, therefore not permitting good variable moisture regimes. It was two weeks after flowering before any appeciable moisture variable could be imposed. By this time there was essentially no appreciable plant development left to affect. The moisture data are given in Table 5 and figure 2.

Yield data for the plots harvested February 8, 1971, is in Tables 6, 7, 8, 9 and 10. Of the three stations, yields are lowest in Las Majaguas. Planting was done the same and fertilization were equal. Generally these yields are only 50% of the yields in Guanare. The soil in Las Majaguas has a tight, clayey subsoil at 25 to 30 cm deep. But the caraota root doesn't require a particularly deep soil. Several other crops grown on this soil also did not generally produce well. Sugar cane has yielded 130 toneladas/hectarea.

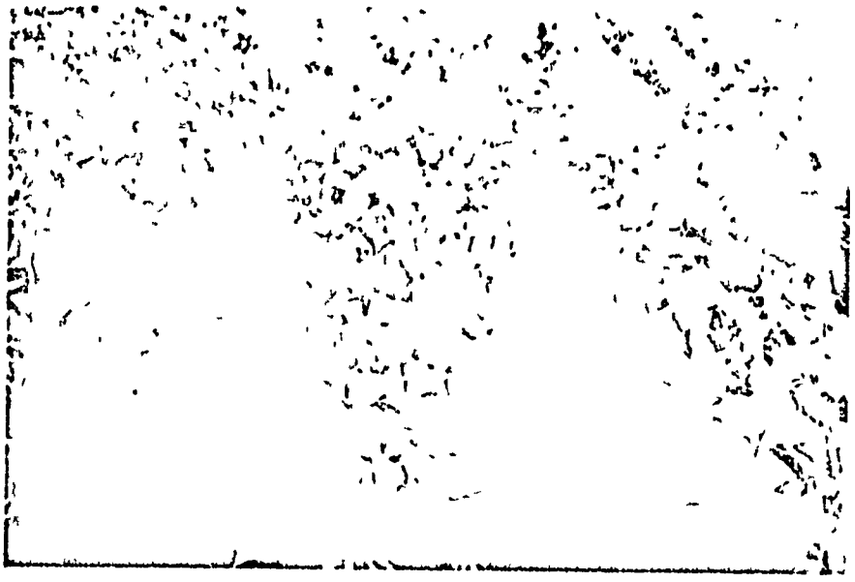


Photo 1. Example of the growth and ground cover for caraota (black bean) variety trials in Guanare station. Densities planted as a result of limited seed available were 30 to 50% of the usual 250,000 to 300,000 plants/ha normally planted. Yet yields were quite good, with the highest yields being 2465, 2358, 1965, 1427 and 1418 kg/ha in the top five. Photo taken 5 weeks prior to harvest, so slight additional growth occurred after this photo was taken. Harvest densities were between 85,000 to 100,000 plants/ha. Lots were 1.2 m by 5 m in size, all planted adjacent for a total field size of 4.8 m x 45 m. I-4 produced 3rd high yield, 1965 kg/ha.

Table 5. Estimates of the soil water status of Las Majaguas black bean (caraota) experiment including rainfall and irrigation additions and presenting losses according to consumptive use estimates given by Christiansen and Hargreaves (1968). Additions minus total pan evaporation is given as a comparison, since the factors given seem too small for early and late season use.

Date interval	Rainfall	Irrigation	Class A pan evaporation	Evapotransp. factor*	Calculated evapotransp.*	Rain + irrigation minus pan evap. accumulative, mm		Rain + irrigation minus calc. evapotransp., accumulative, mm	
	mm	mm	mm		mm	Ir+	Is+	Ir+	Is+
Nov. 26-30	0	Ir = 62.0 Is = 68.0	33.9	0.20	6.8	28.1	34.1	55.2 ‡	61.2 ‡
Dec. 1-7	26.7	0	22.8	0.3	6.9	32.0	38.0	75.0	81.0
Dec. 8-14	27.5	Is - 25.6	31.3	0.4	12.6	28.2	59.8	89.9	121.5
Dec. 15-21	19.3	0	37.3	0.65	24.2	15.1	46.7	85.0	117.6
Dec. 22-28	14.1	Ir - 38.7	33.8	0.85	28.6	34.1	27.0	110.2	102.1
Dec. 29-Jan. 4	7.6	0	30.8	0.90	27.7	10.9	- 3.8	90.1	82.0
Jan. 5-11	0	Ir - 46.9 Is - 48.6	52.2	0.90	47.0	10.8	- 7.4	90.0	83.6
Jan. 12-18	0	Wr - 47.1	50.9	0.80	40.7	7.0	-58.3	96.4	42.9
Jan. 19-25	0	Wr - 58.8	55.0	0.60	32.9	10.8	-113.3	122.3	10.0
Jan. 26-Feb.1	0	0	62.5	0.35	21.9	-51.7	-175.8	100.4	-11.9

* Factor times class A pan evaporation equals an estimate of evapotranspiration. Factor changes with growth changes. Factors from Christiansen and Hargreaves.

\+ Two irrigation regimes used were (1) irrigation on a regular interval of 7 or 8 days, Ir, and (2) irrigation within 3 days of marked symptoms of drying such as slight wilt and change to darker green color, Is.

‡ Irrigation November 26 at planting time was 62.0mm for Ir minus [evaporation times evapotranspiration factor] (= 33.9mm x 0.20 = 6.8mm). Net Ir is 55.2mm. Is had 68.0mm irrigation and net Ir = 61.2mm.

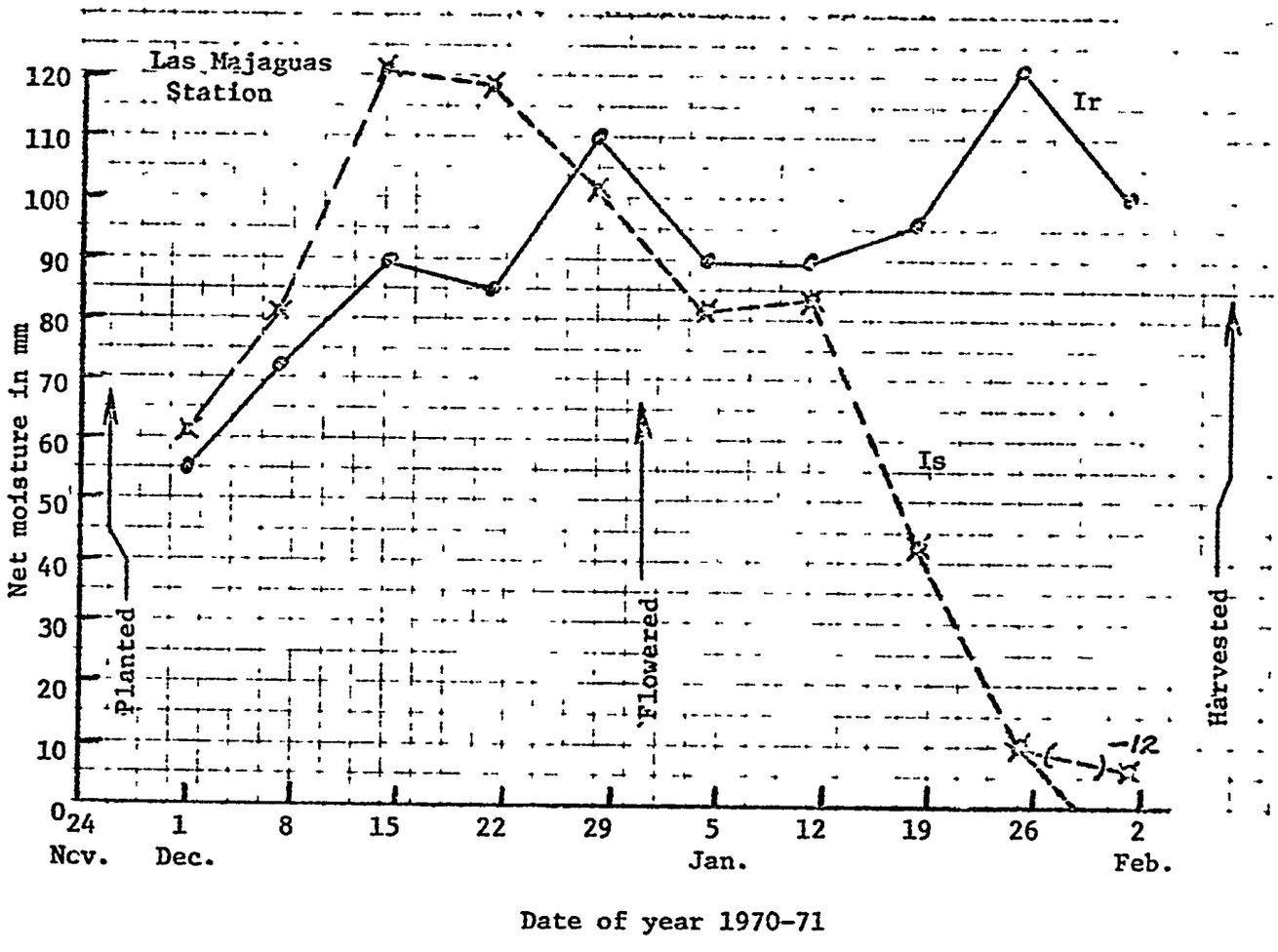


Fig. 2. Net moisture in irrigated black beans (caraota) in Las Majaguas. Ir = irrigation done on an 8-day pattern except when rains made irrigation unnecessary (December); Is = irrigation done only when dryness symptoms were marked. In this graph, net moisture = irrigation plus rainfall minus the product of class A pan evaporation times the evapotranspiration coefficient for beans estimated by Christiansen and Hargreaves (1968). This factor varied from 0.2 to 0.9.

Table 6. Yield data (Kg/ha) for caraota in Las Majaguas. Irrigation blocks are vertical columns; fertility levels are horizontally placed. Irrigations were weekly or within a few days of marked drying symptoms.

Fert trt	Irrigation at given intervals						Irrigation when symptoms show					
	1 c1	2 c3	3 c6	4 c8	5 c8	Total	1 c2	2 c4	3 c5	4 c7	5 c10	Total
F0	348	541	1,116	783	893	3,681	249	653	320	479	417	2,118
F1	488	763	984	1,048	995	4,278	550	647	814	755	567	3,333
F2	442	1,387	952	853	976	4,610	502	466	498	533	925	2,924
F3	574	750	1,375	1,040	971	4,710	537	775	837	542	575	3,266
F4	629	787	1,245	900	587	4,148	992	526	700	869	552	3,639
F5	1,011	1,282	910	1,312	837	5,352	912	995	883	724	1,032	4,566
F6	891	1,282	1,353	1,126	732	5,384	975	1,267	911	1,098	1,184	5,435
F7	1,142	1,322	588	1,249	829	5,130	773	765	642	908	706	3,794
F8	677	792	1,300	660	1,075	4,504	590	597	518	827	418	2,950
F9	1,069	1,320	1,343	1,013	448	5,193	734	1,343	1,115	906	1,178	5,276
F10	1,319	1,021	776	1,140	1,250	5,506	805	794	1,128	940	890	4,557
F11	1,270	1,030	1,434	704	1,138	5,576	849	1,137	1,180	613	1,343	5,122
Total												

F0 = control; F1-F3 levels only of P; F4, F8 levels only of N; all others N plus P mixtures.

Table 7. Yields of caraota (Kg/ha) at Las Majaguas . Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

C			B			A		
Irrigation* Ir-3			Irrigation* Is-2			Irrigation* Ir-1		
B†W	Trt†	B†E	B†W	Trt†	B†E	B†W	Trt†	B†E
712	F2 1387	1307	1271	F6 975	1690	1454	F7 1142	--
384	F4 787	656	1176	F5 912	1545	1408	F10 1319	--
757	F9 1320	1340	896	F3 537	1002	1000	F8 677	--
447	F8 792	775	1360	F9 734	772	830	F1 488	--
676	F6 1282	1350	825	F4 992	910	527	F0 388	--
882	F11 1030	1560	1166	F11 849	1462	579	F4 629	--
412	F1 763	700	898	F1 550	657	1063	F6 891	784
840	F5 1018	941	493	F0 249	313	498	F2 442	600
243	F3 595	536	1121	F7 773	978	1413	F11 1270	1365
267	F0 541	661	1005	F10 805	--	576	F3 574	665
649	F7 1050	1078	677	F8 --	571	982	F5 1011	1103
1030	F10 810	995	833	F2 502	449	1016	F9 1069	1013
Totals			Totals			Totals		

East Edge of Field

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row west (BW) or east (BE) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

Table 8. Yields of caraota (Kg/ha) at Las Majaguas. Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

	E			D			C		
	Irrigation* Is-5			Irrigation* Is-4			Irrigation* Ir-3		
	B†W	Trt†	B†E	B†W	Trt†	B†E	B†W	Trt†	B†E
	--	F3 837	924	898	F10 794	1667	712	F2 1387	1307
	--	F5 883	1069	770	F2 466	902	384	F4 787	656
	--	F6 911	1025	606	F0 653	945	757	F9 1320	1340
	--	F9 1115	1184	791	F8 597	1064	447	F8 792	775
	--	F4 700	720	1190	F11 1137	1342	676	F6 1282	1350
Edge of Field	--	F11 1180	1500	1105	F7 765	1150	882	F11 1030	1560
	765	F1 814	1208	1320	F9 1343	901	412	F1 763	700
	635	F0 320	462	681	F1 647	635	840	F5 1018	941
	804	F7 642	940	468	F4 526	730	243	F3 595	536
	1362	F10 1128	1410	1180	F6 1267	1321	267	F0 541	661
	454	F8 518	745	800	F5 995	1160	649	F7 1050	1078
	1110	F2 498	706	760	F3 775	925	1030	F10 810	995
	Totals			Totals			Totals		

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row west (BW) or east (BE) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

Table 9. Yields of caraota (Kg/ha) at Las Majaguas. Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

H			G			F		
Irrigation* Ir-8			Irrigation* Is-7			Irrigation* Ir-6		
B†W	Trt†	B†E	B†W	Trt†	B†E	B†W	Trt†	B†E
895	F7 1249	--	--	F2 533	633	386	F10 776	--
1230	F10 1140	--	--	F4 864	1155	860	F2 952	--
1157	F8 660	--	--	F9 906	1288	--	F0 1116	--
1670	F1 1048	--	--	F8 827	1443	962	F8 1300	--
573	F0 783	--	--	F6 1098	1339	1634	F11 1434	--
1359	F4 900	1450	--	F11 613	1446	1341	F7 588	--
1342	F6 1126	916	525	F1 755	1192	1757	F9 1343	1815
1030	F2 853	974	905	F5 724	1490	1992	F1 984	1258
1154	F11 704	784	578	F3 542	1490	702	F4 1245	1078
1289	F3 1040	1057	679	F0 479	688	1798	F6 1353	1255
1176	F5 1312	915	1121	F7 908	1318	1584	F5 910	1126
1189	F9 1013	1350	972	F10 940	824	791	F3 1375	1623
Totals			Totals			Totals		

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row west (BW) or east (BE) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

F-BW had heavy grass cover; also G-BE and G-trt

Table 10 Yields of caraota (Kg/ha) at Las Majaguas . Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

Outside Edge of Field

J			I			H		
Irrigation* Is-10			Irrigation* Ir-9			Irrigation* Ir-8		
B†W	Trt†	B†E	B†W	Trt†	B†E	B†W	Trt†	B†E
--	F10 1122	736	1270	F3 971	654	895	F7 1249	--
--	F2 1167	1300	1160	F5 837	1010	1230	F10 1140	--
--	F0 525	730	1315	F6 732	1195	1157	F8 660	--
--	F8 526	980	675	F9 448	1471	1670	F1 1048	--
--	F11 1695	895	1383	F4 587	1014	573	F0 783	--
--	F7 889	867	1206	F11 1138	1277	1359	F4 900	1450
1432	F9 1485	830	1128	F1 995	1016	1342	F6 1126	916
1052	F1 715	817	1062	F0 893	715	1030	F2 853	974
684	F4 695	659	1163	F7 829	1027	1154	F11 704	784
925	F6 1492	1268	1268	F10 1250	1310	1289	F3 1040	1057
875	F5 1300	941	1378	F8 1075	1641	1176	F5 1312	915
243	F3 725	1203	1302	F2 976	1009	1189	F9 1013	1350
Totals			Totals			Totals		

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row west (BW) or east (BE) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

Statistical analyses, as shown in Tables 11 and 12, indicate a strong possibility for an irrigation effect at the 99% confidence level. As can be seen in figure 2, some irrigation done in early growth and after flowering caused some predicted soil moisture differences in early growth but marked moisture differences during later seed development. Such data suggests a sensitivity of the bean to moisture during seed growth.

Fertilizers alter yield. The confidence is greater than 99%. A Duncan's multiple range test indicated that F5, F6, F9, F10 and F11 are all significantly different at the 99% confidence limit from the F0 treatment (control). Only F7 has both N and P as the treatment and is not different than F0. At the 95% confidence level all treatments with both N and P are different from the F0 (control). The addition of P and N is significantly higher than treatments only with N (compare F6, F9, F10 and F11 which are significantly different from F8 which has only 80Kg N/ha). These same treatments, except F10 which is close to being significantly different, are also different from F4, the other N-only treatment (40Kg N/ha).

An example of the importance of P is the yield-ranking position of the treatments. Although the values are too similar to be considered statistically different, the three P-only treatments (F1, F2 and F3) all have higher yield averages than F8 (80Kg N/ha). F3 (90Kg P/ha) is also larger than F4 (40Kg N/ha). Yields with higher levels of both N and P result in yield difference of 200-300Kg/ha higher than either treatments with N or P alone. Control plots are nearly 200Kg/ha lower than the N or P only treatments.

A look at repeat averages in Table 12 generally supports the statistical verification that the more frequently irrigated plots, Ir, had higher yields. The overall average difference is about 190Kg/ha.

Table 11. Analyses of variance and Duncan's multiple range test for black bean (caraota) study in Las Majaguas station harvested February 9, 1971. Split plot design.

Source	Degrees freedom	Sum of squares	Mean square	F distribution
Irrigation	1	1,028,971	1,028,971	11.16*, practically**
Error (A)	8	737,272	92,159	
Fertilizer	11	2,879,293	261,754	5.058**
Irr. x Fert.	11	419,875	38,170	0.738 nonsign.
Error (B)	88	4,554,660	51,747	
Total	119	9,620,071	80,841	

Fertilizer	Ranked Yield Kg/ha	95% Confidence†	99% Confidence†
F0	580	(254)	(366)
F8	745		
F2	753		
F1	761		
F4	779		
F3	798		
F7	892		
F5	990		
F10	1006		
F9	1047		
F11	1070		
F6	1082		

†Treatments bounded by one line are not different at the level indicated. Those values above the beginning of each line are different than those below where the line ends.

Table 12. Statistical data for Las Majaguas station black bean (caraota) study harvested February 8, 1971. Individual numbers are an average of 5 repeat observations.

Fertilizer treatment	Ir[†]	Is[†]	Average	Standard error of means of fertilizer treatments
F0	736	424	580	= 71.9
F1	856	667	761	
F2	922	585	753	
F3	942	653	798	
F4	830	728	779	
F5	1070	909	990	
F6	1076	1087	1081	
F7	1026	759	892	
F8	900	590	745	
F9	1039	1055	1047	
F10	1101	911	1006	
F11	1115	1024	1070	
Average	968	783	875	
Standard error of means of Irrigation = 39.2				
Standard error between individual fertilizer means each with 4 repeat observations = 143.9				

*F = no fertilizer, F1-F3 30, 60, 90 Kg/ha of P, F4 and F8 40 and 80 Kg N/ha, F5-7 and F9-11 levels of both N and P.

†Ir = irrigation regularly (7 or 8 day intervals); Is = irrigations when symptoms of drying were evident.

In looking at moisture patterns in Figure 2, an extra irrigation for Is 3 weeks after planting before new rains fell, did not have the effect on yield that later water did for Ir. Two weeks before flowering (December 15) until three weeks later (January 9) rainfall did not equal calculated evapotranspiration. Ir was irrigated but Is was not. From January 12 on, Ir was irrigated in successive weeks (both weeks rainless) and Is was not. This moisture difference would alter bean size. Weight measurements of 100 seed lots of each treatment plot gave a weight average (of 60 plots each) of 19.20 g for Is and 20.00 g/100 seeds for Ir. This weight difference is not large enough to account for the 20% plus yield difference between Ir and Is means. The number of beans per pod and number of pods per plant were apparently affected by the drier Is blocks just before and shortly after flowering plus the drier late maturity period.

This affect of dryness on flower setting or/and seed-per-pod development could help explain why no obvious irrigation-fertilizer interaction was measured. Both irrigation regimes would have had equal plant development as influenced by the first month's growth with adequate water. Fertilizer differences would have been manifest equally in both irrigation schemes. Dryness at flowering or afterwards would have affected all fertilizer treatments in the dry regime, Is. Smaller differences that might have existed would not be great enough to exhibit statistical significant interactions.

A review of tables 7-10 do not suggest any constant border effect. Yields on border rows do not demonstrate any consistent effect of adjacent irrigation regime or adjacent fertilizer treatment. The furrow and the limited root extension appear to make the use of border rows less critical in studies on beans in furrow plantings.

Sabaneta - 1970-71

The caraota study in Sabaneta was supervised by R. W. Miller and Ing. Evaristo Martinez. Direct field work was under these two men and Perito Chapón.

Caraota were planted December 2, 1970 and irrigated the following day. As observed for Las Majaguas, rainfall in December was adequate or seemed so for plant growth. Therefore, irrigation differentials were not applied during the first 4 weeks. Later irrigations seemed needed in both irrigation regimes by the weekly scheduled time for Ir and only a slight difference in irrigation occurred between the two. Table 13 and figure 3 illustrate the climatic features. It is easily seen in figure 3 that the two irrigation regimes had some differences following flowering, but the differences were not great. It is interesting when comparing figures 2 and 3 that the "net moisture," calculated in the same manner for both Las Majaguas and Sabaneta, is greater in Las Majaguas (100mm) than in Sabaneta (60mm). However the more sandy Sabaneta soil would at this average moisture be quite comparable to Las Majaguas at its higher average moisture.

Sabaneta had a soil that was slowly permeable. For example, irrigation. after planting had an infiltration average of 2.06 cm/hr. After a month of rainfall, a small stream of about 22 l/sec per furrow had over a 5 hour wetting period an average infiltration of 0.24 cm/hr and a 76% runoff of total water applied. A similar flow two weeks later, after some wetting and drying had occurred and more water was being transpired, resulted in an infiltration of 0.43 cm/hr. Runoff was 59% of the total water applied. Deep wetting in this soil is slow and inconvenient. A flow of 22 l/sec per furrow on January 27 for 10 hours resulted in a net infiltration of 2.89 cm. With this soil, attention to tillage pans from compaction

Table 13. Estimates of the soil water status of Sabaneta black bean (caraota) experiment including rainfall and irrigation additions and presenting losses according to consumptive use estimates given by Christiansen and Hargreaves (1968). Additions minus total pan evaporation is given as a comparison, since the factors seem too small for early and late season use.

Date interval	Rainfall mm	Irrigation mm	Class A pan evaporation mm	Evapotransp. factor*	Calculated evapotransp.* mm	Rain + irrigation minus pan evap. accumulative, mm		Rain + irrigation minus calc. evapotransp., accumulative, mm	
						Ir+	Is+	Ir+	Is+
Dec. 1-7	40.1	Ir-24.5 Is-24.9	24.1	0.20	4.8	40.5	40.9	59.8	59.9
Dec. 8-14	9.6	0	27.8	0.30	8.3	12.3	12.7	61.1	61.2
Dec. 15-21	15.8	0	28.6	0.40	11.4	- 0.5	- 0.1	65.5	65.6
Dec. 22-28	0	0	26.3	0.65	17.1	-26.8	-26.4	48.4	48.5
Dec. 29-Jan. 4	32.2	0	27.0	0.85	23.0	-21.6	-21.2	57.6	57.7
Jan. 5-11	0	Ir-11.9	26.0	0.90	23.4	-35.7	-35.3	46.1	34.3
Jan. 12-18	0	Ir-38.1 Is-29.8	35.9	0.90	32.3	-33.5	-41.4	51.9	31.8
Jan. 19-25	4.4	Ir-32.6 Is-33.5	40.0	0.80	32.0	-36.5	-43.5	56.9	37.7
Jan. 26-Feb. 1	0.8	Ir-40.4 Is-41.4	39.0	0.60	23.4	-34.3	-40.3	74.7	56.2
Feb. 2-8	0	0	42.4	0.35	14.8	-76.7	-82.7	59.9	41.4
Feb. 9-15	0	0	52.3	0.20	10.5	-129.0	-135.0	49.4	30.9

* Factor times class A pan evaporation equals an estimate of evapotranspiration. Factor changes with growth changes. Factors from Christiansen and Hargreaves.

\+ Two irrigation regimes used were (1) irrigation on a regular interval of 7 or 8 days, Ir, and (2) irrigation within 3 days of marked symptoms of drying such as slight wilt and change to darker green color, Is.

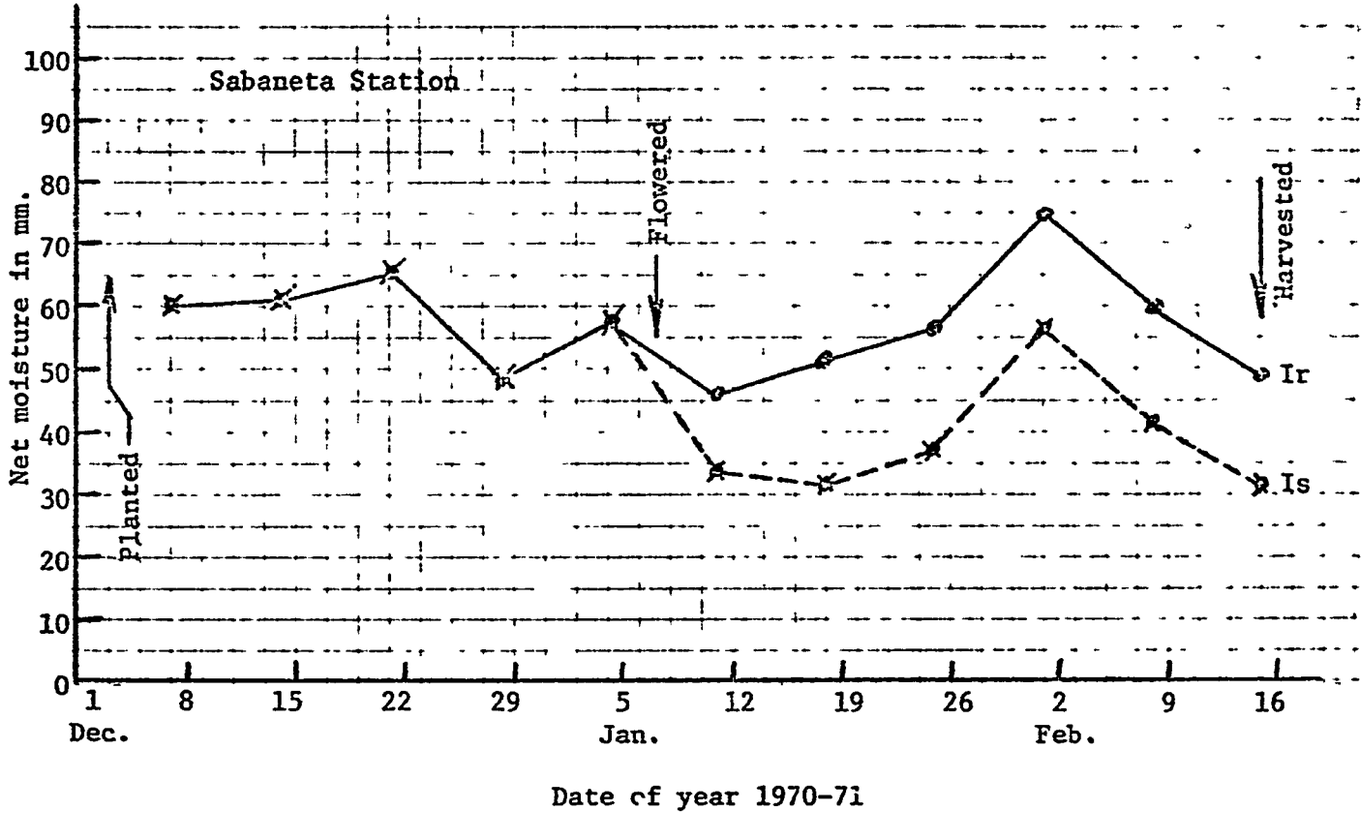


Fig. 3. Net moisture in irrigated black beans (caraota) in Sabaneta. Ir = irrigation done on an 7 day pattern except when rains made irrigation unnecessary (until January 2). Is = irrigation done only when dryness symptoms were marked. In this graph net moisture = irrigation plus rainfall minus the product of class A pan evaporation times the evapotranspiration coefficient for beans as estimated by Christiansen and Hargreaves (1968). This factor varied from 0.2 to 0.9.

and sealing by silt flow clogging pores need to be a part of the management.

Yield data are shown in Tables 14, 15, 16 and 17. Statistical data is presented in Tables 18 and 19. Yields are higher than for Las Majaguas, averaging about 200 Kg/ha higher. As is shown in Table 14, some treatments had good yields of 1400 to 1800 Kg/ha. The analysis of variance (Table 18) lists only fertilizer treatment as a significant effect. As previously discussed, the nearly equal irrigation in both Ir and Is treatments should not result in a differential yield between irrigation regimes.

Field variation in the field used is quite noticeable. A sandy strip of varying width existed toward the top and across the field. Some yield variations shown in field osition in Tables 16, 17 and 18 illustrate this difference. The following data are yields in Kg/ha.

Treatment	Top of field	Lower half of field	Field average for this treatment
F4	572 1380	1605 1390	1169
F0	373 595	785 1525	696
F7	868 1350	1265 1535	1263
F10	780 1365 1630	1415, 1855 1275, 1750	1417
Average	991	1440	

Table 14. Yield data (Kg/ha) for caraota in Sabaneta . Irrigation blocks are vertical columns; fertility levels are horizontally placed. Irrigations were weekly or within a few days of marked drying symptoms.

Fert trt	Irrigation at given intervals						Irrigation when symptoms show					
	1	2	3	4	5	Total	1	2	3	4	5	Total
F0	581	1,525	595	485		3,186	855	373	785	368		2,381
F1	789	680	755	735		2,968	835	1,280	650	615		3,380
F2	1,038	875	590	495		2,998	780	506	960	1,130		3,376
F3	685	1,400	1,435	985		4,505	1,330	1,265	829	469		3,893
F4	1,170	572	1,390	1,130		4,262	1,320	1,605	1,380	784		5,089
F5	763	897	1,395	1,170		4,225	1,720	1,835	855	725		5,135
F6	836	1,105	1,615	1,265		4,821	1,380	2,110	755	642		4,887
F7	1,321	1,535	1,325	1,350		5,531	868	1,275	1,170	1,265		4,578
F8	1,530	940	1,070	795		4,335	862	1,045	1,215	1,550		4,672
F9	1,425	638	1,280	1,235		4,578	1,400	1,365	1,385	625		4,775
F10	1,750	1,855	1,270	1,630		6,505	780	1,365	1,275	1,415		4,835
F11	1,363	1,025	955	1,440		4,783	1,910	1,345	1,310	805		5,370
Total	13,260	13,047	13,675	12,715		52,697	14,040	15,369	12,569	10,395		52,371

F0 = control; F1-F3 levels only of P; F4, F8 levels only of N; all others N plus P mixtures.

Table 15. Yields of caraota (Kg/ha) at Sabaneta . Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

A			B			C		
Irrigation* Ir-1			Irrigation* Is-2			Irrigation* Ir-3		
B†N	Trt†	B†S	B†N	Trt†	B†S	B†N	Trt†	B†S
456	F3 685	1165	1160	F7 868	1040	895	F2 875	985
446	F5 763	1015	1240	F10 780	1000	610	F4 572	752
980	F6 836	1052	955	F8 862	897	780	F9 638	662
1645	F9 1425	1625	945	F1 835	735	1400	F8 940	1345
1425	F4 1170	1470	1110	F0 855	890	1175	F6 1105	1410
1860	F11 1363	1645	1375	F4 1320	1325	1230	F11 1025	1480
892	F1 798	1255	1430	F6 1380	1410	870	F1 680	1210
635	F0 581	1040	825	F2 795	805	1130	F5 897	1470
1520	F7 1321	1605	1590	F11 1910	2005	1550	F3 1400	1800
1805	F10 1750	2055	1240	F3 1330	1566	1380	F0 1525	1805
1695	F8 1530	1810	1350	F5 1720	1791	1813	F7 1535	1745
1210	F2 1038	1245	1274	F9 1400	1383	1632	F10 1855	1752
Totals			Totals			Totals		

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row north (BN) or south (BS) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

Table 16. Yields of caraota (Kg/ha) at Sabaneta . Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

C			D			2 meter path	E		
Irrigation* Ir-3			Irrigation* Is-4				Irrigation* Ir-5		
B†N	Trt†	B†S	B†N	Trt†	B†S		B†N	Trt†	B†S
895	F2 875	985	1650	F10 1365	1560		1210	F10 1270	1267
610	F4 572	752	602	F2 506	847		888	F2 590	896
780	F9 638	662	262	F0 373	472		588	F0 595	1026
1400	F8 940	1345	1370	F8 1045	1775		1208	F8 1070	1226
1175	F6 1105	1410	1500	F11 1345	1565		1126	F11 955	1323
1230	F11 1025	1480	1245	F7 1275	1455		1966	F7 1325	1353
870	F1 680	1210	1550	F4 1365	1770		1235	F9 1280	1401
1130	F5 897	1470	1035	F1 1280	1485		634	F1 755	746
1550	F3 1400	1800	1755	F4 1605	2215		1293	F4 1390	1259
1380	F0 1525	1805	1870	F6 2110	1735		1573	F6 1615	1421
1813	F7 1535	1745	1785	F5 1835	2390		1329	F5 1395	1558
1632	F10 1855	1752	1435	F3 1265	1603		1188	F3 1435	1586
Totals			Totals				Totals		

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row north (BN) or south (BS) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

Table 17. Yields of caraota (Kg/ha) at Sabaneta . Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

F			G			H		
Irrigation* Is-6			Irrigation* Is-7			Irrigation* Ir-8		
B†N	Trt†	B†S	B†N	Trt†	B†S	B†N	Trt†	B†S
997	F2 960	527	486	F3 469	927	1621	F7 1350	1434
1374	F4 1380	1094	1215	F5 725	1567	1872	F10 1630	1416
862	F9 1385	1054	999	F6 642	961	1761	F8 795	1216
883	F8 1215	1326	1077	F9 625	1345	1126	F1 735	958
1108	F6 755	224	437	F4 784	1429	643	F0 485	405
1285	F11 1310	464	673	F11 805	1007	838	F4 1130	680
830	F1 650	292	248	F1 615	826	1213	F6 1265	1019
1186	F5 855	434	157	F0 368	424	703	F2 495	502
864	F3 829	435	875	F7 1265	1227	1515	F11 1440	1151
1007	F0 785	373	1318	F10 1415	1728	1316	F3 985	857
1297	F7 1170	1056	1502	F8 1550	1555	1740	F5 1170	894
1229	F10 1275	1345	877	F2 1130	884	1540	F9 1235	1178
Totals			Totals			Totals		
12,922	12,569	8,664	9,864	10,393	13,880	15,838	12,715	11,710

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row north (BN) or south (BS) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments. Bs of Is-6 was very weedy. Adjacent rows also were affected by weeds.

Table 18. Analysis of variance and Duncans multiple range test for black bean (caraota) study in Guanare station, harvested February 15, 1971. Split plot design.

Source	Degrees freedom	Sum of squares	Mean square	F distribution
Irrigation	1	1,047	1,047	0,005 nonsign.
Error (A)	6	1,177,107	196,184	
Fertilizers	11	4,289,689	389,971	3,35**
Irr. x Fert.	11	880,595	80,054	0,688 nonsign.
Error (B)	66	7,676,430	116,309	
Total	95	14,024,870	147,630	

Fertilizer	Ranked Yield Kg/ha	95% Confidence†	99% Confidence†
		(431)	(640)
F0	696		
F1	792		
F2	797		
F3	1050		
F8	1126		
F4	1168		
F9	1169		
F5	1170		
F6	1213		
F7	1264		
F11	1269		
F10	1418		

†Treatments bounded by one line are not different at the level indicated. Those values above the beginning of each line are different than those below where the line ends.

Table 19. Statistical data for Sabaneta station black bean (caraota) study harvested February 15, 1971. Individual numbers are an average of 4 repeat observations.

Fertilizer treatment*	Ir†	Is†	Average	Standard error of means of fertilizer treatments = 120.5
F0	796	595	696	
F1	740	845	792	
F2	750	844	797	
F3	1126	973	1050	
F4	1065	1272	1169	
F5	1056	1284	1170	
F6	1205	1222	1213	
F7	1383	1144	1263	
F8	1084	1168	1126	
F9	1144	1194	1169	
F10	1626	1209	1417	
F11	1196	1342	1269	
Average	1098	1091	1094	
Standard error of means of Irrigation = 63.9				
Standard error between individual fertilizer means each with 4 repeat observations = 241.2				

*F = no fertilizer, F1-F3 30, 60, 90 Kg/ha of P, F4 and F8 40 and 80 Kg N/ha, F5-7 and F9-11 levels of both N and P.

†Ir = irrigation regularly (7 or 8 day intervals); Is = irrigations when symptoms of drying were evident.

Other noticeable yield differences exist. In block F of Table 17, rows BS and the adjacent treatment row had heavy grass competition in the lower field because herbicide was missed on that strip. Thus several BN plots (without grass) were much higher than the used treatment average or the BS plot (with grass):

Treatment	BN	Trt	BS
F5	1186	855	434
F3	864	829	435
F0	1007	785	373
F7	1297	1170	1056

Reasons for other yield variations between treatments and border rows are not clear. With no appreciable irrigation variable, borders should be the same as treatments. Yet some great variations occur. For examples look up yields for the following treatments and borders in Tables 15, 16 and 17:

Irrigation block	Fertilizer treatments	Irrigation block	Fertilizer treatments
A	F3, F5, F1, F0	E	F2, F0, F7
B	F11, F5	F	F2, F9, F8, F6 etc.
C	F8, F1, F0	G	F3, F5, F9, F4
D	F8, F4, F5	H	F8, F1, F5

Some differences can be attributed to plant densities. Some random counts made January 7 were as follows for 2 meters:

Count	96,	88,	72,	90,	76,	96,	54,	85
Duplicate of above			94		92		70	78

The density for this area should have been 64 plants. So thinning to stand was not done as was reported. Some densities were 525,000 plants/ha instead of 350,000. By January 7 it was too late to benefit by thinning. So some areas were more dense than others and this probably affected yields considerably.

The yield averages listed in Tables 18 and 19 indicate a response of yield to added nitrogen but not much to added phosphorus. At a 95% confidence level F0, all P-only treatments and F8 (only N) are significantly different from (lower than) all other treatments having nitrogen. Even F8 just misses being statistically different. However, as indicated by yield averages in the following tabulation, only nitrogen caused statistically different yields

N level	P level, Kg ha			
Kg/ha	0	30	60	90
0	696	792	797	1050
40	1168	1170	1213	1264
80	1126	1169	1418	1269

Yield increases across a column indicate response to P; increases down a column indicate a response to N. Possibly without N, a response is indicated between 60 and 90 Kg P/ha. The greatest consistent change is from 0 nitrogen to 40 Kg N/ha at most levels of P.

In summary, yield and moisture data on caraota at Sabaneta showed no application differences in field moisture and no yield differences due to irrigation variable. Differences from fertilizer treatments are highly

significant. This response seems to be primarily due to zero nitrogen or plus nitrogen.

Guanare - 1970-71

The caraota study in Guanare was supervised by R. W. Miller and Ing. Eduardo Chávez. Direct field supervision was under these two men and peritos Palacios and Jiménez. R. W. Miller made more frequent observations and directed more of daily operations of this experiment than occurred in Las Majaguas or Sabaneta which were 100 and 65Km distant.

Planting in Guanare was later than in the other experiments (December 16, 1970). In the first three weeks 44mm of rainfall fell. This was supplemented by irrigation. The moisture regime is given in Table 20 and figure 4.

It is interesting to compare the "net moisture" in figure 4 with that in figures 2 and 3 (Las Majaguas and Sabaneta). The net moisture in Guanare is much higher. Even the Is (drier) irrigation treatment is as high as any of the wet treatments in Sabaneta. The Ir treatment had double or greater water than the other stations. The soil will not store this quantity of water addition. A first reaction is deep percolation (the net moisture already has runoff losses subtracted). The short irrigation times and low infiltration values for deep percolation suggest to the senior author that a much higher evapotranspiration occurs than that value calculated. For example, of 5.70cm of water infiltrated on January 23, 4.37cm had infiltrated within 2 hrs. and only 1.33cm more in the next 4 hrs. Most irrigations were less than 6 hours duration. Therefore drying between irrigations must have involved higher than calculated evaporation and transpiration. In any case, the moisture levels in Guanare were high for Ir and much higher than Is, which

Table 20. Estimates of the soil water status of Guanare black bean (caraota) experiment including rainfall and irrigation additions and presenting losses according to consumptive use estimates given by Christiansen and Hargreaves (1968). Additions minus total pan evaporation is given as a comparison, since the factors given seem too small for early and late season use.

Date interval	Rainfall mm	Irrigation mm	Class A pan evaporation mm	Evapotransp. factor*	Calculated evapotransp.* mm	Rain + irrigation minus pan evap. accumulative, mm		Rain + irrigation minus calc. evapotransp., accumulative, mm	
						Ir+	Is+	Ir+	Is+
Dec. 15-21	20.1	Ir-47.7	29.1	0.20	5.8	38.7	- 9.0	62.8	14.3
Dec. 22-28	1.4	Ir-55.5 Is-52.5	31.7	0.30	9.5	63.9	13.2	110.0	57.3
Dec. 29- Jan. 4	22.3	Ir-47.8	28.8	0.40	11.5	105.2	6.7	168.8	45.8
Jan. 5-11	0	Ir-49.8 Is-50.7	40.0	0.65	26.0	115.0	17.4	192.6	70.5
Jan. 12-18	0	Ir-89.5 Is-44.9	43.4	0.85	36.8	161.1	18.9	245.3	78.6
Jan. 19-25	0	Ir-63.5 Is-58.2	41.3	0.90	37.2	183.3	35.8	271.6	99.6
Jan. 26- Feb. 1	0	Ir-74.1 Is-68.2	42.4	0.90	38.1	215.0	61.6	307.6	129.7
Feb. 2-8	0	Ir-60.0	48.4	0.80	38.6	226.6	13.2	329.0	91.1
Feb. 9-15	0	0	50.3	0.60	30.2	176.3	-37.1	298.8	60.9
Feb. 16-22	1.0	0	44.9	0.35	15.7	137.4	-86.0	283.1	46.2
Feb. 23- Mar. 1	7.8	0	41.0	0.20	8.2	88.6	-134.8	274.9	45.8

* Factor times class A pan evaporation equals as estimate of evapotranspiration. Factor changes with growth changes. Factors from Christiansen and Hargreaves.

+ Two irrigation regimes used were (1) irrigation on a regular interval of 7 or 8 days, Ir, and (2) irrigation within 3 days of marked symptoms of drying such as slight wilt and change to darker green color, Is.

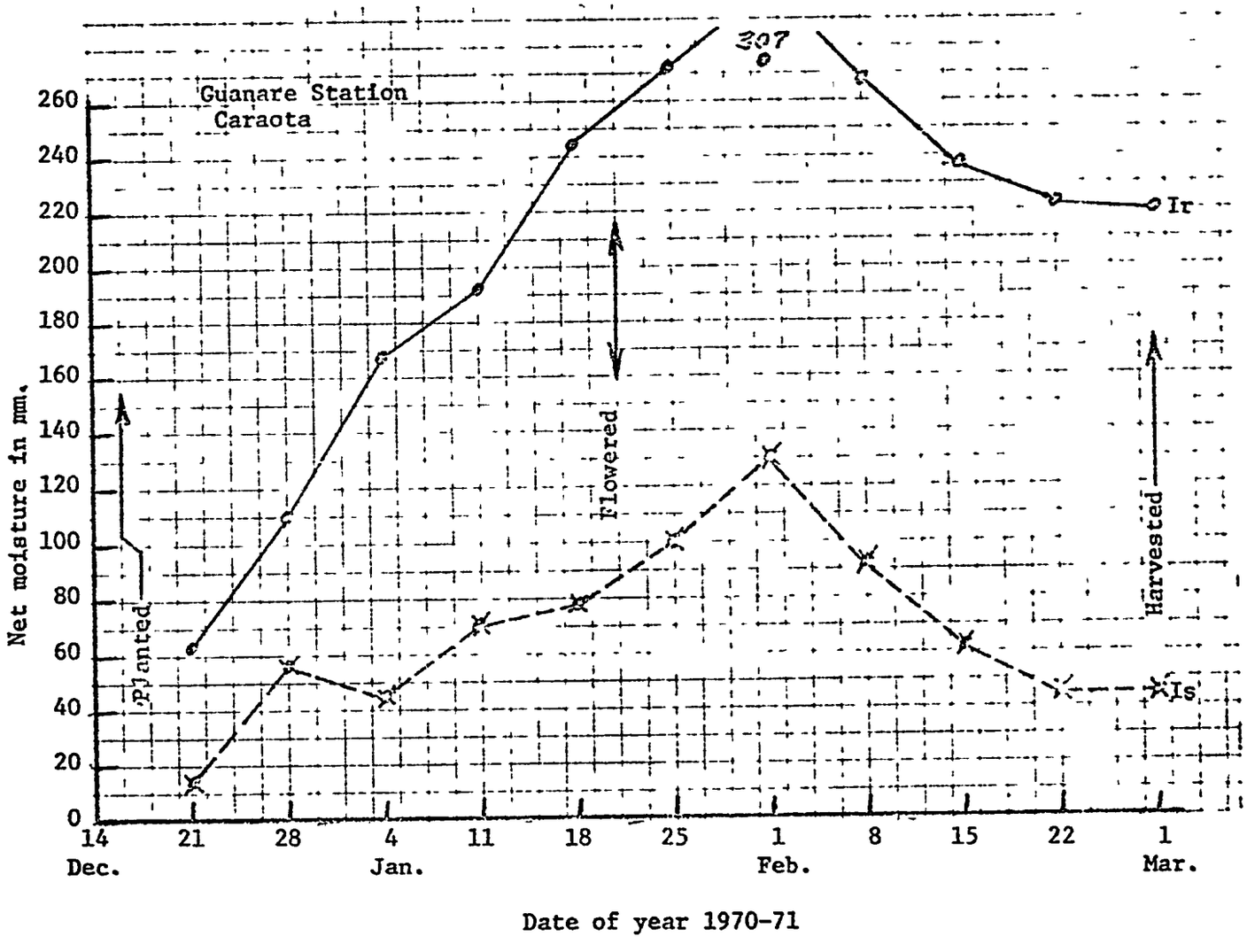


Fig. 4. Net moisture in irrigated black beans (caraota) in Guanare. Ir = irrigation done on an 7 day pattern except when rains made irrigation unnecessary (until January 2). Is = irrigation done only when dryness symptoms were marked. In this graph net moisture = irrigation plus rainfall minus the product of class A pan evaporation times the evapotranspiration coefficient for beans as estimated by Christiansen and Hargreaves (1968). This factor varied from 0.2 to 0.9.

was comparable to Ir in the experiments at Las Majaguas and Sabaneta.

Yield data are given in Tables 21, 22, 23 and 24. Generally, average yields are at least 50% or more higher than the other stations. Tables 22-24 list several samples with yields in excess of 2000 Kg/ha. But an additional problem was made by the data -- the control plots, F0, also had high yields. A tall, well fertilized field of cotton had been grown on this plot the year previous and the field was subsequently clean cultivated periodically until planted to black beans. Therefore, it is likely that the field had a good level of both phosphorus and nitrogen.

Statistical data is presented in Tables 25 and 26. Differences due to irrigation treatments was highly significant. Differences due to fertilizer treatment was also highly significant. Although yield differences between fertilizer treatments was small in Guanare, a better uniformity of yields resulted in more precision. For example, the variation of repeat[1] samples as indicated by the fertilizer mean square and its error mean square was 130,000 over 32,700 in Guanare but was 261,500 over 51,700 in Las Majaguas and 390,000 over 116,300 in Sabaneta. The smaller mean square especially of the error M.S. indicates better agreement among repeat samples.

The ranking of the fertilizer treatments by yields (Table 25) illustrates only that the control plot (F0) and phosphorus-only plots (F1, F2, F3) have lower yields than those with nitrogen. The differences are not great, generally about 200 Kg/ha. It is the opinion of the senior

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[1]Repeat sample is used rather than replicate because field position varied and the "duplicates" are therefore repeats rather than replications.

Table 21. Yield data (Kg/ha) for caraota in Guanare . Irrigation blocks are vertical columns; fertility levels are horizontally placed. Irrigations were weekly or within a few days of marked drying symptoms.

Fert trt	Irrigation at given intervals						Irrigation when symptoms show					
	1	2	3	4	5	Total	1	2	3	4	5	Total
F0	1,680	1,672	1,600	1,698		6,650	1,174	1,345	1,225	925		4,669
F1	1,773	1,721	1,377	1,283		6,154	1,264	1,181	1,043	900		4,388
F2	1,658	1,622	1,490	1,457		6,227	1,137	1,010	1,598	1,218		4,963
F3	1,730	1,452	1,231	1,434		5,847	1,338	1,294	1,142	1,298		5,072
F4	1,785	1,770	1,694	1,491		6,740	1,140	1,325	1,315	1,282		5,062
F5	1,594	1,710	1,758	1,950		7,012	2,067	1,400	1,123	1,317		5,907
F6	1,737	1,891	1,580	1,650		6,858	1,400	1,254	1,643	1,560		5,857
F7	1,976	1,831	2,381	1,691		7,879	1,433	1,401	1,410	1,174		5,418
F8	1,690	1,758	1,673	1,704		6,825	1,466	1,595	2,050	1,298		6,409
F9	1,992	1,830	1,934	1,705		7,461	1,560	1,337	1,536	1,130		5,563
F10	1,707	1,753	2,115	1,862		7,437	1,607	1,383	1,378	1,535		5,903
F11	1,937	1,750	1,775	1,782		7,244	1,420	1,424	1,330	1,193		5,367
Total	21,259	20,760	20,608	19,707		82,334	17,006	15,949	16,793	14,830		64,578

F0 = control; F1-F3 levels only of P; F4, F8 levels only of N; all others N plus P mixtures.

Table 22. Yields of carnota (Kg/ha) at Guanare . Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

⊗ A			B			⊗ C		
Irrigation* Ir-1			Irrigation* Ir-2			Irrigation* Is-3		
B†W	Trt†	B†E	B†W	Trt†	B†E	B†W	Trt†	B†E
1788	F10 1707	2060	1578	F3 1452	1510	1333	F7 1433	1541
1824	F2 1658	1643	1880	F5 1710	1608	1412	F10 1607	1638
1640	F0 1680	1830	1990	F6 1891	1620	--	F8 1466	1394
2187	F8 1690	1847	1959	F9 1830	1528	1185	F1 1264	1039
1893	F11 1937	1815	1656	F4 1770	1720	1080	F0 1170	1080
2166	F7 1976	1982	1865	F11 1750	2054	1234	F4 1140	1220
2160	F9 1992	2324	1890	F1 1721	1435	1528	F6 1400	1330
1870	F1 1773	1770	1772	F0 1672	1418	1220	F2 1137	1211
1745	F4 1785	1911	1780	F7 1831	1680	1390	F11 1420	1459
2176	F6 1737	1980	2052	F10 1753	1980	1507	F3 1338	1289
1633	F5 1594	1690	--	F8 1758	1952	2092	F5 2067	2295
1734	F3 1730	1658	1337	F2 1622	1248	1130	F9 1560	1833
Totals			Totals			Totals		

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row west (BW) or east (BE) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

⊗ = field edge or 1m. cleared pathway.

Table 23. Yields of caraota (Kg/ha) at Guanare . Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

Ⓧ C			D			Ⓧ E		
Irrigation* Is-3			Irrigation* Ir-4			Irrigation* Is-5		
B†W	Trt†	B†E	B†W	Trt†	B†E	B†W	Trt†	B†E
1333	F7 1433	1541	1414	F2 1490	1850	1244	F3 1294	1374
1412	F10 1607	1638	1770	F4 1694	1690	1312	F5 1400	1370
---	F8 1466	1394	1775	F9 1934	2138	1405	F6 1254	1519
1185	F1 1264	1039	1482	F8 1673	1751	1330	F9 1337	1471
1080	F0 1170	1080	1413	F6 1580	1865	1012	F4 1325	1350
1234	F4 1140	1220	1582	F11 1775	2008	1355	F11 1424	1387
1528	F6 1400	1330	1106	F1 1377	1341	1220	F1 1181	1161
1220	F2 1137	1211	1344	F5 1758	2104	1342	F0 1345	981
1390	F11 1420	1459	1202	F3 1231	1603	1170	F10 1383	1243
1507	F3 1338	1289	1410	F0 1600	1868	[illegible]	F7 1401	1455
2092	F5 2067	2295	2407	F7 2381	1965	1928	F8 1595	1465
1130	F9 1560	1833	2132	F10 2115	1855	1016	F2 1010	1522
Totals			Totals			Totals		

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row west (BW) or east (BE) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

Ⓧ = field edge or 1m. cleared pathway.

Table 24. Yields of caraota (Kg/ha) at Guanare . Blocks are in actual field position with a border double row on each side of a two-double-row treatment plot.

F			G			H		
Irrigation* Ir-6			Irrigation* Is-2			Irrigation* Is-8		
B†W	Trt†	B†E	B† W	Trt†	B†E	B† W	Trt†	B†E
1740	F10 1862	1676	1251	F2 1598	1608	1401	F3 1298	1690
1393	F2 1457	1558	1108	F4 1315	1437	1240	F5 1317	1770
1688	F0 1698	1691	1382	F9 1536	1260	1310	F6 1560	1870
1655	F8 1704	1795	1238	F8 2050	1261	1249	F9 1130	1390
1637	F11 1782	1870	1597	F6 1643	1383	1374	F4 1282	1199
1497	F7 1691	1630	1400	F11 1330	1188	1098	F11 1193	1316
1455	F9 1705	1760	895	F1 1043	762	840	F1 900	945
1220	F1 1283	1342	1119	F5 1123	942	782	F0 925	996
1287	F4 1491	1467	936	F3 1142	1213	930	F7 1174	1410
1374	F6 1650	1719	1008	F0 1225	1253	1350	F10 1535	1727
1723	F5 1950	1786	1200	F7 1210	1512	1247	F8 1298	1532
1581	F3 1434	1486	1257	F10 1378	1220	1176	F2 1218	1617
Totals			Totals			Totals		

*Irrigation differences were on a regular time period interval, "Ir," or after marked symptoms of drying were observed, "Is."

†Border double row west (BW) or east (BE) of the 4 treatment rows (two double rows). Treatments are F0 control; F1-F3 only P levels; F4 and F8 only N levels; all others are N plus P mixtures. A small amount of K is in all treatments except F0. Borders have same additions as treatments.

Ⓧ = field edge or 1m. cleared pathway.

Table 25. Analysis of variance and Duncans multiple range test for black bean (caraota) study in Guanare station, harvested March 1971. Split plot design.

Source	Degrees freedom	Sum of squares	Mean square	F distribution
Irrigation	1	3,284,120	3,284,120	565**
Error (A)	6	348,764	58,127	
Fertilizers	11	1,440,624	130,965	4.00**
Irr. x Fert.	11	464,431	42,221	1.29 nonsig
Error (B)	66	2,157,329	32,686	
Total	95	7,695,269	81,003	

Fertilizer	Ranked Yield Kg/ha	95% Confidence†	99% Confidence†
		(229)	(339)
F1	1318		
F3	1365		
F2	1399		
F0	1415		
F4	1475		
F11	1576		
F6	1589		
F5	1615		
F9	1628		
F8	1654		
F7	1662		
F10	1667		

†Treatments bounded by one line are not different at the level indicated. Those values above the beginning of each line are different than those below where the line ends.

Table 26. Statistical data for Guanare station black bean (caraota) study harvested March 1971. Individual numbers are an average of 4 repeat observations.

Fertilizer treatment*	Ir†	Is†	Average	Standard error of means of fertilizer treatments = 63.9
F0	1662	1167	1415	
F1	1538	1097	1318	
F2	1557	1241	1399	
F3	1462	1268	1365	
F4	1685	1265	1475	
F5	1753	1477	1614	
F6	1714	1464	1589	
F7	1970	1354	1662	
F8	1706	1602	1654	
F9	1865	1391	1628	
F10	1859	1476	1667	
F11	1811	1342	1576	
Average	1715	1345	1530	
Standard error of means of Irrigation = 34.8				
Standard error between individual fertilizer means each with 4 repeat observations = 128				

*F = no fertilizer, F1-F3 30, 60, 90 Kg/ha of P, F4 and F8 40 and 80 Kg N/ha, F5-7 and F9-11 levels of both N and P.

†Ir = irrigation regularly (7 or 8 day intervals); Is = irrigations when symptoms of drying were evident.

author that the Guanare plot has had enough previous fertilizer additions to earlier crops to not need much phosphorus. The data on P in Table 3 illustrate a high P level in Guanare soil. Tests of the soil of 8 control plots at 2 depths in each experiment during bean growth are shown in Table 27. Tests indicate a high phosphate level in Guanare soil, a very low level in Las Majaguas (response to added P expected) and in Sabaneta a likely response. These conclusions are confirmed by yield data already discussed in these various studies.

The difference due to irrigation is much greater (F-test value of 565**) than that of either Las Majaguas (11.2*) or Sabaneta (0.005-nonsignificant). Yield averages in the irrigation treatments are different (Ir = 1715 Kg/ha; Is = 1345 Kg/ha). The high moisture seems to benefit yield. Irrigations less frequent than 7 or 8 day intervals during the period 2 weeks before and about 3 weeks after flower set would seem to reduce yields, as a first approximation.

It is somewhat surprising that there is no significant fertilizer-irrigation interaction in this experiment. Perhaps both irrigation regimes are wet enough during the maximum fertilizer use periods (up to just past flowering) to grow equally at a given fertilizer level, but late season drying alters pod filling or number of pods formed. Seed weights for Is treatments average 5-8% lower than those of Ir. This is not enough to explain the effect of irrigation.

Some plot variation was likely due to non-uniform densities. Some random counts of plant numbers were: 74, 59, 63, 73, 58, 53, 61, 53 and 60. The average is 61. A density of 350,000 plants/ha would have 64 plants for the area counted in each instance. Thinning was poorly done and a few areas not done at all. However, the general appearance of all the plots

Table 27. Analysis of soil growing caraota in control plots (F0). All values in parts per million. Data by Ing. B. Fermín, director of the Soils Laboratory, Oficina Edafología, Guanare, Venezuela.

Sample No.	Depth, cm	Location of Sample			
		Guanare		Las Majaguas	Sabaneta
		B-K*	Olsen*	B-K	B-K
1	0-20	63		Trace	9
	20-40		120		1
2	0-20		64		15
	20-40	4			5
3	0-20		100		3
	20-40		36		3
4	0-20		92		3
	20-40	34			1
5	0-20		144		9
	20-40	49			6
6	0-20		200		2
	20-40		96		2
7	0-20	47			4
	20-40		9		2
8	0-20		96		8
	20-40	3			2

*Bray-Kurtz method for acid soils; Olsen bicarbonate method for neutral and alkaline soils; all in ppm.

Reference values:	Bray-Kurtz	Olsen
Needs added P	less than 7	less than 5
May need P	7-20	5-10
Has adequate P	20 or more	10 or more

Parcela 90 averages between 5 and 12 ppm with the Bray-Kurtz test.

was a uniform, dense cover that appeared quite satisfactory. Sparse plots grew plants that extended and branched more than those in dense plots.

In summary, the caraota yields in Guanare were 20% higher in the wetter irrigation -- weekly irrigations -- than in the treatment allowing more drying at some stages near flowering and during seed development. Only nitrogen or nitrogen plus phosphorus resulted in some yield increases.

Parcela 90 - 1970-71

Caraota in Parcela 90 were of much interest. A previous observation a year earlier on caraota planted by Ing. Tito Guilarte had indicated a strong response to nitrogen could be expected (see photo 2). The value of available P listed in Table 27 (5-12 ppm by the Bray-Kurtz method) indicated the P level is moderate; perhaps a response to P would be observed.

An error in the decision to use Cartoran herbicide rather than Laso caused the initial planting to die so extensively that it was replanted 3 weeks later by carefully raking over the original site and replanting in the identical pattern. Unfortunately the effect of the cortoran was still enough to affect the crop in some locations. No meaningful harvest or yield data were possible.

However, visual observations of growth indicated almost no response to added phosphorus but a marked difference due to added nitrogen. Photos 3 and 4 show caraota growth at seed development time. Growth in a different part of the same field in January 1970 is shown in photo 5. There were no exceptions in the 104 experimental plots that added N was the primary factor causing an increase in growth. Where nitrogen was in the treatment, the bean plants grew much better than where the fertilizer added contained only P and K or no fertilizer. For this example of Guanaguanare soil series,

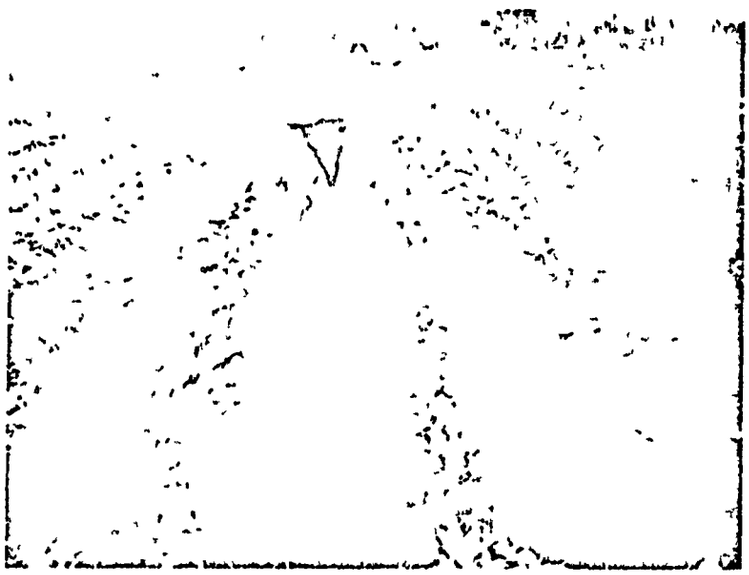

Photo 2. Growth of caraota (black beans) in Parcela 90 in the Guanare Irrigation System, December 1968. Rows of larger plants had nitrogen drilled when planting. Rows of smaller plants were planted without fertilizer added. Plants used moisture from the natural rainfall which decreases in October, November and December. The soil is Guanaguanare clay, one year out of forest cover, but with only clearing and pasture seeding operations that were unsuccessful. Phosphorus tests the following year indicate a possible response to phosphorus (7 to 12 ppm P in the Bray-Kurtz test). Soil oxidizable organic matter is approximately 2.9%, but variable. Response to N is clear.

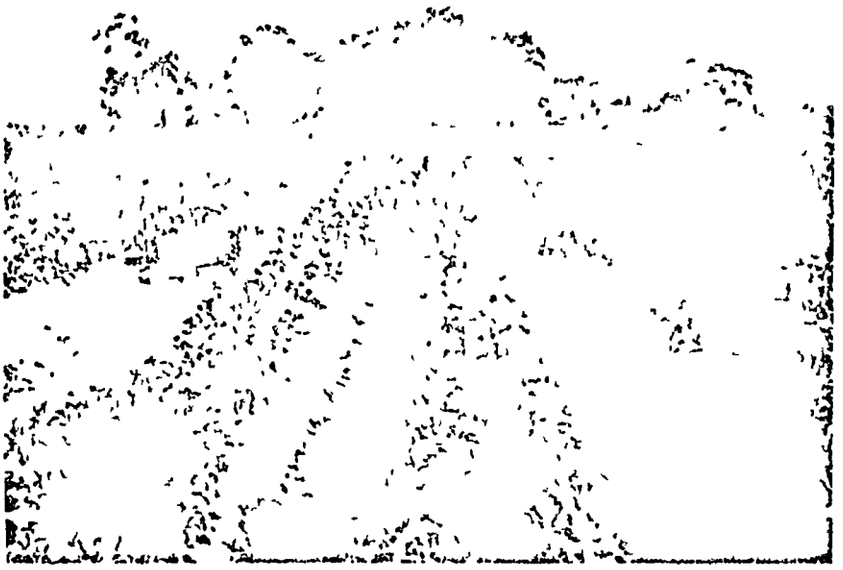

Photo 3. View of caraota (black beans) in Parcela 90, Guanare Irrigation System. Rows to extreme left are untreated control rows set up for other uses, but comparable to the regular plots. The four double rows (8 rows) from top to bottom are F10 (80 kg N, 60 kg P, and 15 kg K/ha), then F2 with the notebook and pencil (60 kg P and 15 kg K/ha), and the end of F8 (80 kg N plus 15 kg K/ha). Caraota responded well to nitrogen. Plants still show effect of an error in applied herbicide, cortoran, which should not have been used.

Photo 4. View of caraota (black beans) in Parcela 90, Guanare Irrigation System. From top to bottom for the four double rows from the right: F10 (80 kg N, 60 kg P, 15 kg K/ha), the short growth of F3 (90 kg P and 15 kg K/ha) and the closer view of the lower part of F5 (40 kg N, 30 kg P and 15 kg K/ha). The lack of N in F3 reduces growth noticeably. The next four double rows to the left are F2 (60 kg P/ha) for the short growth and F10 for the end of the field (top of photo). Again, the lack of N results in very poor growth.

Photo 5. Close-up view of caraota (black beans) in Parcela 90, Guanare Irrigation System. Growth is still in early stages. However, the F5 treatment (40 kg N, 30 kg P plus 15 kg K/ha) is considerably better than the F2 treatment (60 kg P and 15 kg K/ha). Response to added nitrogen is easily evident for caraota in this Guanaguanare soil series field.

caraota responed markedly to added N and good growth of plants depend on it. Response to added phosphorus is less clearly visible, but response seemed likely when added with additional nitrogen.

Extra Observations

In Table 28 is listed a summary of yields in the three stations. All of these plots had identical fertilizer treatments. Yields should be affected only by irrigation differences. The four double rows in each of the 8 irrigation blocks were harvested separately and the two outside border rows are labelled east and west (or north and south). Therefore all yields down one column should be identical if there was no error, border effect or other error factor. The variation also indicates experimental error, except that all these plots exist at the bottom of the field, and do not exhibit soil variation from top to bottom of the field.

Irrigation affects are only obvious in the Guanare treatment, which correspond to the conclusion by statistical analyses already discussed. The data emphasize the need for 5 or more replications (repeats) in future studies in order to have confidence in the results.

Table 28. Yields in Kg/ha of black beans (caraota) in 3 locations in Portuguesa State, Venezuela. All treated with 80 Kg N/ha, 60 Kg P/ha and 15 Kg K/ha. Code numbers do not indicate position. Blocks of different irrigation schemes were intermixed. Locations are Guanare, Las Majaguas and Sabaneta.

Code number of row	Irrigation at regular time intervals			Code number of row	Irrigation when symptoms of drying are evident		
	Guan.	Maj.	Sab.		Guan.	Maj.	Sab.
East* 1	1980	1038†	1928†	East 17	1528	666	2061
2	1866	863	1588	18	1572	1070	2030
3	1933	1023	1430	19	1628	721	1758
West 4	2170†	755	1928	West 20	1600†	863	1570
East 5	2010†	979	1860	East 21	1585	1141	2280
6	1855	830	1870	22	1532	851	1890
7	1855	1078	1660	23	1532	943	1990
West 8	1852	910	1760	West 24	1677†	913	2050†
East 9	2090†	795†	2075†	East 25	1603	735	1500
10	1977	1008	1935	26	1505	513	1580
11	1821	888	1825	27	1543	844	1590
West 12	1808	787	1865	West 28	1320†	484	1490
East 13	2046†	1088	1505	East 29	1678†	590	1720
14	1722	962	1285	30	1558	766	1505
15	2000	1094	1575	31	1687	994	1710
West 16	1518	412	1555†	West 32	1472	617†	1435
Ave.	1969	908	1728	Ave.	1565	795	1757

* For Sabaneta, east corresponds to north, west to south.
† Rows adjacent to cleared foot paths or other open area.

SUMMARY AND CONCLUSIONS

1. Of 35 varieties of caraota (black beans) planted in trials with irrigation and low planting densities (150,000 plants/ha) the yield ranking was as follows:

Best ——→	Venezuela 36	2465 Kg/ha
	Cubagua	2358 Kg/ha
	I - 4	1965 Kg/ha

and in order of decreasing yield,

Jamapa, Porillo No. 1, Venezuela 44-1, Cubagua (second plot), ICA-Tuf, I-113 and ICA-Ha. Most varieties with prefixes "Guatemala" did quite poorly.

2. Yields of caraota in Las Majaguas Irrigation district on Algodonal soil series (mixed with some Agua Blanco series) was relatively low, averaging 875 Kg/ha. Because of early season rainfall, irrigation variables occurred only during the period just before flowering until 3 weeks after flowering. Yet the weekly irrigations averaged yields 190 Kg/ha more than those lots with less irrigation.

Yield differences due to fertilizer treatments were significant at the 99% confidence level. Five of the 6 treatments with both N and P added were significantly different from the control at the 99% level. At 95% confidence, all treatments with N plus P were different from the control.

Response to P is apparent. Soil test for available P are very low (tests are given as "trace"). Generally, P-only treatments yielded greater than the control and some N-only treatments.

Approximate yield categories were as follows:

Treatment	Yield	Approximate increase over control
Control	580 Kg/ha	---
N or P only	760 Kg/ha	180 Kg/ha
N plus P mixtures	900-1060	400 Kg/ha

3. Yields of caraota in Sabaneta (Bocono Irrigation System) on Fanfurria soil series (1094 Kg/ha) were greater than in Las Majaguas. Differences due to irrigation regimes did not occur. This was because early rainfall and the need for irrigation resulted in essentially equal moisture regimes in all blocks. The soil seemed to seal easily (high sand and silt content) and infiltration was low. Weekly irrigation seems needed on this soil.

   Differences in yield due to fertilizer variables were statistically highly significant. It is difficult to compare averages too closely because of soil variations that caused repeat treatments to have yield variation. Response was evident to added N, but very little obvious effect of P was measured. Several soil tests average test values for the Bray-Kurtz method of 7ppm; a range of 7-20 indicates a need for P is possible. A response to P should be more evident. The senior author recommends use of phosphorus in future tests.

4. Yields of caraota in Guanare Irrigation System on Guanare soil series (1530 Kg/ha) were the highest of the 3 locations. There were highly significant differences due to both irrigation and fertilizer variables. Plots with weekly irrigations averaged yields of 360 Kg/ha more than plots with less frequent irrigation. The dry regime in this study was as wet as any regime in the other two studies and its yield is higher. Frequent irrigation seems very valuable. The senior author

also believes that this attention to irrigation frequency is most important approximately 2 weeks before and 2 weeks after flowering or until drying time.

Several plots yielded over 2000Kg/ha. Yet yield differences due to fertilizer treatment are low (maximum of about 300Kg/ha). This is believed a result of high fertility of the field from previous history of cropping and fertilizer. As an example, available P tests are very high. The Bray-Kurtz method tests 55ppm (20ppm is adequate) and the Olsen method tests 127ppm (10ppm is adequate). Yields on high fertility Guanare soil can be high with adequate (weekly) irrigation. Yields were increased by additional nitrogen.

5. Visual observations of plant growth in Parcela 90 of Guanare Irrigation System (Guanaguanare soil series) produced the conclusion that caraota will respond markedly to additions of 40Kg/ha or more of N. Response to P will only be obvious if added with N, but increased plant growth from added P will be less than for added N.

RECOMMENDATIONS

1. Study responses to N and P fertilizer applied by machine (at set distances from the seed) for earlier response and more efficiency. Larger and fewer random plots would need to be used, but harvest many replications within a single block.
2. Continue N tests with caraota plantings on heavy soils.
3. Investigate in detail the problems of the Algodonal soil series on the Los Majaguas station. Make a good detailed laboratory analysis, root penetration study and yields under heavy fertilization study.

4. Study sealing properties of the Fanfurria soil series in Sabaneta station including trials to increase infiltration such as shallow chiselling before irrigation and Serpentine irrigation.
5. Make experiment station maps for each experimental parcela with location and nature of all experimental treatments on it. These need to be done at least twice yearly. The fertility in the Guanare station soil indicated what a gradual buildup will do to subsequent research studies. Continual records need to be kept.

RESUMEN Y CONCLUSIONES

1. De las 35 variedades de caraota (frijol negro) plantadas en pruebas con riego y densidades bajas de siembra (150,000 plantas/Ha.) el orden de los rendimientos es el siguiente:

El mejor ——→	Venezuela 36	2465 kg/Ha.
	Cubagua	2358 kg/Ha.
	I - 4	1965 kg/Ha.

y el orden de los rendimientos decrecientes:

Jamapa, Porillo No. 1, Venezuela 44-1, Cubagua (segunda parcela), ICA-Tuf, I-113 y ICA-Ha. La mayoría de las variedades con prefijos "Guatemala" dieron pobre resultado.

2. Los rendimientos de caraota en el Distrito de Riego de Las Majaguas, en la serie de suelo Algodonal (mezcladas con alguna serie de Agua Blanco) fueron relativamente bajos con un promedio de 875 kg/Ha. Debido a la temprana estación de lluvia, las variables de riego ocurrieron solamente durante el período apenas antes de floración hasta tres semanas después de ésta. No obstante, las parcelas donde se aplicaron riegos semanales tuvieron un rendimiento de 190 kg/Ha. más que las parcelas donde hubo un riego menor.

Las diferencias en rendimiento debidas a los tratamientos de fertilización fueron significativas al nivel de confianza del 99%. Cinco de los seis tratamientos en los cuales se agregaron tanto N como P fueron significativamente distintos de los del control al nivel del 99%. Al nivel de confianza del 95%, todos los tratamientos con N más P fueron distintos del control.

La respuesta al P es aparente. Los resultados en los ensayos de suelo para P disponible son muy bajos. (Se dan los ensayos como "trazas".) En general los tratamientos unicamente con P dieron rendimientos aparentemente mayores que los del control y algunos de los tratamientos unicamente con N.

Las categorías de rendimiento aproximado fueron como sigue:

Tratamiento	Rendimiento	Incremento Aproximado Sobre el Control
Control	580 kg/Ha.	---------
N o P solamente	760 kg/Ha.	180 kg/Ha.
N más mezclas de P	900-1080	400 kg/Ha.

3. Los rendimientos de caraota en Sabaneta (Sistema de Riego de Boconó) en serie de suelo Fanfurria (1094 kg/Ha.) fueron mayores que los de Las Majaguas. Las diferencias debidas a regímenes de riego no ocurrieron. Esto fue debido a que la lluvia temprana y la necesidad de riego resultaron en regímenes esencialmente iguales de húmedad en todos los bloques. El suelo pareció sellarse facilmente (contenido alto en arena y limo) y la infiltración fue baja. Este suelo parece necesitar riego semanal.

Las diferencias en rendimiento debidas a las variables de fertilizante fueron altamente significativas estadisticamente. Es difícil comparar estrechamente los promedios por la variación grande en el campo, la cual ocasionó una variación grande en los tratamientos repetidos. Una respuesta fue evidente cuando se agregó N, pero se observó muy poco efecto obvio de P. Varios ensayos de suelo promedian valores de ensayo por el método Bray-Kurtz de 7 ppm.; un rango de 7-20 indica que sea posible una necesidad para P. Una respuesta a P debería ser más evidente. El autor principal recomienda el uso de fósforo en ensayos futuros.

4. Los rendimientos de caraota en el Sistema de Riego de Guanare en serie de suelo Guanare (1530 kg/Ha.) fueron los mayores de las 3 localidades. Hubieron diferencias altamente significativas debidas a ambas variables de riego y fertilizante. Las parcelas con riegos semanales promediaron rendimientos de 360 kg/Ha. más que las parcelas con riego menos frecuente. El regímen seco de este estudio fue tan húmedo que cualquier regímen en los otros dos estudios, y su rendimiento es más alto. El riego frecuente parece ser muy valioso. El autor principal también cree que la atención a la frecuencia de riego es más importante aproximadamente 2 semanas antes y dos semanas después de la floración o hasta el tiempo de seca.

   Varias parcelas rindieron más de 2000 kg/Ha. No obstante, las diferencias de rendimiento debidas a los tratamientos de fertilizante son bajas (un máximo de aproximadamente 300 kg/Ha.). Se cree que esto es un resultado de la fertilidad alta del campo, debida a la historia previa de cultivo y fertilizante. Por ejemplo, ensayos de P disponible son muy altos. El método de Bray-Kurtz resulta en 55 ppm. (10 ppm. es adecuado.). Los rendimientos en suelo de Guanare de alta fertilidad pueden ser altos con riego adecuado(semanal). Los rendimientos fueron aumentados por nitrógeno adicional.

5. Observaciones visuales del crecimiento de las plantas en Parcela 90 del Sistema de Riego en Guanare (serie de suelo Guanaguanare) llevaron a la conclusión de que la caraota responderá marcadamente a adiciones de 40 kg/Ha. o más de N. Una respuesta al P será obvia solamente si es agregado con N, pero el aumento de crecimiento de las plantas por P agregado será menos que por N agregado.

RECOMENDACIONES

1. Estudiar las respuestas con respecto a fertilizantes de N y P aplicados por medio de máquina (a distancias fijas de la semilla) para obtener más eficiencia y una respuesta más temprana. Deberían ser usadas menos parcelas de mayor tamaño y escogidas al azar, pero debería cosecharse varias repeticiones dentro de un bloque simple.
2. Continuar ensayos de N con siembras de caraota en suelos pesados.
3. Investigar en detalle los problemas de la serie de suelo Algodonal en la estación de Las Majaguas. Hacer un buen análisis detallado de laboratorio, un estudio de la penetración de las raices, y los rendimientos bajo condiciones de alta fertilización.
4. Estudiar las propiedades de sellarse de la serie de suelo Fanfurria en la estación de Sabaneta incluyendo pruebas para aumentar la infiltración tales como cinceleo poco profundo antes del riego y riego en Serpentina.
5. Hacer mapas de la estación experimental para cada parcela experimental incluyendo la ubicación y naturaleza de todos los tratamientos experimentales en ella. Esto debe hacerse por lo menos dos veces al año. La fertilidad del suelo en la estación de Guanare indicó lo que podría resultar por una acumulación gradual en cuanto a estudios de investigaciones subsecuentes. Archivos continuos deben ser mantenidos.

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