

BAC

MODULO DIGITAL



El documento fuente se encuentra en
La Biblioteca Agropecuaria de Colombia

ELEMENTOS BIBLIOGRAFICOS

AUTOR (ES): Fullertón, T.M.; García Saad, H.; James, D.W.
TITULO: Terminal report on-farm water management research at Granja Malambito; Atlántico no.3 irrigation distric Atlántico, Colombia
LUGAR DE PUBLICACION: [s/] (Colombia)
EDITORIAL: [Instituto Colombiano Agropecuario]
AÑO DE PUBLICACION: 1973
PAGINAS: 46 p.

INTRODUCTION

The purpose of the Utah State University (USU) program is to increase food production in the arid and sub-humid lands of the less developed countries through improvement of irrigation management practices and the coordination of these practices with other crop production management procedures. Within this broad criterion, specific objectives vary according to the needs of the particular host government and USAID Mission where projects are located. In Colombia studies were conducted in collaboration with the Colombian Agricultural Institute (ICA) over a two year period on heavy soils of an irrigation district in a Northern province. The original objectives included the development of consumptive use data and the determination of yield functions of soil moisture and fertility for crops of economic importance to the district. Another objective was to provide the opportunity for Colombian counterparts to gain experience in both investigative and applied aspects of irrigation technology.

These objectives were not achieved: Field experiments with crops common to the district were established soon after initiation of the project. But crops grown in the study plots were highly erratic due to the presence of stunted and chlorotic areas randomly interspersed with areas of plants which appeared normal. Variability within experimental stands obscured the effects of irrigation and fertilizer treatments. Crop root development was found limited to the first few inches of the soil profile for both stunted and normal plants. Problems observed

on research plots were identical to those of farmers in the region utilizing the same crops on similar soils. Crop growth problems appeared to be more closely related to soil than to any other factor. (Six different crops were evaluated under a variety of treatments in one or more of fourteen field tests.)

It was concluded that valid irrigated crop production information could not be developed unless the source of crop variability could be determined and corrected, or unless alternative crops well adapted to conditions of the area could be found. Objectives of the project were thus modified to include these considerations. Mr. William Rubink, candidate for the M.S. degree in soils at USU was subsequently assigned to the project for a period of three months in order to carry out intensive sampling of the heavy soils for both chemical and physical analyses. Numerous samples were forwarded to Colombian laboratories and to the Department of Soil Science and Biometeorology, USU.

The purpose of this report is to provide a record of the research conducted and to present conclusions pertaining to agricultural production in Southern portions of the Atlantico #3 irrigation district which were developed as a result of the Water Management Project.

LOCATION

The Atlantico #3 irrigation district of the Colombian Agrarian Reform Institute (INCORA) is located on the North coast of Colombia in the southern most part of the state of Atlantico. Latitude is

approximately 10" N. Climate of the area is tropical and sub-humid with about one meter of rainfall annually. Cropping cycles are referred to as semesters. Planting occurs during April followed by harvest in July or August (Semester A). The second cropping cycle (Semester B) is initiated in August. The period of greatest rainfall usually begins in August and terminates in December. January through March are characterized by drought. The mean annual temperature of the area is 28" C which varies from a low of 20" C to a high of 38" C. The relative humidity commonly fluctuates from 50% at midday to more than 90% during the night. Pan evaporation is listed at two meters annually, ranging from a high of more than 200 mm in March to a low of near 100 mm in November. Elevation above sea level for the zone where studies were located varies from 3 to 6 meters. Much of the district consists of former marshland which was subject to periodic inundation from the Magdalena River and the Canal del Dique. The area was drained through construction of dikes and drainage canals. Excess waters of the canal system are currently pumped into the Canal del Dique.

The Malambito Experiment Station of INCORA is situated on flood plain soils near the divergence of the Magdalena River and the Canal del Dique. Soils on the side of the station which parallels the Magdalena River are light in both color and texture, containing a high percentage of fine sand. Soils of the Northwest side of the farm are dark, of heavy texture and characteristically shrink upon drying. Results of field tests with crops and soil analyses discussed in this report are limited to the heavy soil area of the Malambito farm.

The Southern sector of the irrigation district consists of approximately 37,000 hectares. Soils of the site where studies were conducted are considered representative of 40% of this area. Most of the lands surrounding the Malambito station are utilized for commercial crop production as a part of the land reform program of INCORA. The region constitutes an important part of the district due to a large investment in irrigation and drainage facilities.

PROCEDURES

Project activities were initiated in October, 1971, with emphasis on obtaining water/fertilizer interaction data for economically important crops. This emphasis gradually changed to obtain a resolution of soil-related problems. This report gives the results somewhat in the same order in which they occurred. Tests conducted on the Malambito experiment station are summarized individually according to the crop involved followed by a brief review of information developed on soils.

The M.S. thesis of Mr. William **Rubink** entitled An Intensive Edaphological Characterization of the Soils of Malambito Experimental Station and its Implications in Future Agricultural Research has been submitted as a separate project report. Mr. **Rubink's** thesis provided a basis for further research at USU concerned with chemical properties of the heavy soil as related to erratic crop growth and low yields. A manuscript of this work has been submitted as part of the overall project report. The soils information presented here consists primarily of **a review** of these two reports. Persons desiring a more complete

treatment of this subject should direct requests for copies of these reports to the Department of Agricultural and Irrigation Engineering, USU or Departamento de Ingenieria Agricola, ICA.

CROPS

Sorghum and cotton were produced more extensively than other crops in the irrigation district at the time the Water Management Program was established in **Atlantico #3**. Sorghum was generally planted the first semester and rotated with cotton the second semester. Sesame was widely grown by irrigation district farmers during 1970 and 1971 but with little success. Limited plantings of soybeans had led to the conclusion that this crop was highly unsuitable for the Southern region of the district. Less than ten hectares were under cultivation in the South Sector in late 1971. Corn was produced by campesinos throughout **Atlantico #3** for home consumption but not as a cash crop. No rice was grown in the district at the time project activities were initiated.

Sesame

A field test for the purpose of comparing the response of sesame to various combinations of nitrogen and phosphorous under irrigated and **dryland** conditions was initiated in November 1971. A split-split plot design was utilized for the experiment with irrigated and **non-**irrigated treatments as main plots, nitrogen levels as subplots and phosphorous and a control as split-subplots. Nitrogen treatments consisted of 0, 25, 50 and 75 kg/ha applied as urea. Phosphorous

applied in bands as triplesuperphosphate equivalent to 50 kg/ha of P_2O_5 was randomized with a control (zero rate) within each nitrogen plot. The test was replicated four times.

Adequate soil moisture from rain was present in the study area through most of December for crop growth. In late December, 5 cm of water were applied as an irrigation treatment which resulted in heavy crop lodging. Programmed additional applications of water were suspended. In the study crop variability was also increased by extreme, localized differences in soil. In some plots the test plant height at maturity varied from well over 100 cm to as low as 50 cm within a distance of two or three meters, irrespective of water or fertilizer treatment.

No statistical differences were found between the irrigated and non-irrigated treatments or the nitrogen treatments as reflected by measurements of plant height or yield. Application of phosphorous resulted in significant decreases in both height and yield (Table 1). Sesame in plots which received irrigation water appeared greener and more vigorous. However, reductions in yield from lodging may have masked any beneficial effects of applying water. Error introduced by extreme soil variation could account for the lack of a measurable response to water or nitrogen. Antagonistic interactions between phosphorous and other plant nutrients could have caused the depressed growth where phosphorous was applied.

Sesame plants examined after lodging had occurred were found to have roots which extended only 10 to 15 cm in depth for mature plants rather than 40 to 60 cm as normally expected. Formation of a **hardpan** through

excessive machinery use during **seedbed** preparation could be a cause of stunted roots in sesame on the heavy soils. It was observed during the experiment that rain or irrigation water accumulated rapidly at the soil surface, saturating only the first few centimeters of soil. Failure of water to penetrate could also be the result of a shallow **hardpan**.

Throughout the test area sesame developed interveinal chlorosis shortly after 50 cm of plant height had been attained. The symptom remained until flowering was initiated. Tissue analysis of both normal and chlorotic leaves suggested that all nutrients measured were present in adequate quantities, perhaps with the exception of manganese (Table 2).

A second field test with sesame was planted in April, 1972, to determine if foliar applications of manganese or other minor element solutions would improve both plant color and growth. Solutions containing varying amounts of manganese, iron, zinc, and magnesium were applied after plants had reached approximately 50 cm of height. Treatments and rates are listed in Table 3. Each solution was applied with and without a surfactant (1% v/v). Individual plots contained three rows of sesame plants 5 meters in length. Treatments were applied to two of the rows and compared to the third which served as a control in an attempt to remove experimental error created by soil differences. The test involved four replications. Visual estimates of color were not analyzed statistically.

Foliar treatments with manganese resulted in the development of a more intense, green color by sesame within two weeks after the applications were made (Table 3). Addition of a surfactant to the

Table 1. Chino Rojo sesame. Yield and plant height as influenced by phosphorous.

Phosphorous treatments	Plant height (m)	Yield (kg/ha)
control	1.26 a	594 a
P_2O_5 (50 kg/ha)	1.19 b	544 b

¹Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 2. Chino Rojo sesame. Tissue analyses of normal and chlorotic sesame leaves in parts per million

Leaf condition	<u>P</u>	<u>K</u>	<u>Na</u>	<u>Ca</u>	<u>Mg</u>	<u>Mn</u>	<u>Zn</u>	<u>Cu</u>	<u>Fe</u>
normal	2950	18775	375	13000	4050	20	66.5	35	380
chlorotic	4050	26875	500	13750	3475	20	73.5	40	313

Table 3. Chino Rojo sesame. Color ratings and fresh weight as % of control as influenced by foliar treatments with trace elements.

Treat- ments	Rate (kg/ha) ¹	Color ratings ²			Fresh wt. % of control
		Without surf- tant	Surfac- tant added	Ave. for total	
control		2.5	2.5	2.5	100 a ³
FeSO ₄	1%	1.9	2.5	2.2	103 a
" 4	1% + 1%	2.2	2.2	2.2	92 ab
Mnso	1	2.7	4.1	3.4	111 a
" 4	2	2.9	3.0	2.9	103 a
"	8	3.3	3.6	3.4	109 a
"	30	4.4	4.6	4.5	95 a
ZnSO ₄	1	2.6	3.0	2.8	94 ab
" 4	2	3.8	3.5	3.6	92 ab
"	4	2.3	3.7	3.0	101 a
"	8	3.4	3.3	3.3	75 b
MgSO ₄	5	2.3	2.8	2.5	94 ab
" 4	10	2.6	2.7	2.6	98 a
"	20	2.4	2.9	2.6	97 a
"	40	2.6	2.5	2.5	103 a

¹FeSO₄ was applied as a 1% solution on one date or two dates with a one week interval between applications.

²0 = chlorotic; 5 = intense green.

³Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

solution seemed to amplify this effect. The chlorosis became apparent again after three weeks, following the production of new leaves. Plants were harvested the third week in June and fresh weights as a percent of the control were calculated. No significant increases in fresh weights over those of the control were found as a result of foliar treatments with trace elements.

An attempt was also made to study soil-applied manganese effects on sesame. The test included a control and lime treatments incorporated into the soil at rates of 1000, 3000, 5000 and 7000 kg/ha in early September, 1972. The purpose of the lime treatments was to aggravate manganese deficiency symptoms noted in earlier sesame experiments as well as to determine if sesame would respond to this soil amendment. A 25 kg/ha treatment of MnSO_4 and a control were randomized within each lime plot as subplot treatments shortly before seeding on November 30, 1972.

The sesame was characterized by interveinal chlorosis within two weeks after germination in both the control and soil-applied Mn treatment. Erratic growth was observed throughout the test area at six weeks after seeding. Lime at all rates appeared to have no effect either on plant color or stunting. Lime may not have been present in the soil long enough to affect the soil reaction. A foliar Mn solution (2 kg/ha) was applied to sesame plants in different areas of the experiment which resulted in the development of a dark green color. However, plants remained stunted following treatment with this material. The test was abandoned in late February due to extreme variability and drought.

Soybeans

A water/fertility interaction study involving ICA Taroa soybeans was initiated in January, 1972. Field plots were arranged according to a split-split plot design. Moisture levels were varied during **podfill** for mainplots with a control and nitrogen at rates of 50, 100 and 150 kg/ha as subplots. Phosphorous applied as 100 kg/ha of P_2O_5 and a control were randomized within each nitrogen plot for the split-split plot treatments.

Furrows were formed and the soybeans were seeded into the dry ridges. Germination was induced by irrigating from a single line of sprinklers which extended the entire length of the experiment. The inside row of each plot or that nearest the sprinkler line received 7.0 cm of water. This amount gradually decreased across the plots to the outside row where 5.5 cm were measured. Dry soil was noted within the ridges at points furthest from the sprinklers. Soil moisture of the entire study area was not brought to field capacity until a period of three weeks had passed due to a breakdown in the irrigation system serving Malambito. Although excellent germination was obtained, parts of the stand were lost during this period from lack of moisture. This effect was most pronounced in the outermost three rows of each plot which were not harvested. After adequate soil moisture had become available, plants in all areas of the experiment remained stunted. All treatments received equal amounts of water during February.

Soil moisture levels in the irrigation treatments were adjusted according to tensiometer readings from a soil depth of 12". During the

enlargement was in progress, 11 cm of water was applied by furrow irrigation when the tensiometers read 0.5 bars in the high moisture treatments. An additional 11 cm were applied in these plots three weeks later when soil moisture tension again reached 0.5 bars and also in those of the intermediate moisture treatment. Control plots received no irrigation water after February. The soybeans were harvested when shattering began to occur. Harvesting was required in the control irrigation treatment plots three weeks earlier than those of the other two treatments.

As expected, soybean yields increased as a result of treatments which involved irrigation during **podfill** over yield of the control treatments (Table 4). The difference in total quantity of water utilized would account for greater yield where 11 cm were applied on two dates rather than one. Earlier irrigation could also have contributed to this increase since adequate soil moisture at the initiation of **podfill** is considered essential for soybean production.

Significant increases in yield of plots receiving nitrogen as compared to control plot yields were found only where water had been applied on two dates (Table 5). No statistical differences were measured between the phosphorous and non-phosphorous treatments. Although plants were stunted and yields depressed due to severe water stress, soybeans appeared better adapted to the heavy soils of Malambito than other crops common to the area.

A second soybean experiment utilizing ICA Lili variety was initiated in April, 1972, to determine if inoculation and other seed

Table 4. ICA Taroa soybeans. Yield, seed size and plant height as influenced by irrigation treatments.

Irrigation treatments	Height (cm)	Seed size (g/100 seeds)	Yield (kg/ha)
control	18.6 b ¹	13.7 b	408 c
11 cm	23.8 a	20.0 a	644 b
11 cm + 11 cm	23.8 a	19.2 a	1060 a

¹Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 5. ICA Taroa soybeans. Yields' according to different irrigation and nitrogen treatments.

Nitrogen treatments	Hate (kg/ha)	Irrigation treatments (cm)			Ave. for nitrogen
		Control	11	11 + 11	
control	--	365 a ²	683 a	865 b	638 b
nitrogen	50	478 a	581 a	1082 a	713 ab
nitrogen	100	441 a	727 a	1188 a	785 a
nitrogen	150	351 a	582 a	1105 a	679 b

¹Compare in columns only

²Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

treatments would contribute appreciably to the overall vigor of the soybean plants as a basis for improving succeeding field tests pertaining to irrigation management of this crop. A randomized complete block design with four replications was utilized for the study. Seed treatments consisted of several combinations of inoculum and molybdenum. Manzate (a fungicide) is sometimes employed as a seed protectant in the **Atlantico** area. Treatments with this material were included in the test in order to establish if the fungicide would inhibit the development of nodules. Soil treatments of 100 kg/ha of nitrogen applied in bands prior to seeding were also included in the experiment.

Stand counts of soybean plants are presented according to treatments in Table 6. Almost no germination was recorded in plots where seed had received inoculant or molybdenum. The process of applying the inoculant and/or molybdenum could have caused the seedcoats to become moist and pliable. Subsequent handseeding could have resulted in mechanical damage to the seedcoats, making the seed more susceptible to soil pathogens. No nodules were found on surviving plants regardless of treatment. Vigorous, well developed stands of ICA Lili were present in those plots where germination had occurred normally at the time the test was abandoned.

These soybean tests exhibited a high degree of stand uniformity in contrast to field experiments with corn, cotton, sesame, and sorghum. Extreme differences in plant development within distances of only a few meters were thought related to soil variability for other crops. A soybean test was established in an area of known soil heterogeneity (previously utilized for a sesame test involving lime

Table 6. ICA Lili soybeans. Stand counts as influenced by seed treatments.

Treatments	Counts (plants/32 M ²)
Control	480 b ²
nitrogen (100 kg/ha)	494 b
molybdenum	72 cd
inoculum	90 c
Mo + inoculum	42 e
N + Mo + inoculum	34 e
N + inoculum + manzate	53 de
N + manzate	602 a

¹Nitrogen was applied as a soil treatment prior to seeding.

²Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 7. H 207 corn. Yield, % blank stalks and % barren ears of corn according to nitrogen treatments.

Nitrogen treatments (kg/ha)	% blank stalks	% barren ears	Yield (kg/ha)
control	45.3 a ¹	38.3 a	1288 a
50	44.5 a	34.4 a	1130 ab
100	48.0 a	34.1 b	1067 b
150	52.0 a	41.5 a	1016 b

¹Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

and manganese treatments), to determine if one or both of two soybean varieties would tolerate the soil problems related to the previous trial. A secondary objective was to measure the effect of lime applications on soybean production.

The experiment was initiated in March, 1973 with the same lime treatments already described for sesame as mainplots and ICA Lili and Mandarin soybean varieties as subplots. Excellent yields were obtained from both varieties with 2735 and 2745 kg/ha recorded for ICA Lili and Mandarin, respectively. No statistical differences were found between lime treatments or varieties. Soybeans in plots formerly treated with manganese were equal in appearance to those of non-treated plots.

Stand development was highly uniform. There were slight decreases in Plant height in those portions of the test area where severe stunting had been noted for sesame. Above-ground plant parts appeared normal in color and vigor for both varieties. Reduced root systems were observed in all areas of the test, however, penetrating to a depth of only 15 to 20 cm. Primary roots were frequently characterized by distorted growth, especially in locations where severe stunting had been recorded for sesame. Soybeans generally started to show signs of wilt three or four days after receiving water. Irrigation was required more than once per week to maintain development of the crop.

It was concluded that a greater probability for attaining normal yields exists with soybeans than for sesame or for corn, cotton, or sorghum (See below). However, irrigation frequencies **utilized during** this test would be difficult to carry out on a commercial basis and probably would contribute to insect and disease problems.

Corn

Native corn is one of the more common crops produced by campesinos throughout the southern sector of the **Atlantico #3** irrigation district. Increases in yields of this crop should be possible through more extensive use of improved varieties. A field test with H 207 corn was initiated in March, 1972, for the purpose of measuring the response of this variety to nitrogen and phosphorous treatments under differing water regimes on the heavy soils of Malambito.

Experimental design and fertilizer treatments were identical to those already described for the study involving ICA Taroa soybeans. Scheduled irrigation treatments were not applied due to frequent, heavy rains during the period the experiment was in progress. Stand development was highly uneven in most areas of the experiment due to the presence of stunted and chlorotic plants which were thought to represent abrupt and extreme soil differences. Corn in four of the subplots was uniform, however, and considered normal in both height and appearance. Measurements of yields, percent blank stalks and percent barren ears were taken from these plots and the data analyzed as a splitplot experiment with nitrogen treatments as mainplots and phosphorous treatments as subplots.

Corn yields were found low in all of the treatments (Table 7). Applications of 100 and 150 kg/ha of **nitrogen** resulted in significant decreases in grain from that harvested in control plots. No differences were found between the phosphorous and non-phosphorous treatments. Low production was, in large part, attributed to lack of ear or grain development by a high percentage of the plants.

Failure of corn plants to produce ears or grain may indicate boron deficiency. A deficiency of this element has been reported for citrus near Malambito.¹ Visiting experts have suggested low levels of soil boron to account for morphological abnormalities of cotton produced on heavy soils in southern parts of the irrigation district. A field test was initiated with H 207 corn in September, 1972, to determine if a 4 kg/ha soil-applied boron treatment would result in normal ear and grain development. Corn of boron-treated plots was compared with that of control plots according to a paired-comparison design. There were eight replications.

Corn plants were found to be highly erratic in growth within one month after seeding. No relationship could be seen between growth variability and boron treatments. Only a small percentage of plants of the entire test had survived at harvest time. Many surviving plants displayed symptoms highly similar to those described for copper or calcium deficiency. The disorder included failure of the upper leaves to unroll, followed by eventual breaking of the leaves through continued elongation of the stem. Still later, the upper stem became discolored and started to deteriorate. The disorder was generally limited to plants which had attained normal heights rather than stunted ones.

Inferences based on yield data would have been invalid due to the confounding factors described above. Therefore, the plots were not

¹Brosh, Perez. 1972. Personal communication. **Tahal** Consulting Engineers, **INCORA, Atlantico** No. 3.

harvested. Observations made during the test indicate that if low soil boron constitutes a problem in corn production, then it is a secondary one.

Potassium is generally considered adequate to high for plant growth in soils surrounding Malambito. Soil samples from the study area were forwarded to the laboratory of Dr. Arvell Hunter of North Carolina State University. Analyses of the samples showed that while K levels would normally be interpreted as adequate, the Mg/K ratio appeared to be high.

In order to examine this idea further, a third corn experiment was seeded in April, 1973. Mainplots consisted of a control and potassium treatments of 50, 100, 200, 400 and 800 kg/ha as K_2O . A foliar treatment equivalent to 1.0 kg/ha of $MnSO_4$ was applied on two dates. The Mn treatment was randomized with a control plot within each K level. Corn plants scattered throughout the test started to develop symptoms described above approximately one month after germination had occurred. Half of the corn in each Mn plot was treated with a 0.75 kg/ha foliar application of $CuSO_4$ as a split-subplot treatment in mid-May. The percentage of plants displaying symptoms was determined in late May and is referred to, hereafter, as "percent corn with disorder." Plant height was also determined the last week in May. Yield, percent blank stalks and percent barren ears data were obtained in early August.

Fewer corn plants failed to develop ears as a result of the potassium treatments (Table 8). Tendencies toward increased yield and plant height were observed for plots where K had been applied. However,

Table 8. H 207 corn. Percent of corn plants with disorder, % barren ears, % blank stalks, plant height and yield according to potassium treatments.

	Potassium treatments (kg/ha)					
	Control	50	100	2 0 0	400	800
% with disorder ¹	23 a ²	14 a	16 a	14 a	24 a	24 a
% barren ears	27 a	25 a	24 a	23 a	32 a	33 a
% blank stalks	23 a	6 c	4 c	21 ab	7 bc	8 bc
Plant height (cm)	154 a	172 a	169 a	182 a	161 a	169 a
Yield (kg/ha)	1430 a	2351 a	1990 a	1772 a	1956 a	1875 a

¹The term "disorder" is used to signify corn plants displaying symptoms similar to those usually associated with copper or calcium deficiency which include twisted and broken leaves and deterioration of the upper stem.

²Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 9. H 207 corn. Percent of corn plants with disorder, % barren ears, % blank stalks, plant height and yield, according to manganese and copper treatments.

Foliar treatment	% with disorder ¹	% barren ears	% blank stalks	Plant height (cm)	Yield (kg/ha)
Control	9 b ²	27 a	10 a	175 a	2019 a
Manganese	30 a	27 a	12 a	160 b	1773 a
Control	16 b	28 a	9 a	167 a	2022 a
Copper	22 a	27 a	13 a	168 a	1769 a

¹The term "disorder" is used to signify corn plants displaying symptoms similar to those usually associated with copper or calcium deficiency which include twisted and broken leaves and deterioration of the upper stem.

no statistical differences were found. In this test, potassium was incorporated with hand-rakes prior to seeding. Further study concerned with the response of corn to potassium in the Malambito area should be conducted utilizing better fertilizer incorporation techniques. Foliar applications of Mn and Cu solutions both resulted in a higher percent of corn plants with the described disorder (Table 9). Average plant height for corn treated with manganese and for corn of the control plots was 160 and 175 cm, respectively.

Native corn planted by campesinos of the zone generally appeared better adapted to the heavy soils of Malambito than H 207.

Sorghum

Sprinkler irrigation on the heavy soils of Malambito results in the first few centimeters of soil becoming saturated rapidly with further downward movement of water very slow. Subsequent drying of this upper layer is also rapid, usually occurring within four to five days after water has been applied. These observations in addition to the incidence of root system retardation in sesame and other crops led to speculation that a shallow **hardpan** may be general throughout the experiment station.

A field test was implemented in May, 1972, to determine if subsoiling would increase sorghum yields. Since the heavy soils are frequently harrowed up to six or eight times during the **seedbed** preparation, disk treatments consisting of 0, 3, and 6 times over prior to subsoiling were also included. Fertilizer treatments were

subdivided within the disk treatments. Sorghum variety, A 14, was utilized for the test.

Greater sorghum yields were obtained from plots where subsoiling had been accomplished than from control plots (Table 10). A trend in reduction of grain produced was recorded with increased harrowing. Application of fertilizers generally resulted in decreased yields except in plots where the subsoiler had been utilized (Table 11). The data indicate that inputs normally designed to increase yields may be limited through improper use of farm equipment. Minimum tillage should be evaluated as a means of increasing yields as well as decreasing production costs.

Cotton

Topography of the lands surrounding Malambito are gently undulating. The heavy soils drain poorly and water frequently collects in low spots during extended periods of rain. Water table levels have been encountered within 1.15 m of the soil surface in certain areas of the experiment station near the end of the rainy season. Yields of cotton and other crops planted in August or September are often suppressed because of excess soil moisture. The problem of excess moisture could be eliminated in large measure through surface drainage. A field experiment was initiated in mid-September, 1972 in order to obtain yield data for cotton produced in **surface-**drained and non-drained areas. Secondary objectives were to observe the adaptability of cotton to heavy soils typical of the zone, gain

Table 10. A 14 sorghum. Yields as influenced by subsoiler and disk treatments.

Subsoiler	Control		Subsoiled		
	Yield (kg/ha)	2205 bl		2682 a	
Disk	No. times over with disk				
	Control	3		6	
Yield (kg/ha)	2614 a		2455 ab		2250 b

¹Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 11. A 14 sorghum. Yields¹ in kilograms per hectare within subsoiler treatments according to fertilizer treatments.

Subsoiler treatments	Fertilizer treatments' (kg/ha)		
	control	200 10-10-10 + 100 urea	400 10-10-10 + 200 urea
Control	2591 a	2136 ab	1886 b
Subsoiled	2386 b	2977 a	2705 ab

¹Compare in rows only. Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

further information concerning crop response to nitrogen and to determine the effect of boron on cotton production.

The area was leveled prior to initiation of the test. Treatments were arranged according to a split-splitplot design. **Mainplot** treatments consisted of cotton seeded on ridges 45 cm in height. The bedded plots were drained by adjusting the slope of a series of small, inter-connecting canals. Subplots were comprised of a control and nitrogen applied at levels of 50, 100 and 150 kg/ha. A soil-incorporated boron application (3 kgB/ha) and a control were randomized within each N treatment. Four replications were utilized. Harvests occurred the third week in January and in Mid-February, 1973.

No significant differences in seed cotton yield were found among the treatments. The experiment was conducted during an exceptionally dry period. Application of excess water by sprinklers was not possible since the irrigation system serving Malambito was not functioning most of the time the test was in progress. The cotton was often subject to drought stress. This effect appeared more pronounced where plots were surface drained although the yield data did not substantiate this. Cotton growth was highly irregular within plots. This variability could have obscured plant response to the treatments.

The average seed-cotton yield for all treatments was 1393 kg/ha. The value of surface drainage should be determined under normal rainfall conditions. Deltapine 16 cotton appeared somewhat better adapted to Malambito soils than corn, sesame and sorghum but less so than soybeans.

Multicrop Test

Heavy soils of the Malambito Experiment Station are poorly structured and characteristically shrink upon drying. Alkalinity or localized areas of high acidity resulting from the degradation of **sodic** soil were often mentioned as causes for variable crop growth and subsequent low yields in the Malambito region. A field test was conducted for the purpose of measuring the response of corn, cotton, sesame, sorghum, soybeans, tomatoes and upland rice to soil-incorporated lime and gypsum treatments. The test also provided the opportunity to observe the relative adaptation of these crops to area conditions when produced in adjacent plots.

The test was initiated the third week in August, 1972. A control plot was randomized with lime and gypsum treatments applied at rates of 5000 and 4000 kg/ha, respectively (in 3 x 45 m plots). The crops were seeded in mid-November in 2 x 36 m strips which extended at right angles across the soil amendment treatments. The crop units were duplicated 3 times for a total of 12 observations per treatment. Plant height and fresh weight were measured in mid-January, 1973. The data from duplicated units were averaged and analyzed as a randomized complete block design for each crop individually. Correlation values (r) between relative elevation² and both height and fresh weight were calculated from data obtained in the twelve control plots. Little or no germination occurred in plots where soybeans or tomatoes had been planted due to poor quality seed. Excellent stands of upland rice were observed until early

²Elevation above bench mark.

January, 1973. However, rice plots were lost at that time because of extreme drought conditions since irrigation water was not available.

Statistical differences in plant height or weight according to control, lime or gypsum treatments were not found for corn, cotton or sesame (Table 12). Sorghum height was significantly greater where lime had been applied as compared to the mean of the control plots. Analyses of soil samples collected two weeks prior to obtaining crop height and weight data did not demonstrate differences in pH between the control and either of the soil amendment treatments.

Crop growth was extremely variable throughout the test area ranging from stunted to normal within distance of only a few meters. This effect appeared related to differences in micro-relief of only a few centimeters. Correlation coefficients for plant height and fresh weight with elevation above bench mark are presented in Table 13. 'Using r values as criteria, the order of decreasing crop adaptability to test site conditions would be cotton, sorghum, corn and sesame. Upland rice was uniform and vigorous in all parts of the study area during the first few weeks of this test. As stated above, soybeans appeared to be better adapted to Malambito soils than corn, cotton, sesame or sorghum when tested under similar experimental conditions.

Rice

Shallow water tables are common throughout Southern portions of the **Atlantico #3** district. Due to a high irrigation requirement, rice has not been included in INCORA production systems for fear of further elevating ground water levels. However, recent installation

Table 12. Multicrop test. Average height and fresh weight per plant of corn, cotton, sesame and sorghum according to lime and gypsum treatments.

Crop	Height (cm)			Weight (g/plant)		
	control	lime (5000 kg/ha)	gypsum (4000 kg/ha)	control	lime (5000 kg/ha)	gypsum (4000 kg/ha)
Corn	140	126	125	171	153	154
Cotton	59	53	51	45	40	38
Sesame	96	103	97	82	77	75
Sorghum	76 b ¹	86 a	82 ab	100	104	88

¹Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 13. Multicrop test. Correlation coefficients (r) and ¹"t" values for plant height and fresh weight with elevation.

Crop	Plant height		Plant weight	
	r	t ²	r	t
Corn	.68	4.00	.69	4.16
Cotton	.60	2.97	.52	2.25
Sesame	.75	5.42	.81	7.44
Sorghum	.65	3.85	.69	4.16

¹Elevation above bench mark. Observation points for all crops were within a range of 32 to **47** cm above the bench mark.

²t.05 = **2.23** (d.f. = 10)

of pumping facilities for transfer of drainage waters into the Canal del Dique as well as completion of the main interceptor canal have increased the feasibility of rice as an alternative for other crops which appear poorly adapted to the zone.

A preliminary test with rice was initiated the first week of October, 1972. The purpose of the test was to determine if a uniform stand of rice could be produced on heavy soil of the Malambito Experiment Station and to obtain yield information as influenced by nitrogen fertilization. CICA 4 variety was seeded at a rate of 120 kg/ha in rows spaced at 17 cm and managed as upland rice with supplemental sprinkler irrigation. The test was located adjacent to an area where an extremely uneven stand of sesame had been present the previous semester. Nitrogen treatments consisting of 0, 50, 100 and 150 kg/ha were compared according to a latin square design. Half of each treatment was applied prior to seeding and half again the third week in November. All plots were replicated four times. The rice was heavily grazed by cattle on three occasions during December. It was also subjected to severe drought conditions in late December and early January. The plots were inundated in mid-January following the availability of irrigation water for a brief period. Harvest was accomplished the first week in February, 1973.

The rice was characterized by even, vigorous growth and responded well to N treatments as reflected by greater height and improved color. Several plots were found to yield up to 3000 kg/ha of grain in spite of exposure to intense grazing and drought. A statistical analyses of yield data was not attempted due to the above confounding factors.

A second field experiment with CICA 4 was established on April 25, 1973 in order to further evaluate the adaptability of rice as a potential crop for the area. Since defining the minimal water requirement for optimum production would be a prerequisite for rice culture in this section of the district, a primary objective of the test was to develop yield data for rice produced under upland and inundation moisture conditions as a basis for future research concerned with irrigation efficiency. Responses to various management factors as influenced by upland and inundation moisture conditions were also examined.

A split-splitplot experimental design with 3 replications was utilized for the test. Main plots were 12 x 12 m and consisted of CICA 4 rice grown under inundated and upland conditions. Soil moisture content in both treatments was maintained between saturation and field capacity by sprinkler irrigation through May 28. The upland plots received supplemental sprinkler irrigation, thereafter, when tensiometers installed to a depth of 15 cm demonstrated 50 centibars of tension. The inundation plots were flooded on May 30. Subsequent inundations were scheduled according to the rate of drainage and the availability of irrigation water. Total depth of applied water for the upland and inundation plots was 55 and 230 cm, respectively. Accumulated rainfall measured during the course of the experiment was 21 cm. Subplots included nitrogen treatments of 75, 150 and 225 kg/ha and an untreated control, Nitrogen for each treatment was divided into three equal parts and applied on May 25, June 15 and July 6. Plot size was 6 x 6 m. Sub-subplot comparisons were comprised of three population densities in 2 x 6 m plots randomized within each nitrogen treatment. All plots

were planted in rows spaced at 18 cm. The seeding rates utilized were 60, 100 and 140 kg/ha. Harvest was initiated on August 22.

Irrigation treatments were separated by a minimum distance of 15 m. Observation wells 3 m in depth were installed at 3 m intervals from the center of the inundation plot to the center of the upland plot in each replication. The entire study area received a 10.5 kg/ha (active ingredient) application of fluorodifen (p nitrophenyl a, a, a-trifluoro-2-nitro-p-tolyl ether) on April 27. Handweeding was required for the removal of Euphorbia heterophylla L. three weeks after the test was initiated. Weed control ratings were taken by visual estimate on August 16 according to a scale of 0.0 to 100%. A rating of 0.0 would signify a complete weed cover while 100% control would indicate that no weeds were present. Plant height and percent lodging were measured on August 15. Root depths were measured shortly after harvest. Plant heights as related to bulk density and soil layering were taken in mid-June.

A recognized advantage of inundated rice as compared to upland rice is weed control. Upland plots were invaded by a morning glory species (Ipomoea sp.) during the last month of the study. The infestation did not appear of sufficient magnitude to contribute to yield reduction but would have interfered with combined harvesting. Almost no weeds were present in the inundation plots at the initiation of harvest (Table 14). Differences in the response of rice to the two irrigation treatments were reflected by measurements of root depths and plant heights. Normally, rice roots penetrate to greater depths when produced under upland conditions. In this experiment, however, average root depths

Table 14. CICA 4 rice, Percent weed control, % lodging, root depth, plant height and yield as influenced by irrigation treatment.

Irrigation treatment	%weed control	% lodging	Root depth(cm)	Plant height (cm)	Yield (kg/ha)
Upland ¹	72 b ²	0.5 a	4.7 b	67 b	3951 a
Inundation	98 a	28.0 a	6.3 a	94 a	7302 a

¹Upland rice with supplemental sprinkler irrigation.

²Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 15. CICA 4 rice. Percent lodging, plant height and yield according to irrigation and nitrogen treatments.

	Irrigation treatment	Nitrogen treatment (kg/ha)			
		control	75	150	225
% lodging	Upland	0 a ¹	2 a	0 a	0 a
	Inundation	7 c	22 bc	35 ab	48 a
	Average	4 b	12 ab	18 a	24 a
Plant height (cm)	Upland	66 a	66 a	69 a	67 a
	Inundation	87 c	93 b	99 a	98 a
	Average	77 c	80 b	84 a	83 a
Yield (kg/ha)	Upland	4126	4135	4228	3313
	Inundation	7798	8200	6255	6955
	Average	5962 ab	6168 a	5242 bc	5134 c

¹Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

for the upland and inundation treatments were 4.7 and 6.3 cm, respectively. Root depths for both treatments would be considered shallow. Increases in plant height were recorded in those plots where flood irrigation was utilized. As expected, more grain was obtained from the inundation plots than the upland plots although yields from these two treatments were not found statistically different.

The response of rice to nitrogen treatments was highly influenced by water management. Field plots which received large quantities of both nitrogen and water were characterized by vigorous plant growth and, therefore, greater susceptibility to lodging. Significant increases in plant height as a result of increased amounts of applied nitrogen were found only where the rice had been irrigated by flooding (Table 15). Percent lodging data followed a trend consistent with that of plant height. Lodging within the inundated rice ranged from a mean of 7 percent where no nitrogen was applied up to 48 percent for the 225 kg/ha nitrogen rate. Essentially no lodging occurred in plots managed as upland rice.

Grain losses were not incurred as a result of lodging under the system of harvest utilized. More rice was produced from treatments which consisted of no nitrogen or 75 kg/ha than the treatment involving 225 kg/ha, regardless of the amount of water applied (Table 16). The average yield for inundation plots that received 75 kg/ha of nitrogen was 8200 kg/ha. Grain production tended to decrease with an increase in seeding rate from 60 to 140 kg/ha while percent weed control measurements reflected a reverse trend (Table 16).

Crop stands on heavy soils in the vicinity of Santa Lucia are frequently mottled in appearance due to the presence of stunted and

Table 16. CICA 4 rice. Percent weed control and yield as influenced by seeding rate.

	Seeding rate (kg/ha)		
	60	100	140
% weed control	82 b ¹	83 b	89 a
Yield	5823 a	5638 ab	5422 b

¹Means followed by different letters are significantly different at the 5% level of probability according to Duncan's multiple range test.

Table 17. Average depth to water table in meters as measured within upland and inundation irrigation treatments and for the immediate study area.

Date	Irrigation treatment		Study area
	Upland	Inundation	
July 13	1.83	0.71	2.62
July 17	1.92	1.45	2.57
July 18	1.90	0.51	2.55
July 25	1.89	1.62	2.50
August 3	1.43	0.79	2.48
August 8	1.43	0.82	2.59
August 16	1.86	1.66	2.54

chlorotic plants. Contrary to observations of the preliminary test presented above, upland rice in two of three replications of the field experiment displayed these effects during the first few weeks the study was in progress. Plants within these areas were also characterized by decreased tillering and severely retarded root systems. The crop demonstrated drought symptoms soon after being irrigated. Rice stands of the inundation irrigation treatment were highly uniform in both color and growth.

Bulk density of areas of upland plots characterized by normal rice growth was 1.26 for the surface 15 cm of soil and gradually became more dense with increasing depth. Where the incidence of stunting was most pronounced an abrupt change in soil density was easily detected from 10 to 30 cm of depth. Bulk density of the soil above the layer of greater density averaged 1.08 as compared to 1.35 within it. A positive correlation was found between plant height and depth from the soil surface to the denser layer (Figure 1). Reduced root depth or the relationship between rice height and depth to a more dense soil layer cannot be attributed to the presence of a hard pan since a bulk density of 1.35 would not represent extreme compaction for a clay soil. Further, roots of stunted rice plants did not penetrate to the denser layer but were found only in that portion of the profile with an average bulk density of 1.08. Upland rice was normal and vigorous where this layer could not be detected.

Amounts and distribution of rainfall and applied water for the field experiment are illustrated in Figure 2. Accumulated rainfall measured during the course of the experiment was 21 cm. Rice plots

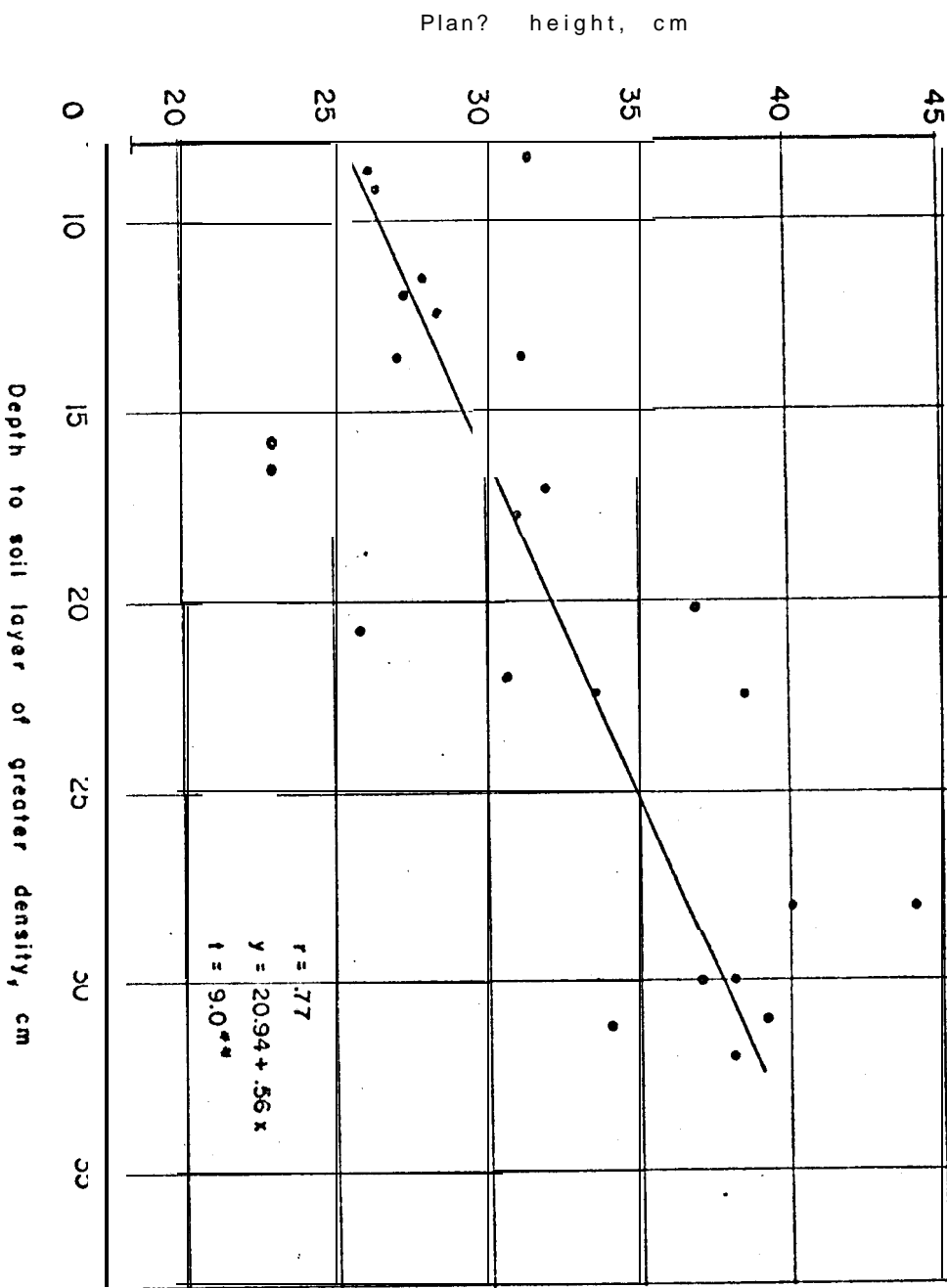


Figure 1. Correlation between plant height and depth from soil surface to soil layer of greater density.

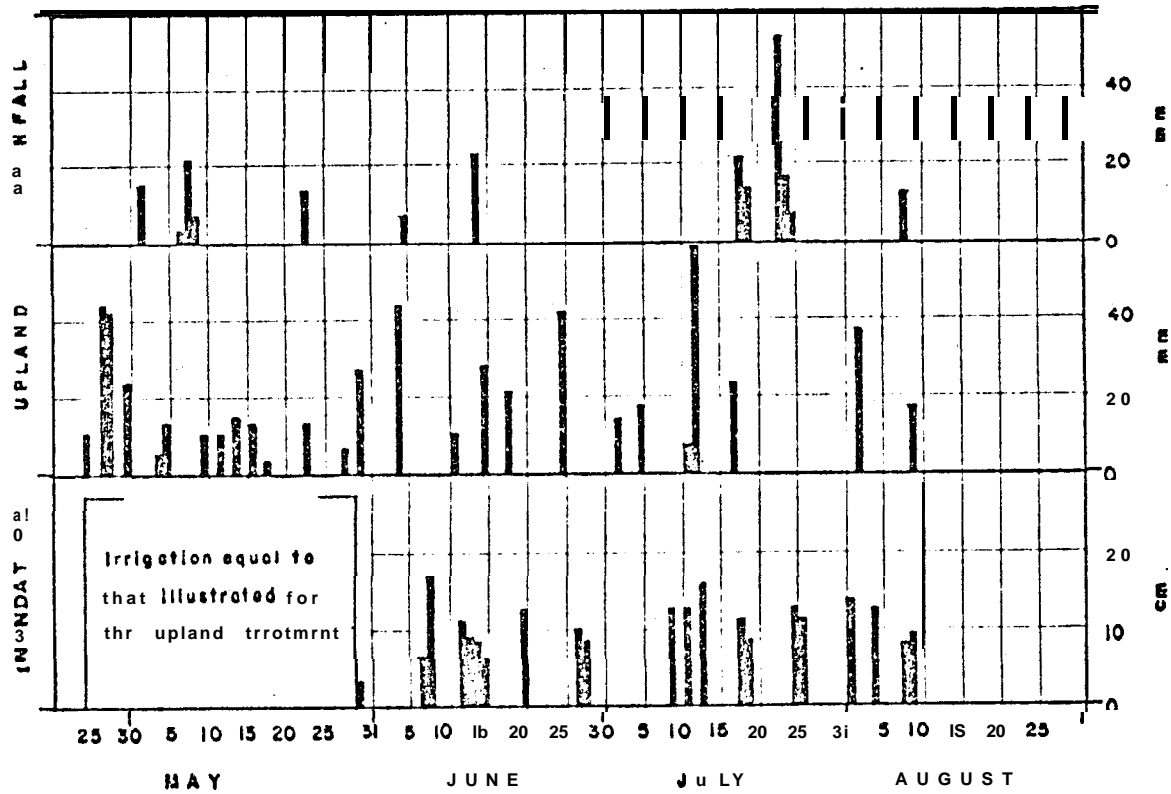


Figure 2. Rainfall and irrigation for the upland and inundation treatments.

of the inundation treatment received a total of 230 cm of irrigation water as compared to 55 cm for the upland plots. Consumptive use of water by rice was estimated from climatological data collected while the experiment was in progress. The seasonal requirement was calculated at approximately 75 cm utilizing both Blaney-Criddle and Hargreaves equations³ or about 6.1 mm per day. Combined rainfall and irrigation of the upland treatment was equal to the estimated seasonal requirement. A portion of this moisture would have been unavailable, however, due to gravitational losses. Using the evapotranspiration estimate as a criterion, more than 1.0 cm per day would have been contributed to the ground water reservoir through percolation of irrigation water alone in plots of the inundation treatment. This amount would be considered excessive.

Percolation losses from flooded plots were appreciable as evidenced by differences in water table levels between the inundation treatment and the study area in general (Table 17). The data were not interpreted as predictive of water table elevations as they would occur under similar irrigation management in the Santa Lucia zone since lateral water movement through the soil would also have taken place from the experimental plots. They do seem to demonstrate a high rate of water movement within the soil. For example, free ground water levels beneath the inundation plots were measured at an average depth of 0.71 m on July 13 after receiving more than 40 cm of water over a period of 5 days.

³**Seasonal** consumptive use estimates for rice were 75.6 and 74.6 cm as calculated according to the Blaney-Criddle (1950) and Hargreaves (1956) formulas, respectively.

Yet, water table elevations had receded to 1.45 m when measured again on July 17.

Irrigation treatments were separated by a minimum distance of 15 m. As expected, free ground water within the upland plots was encountered at greater depths than in the inundation plots (Table 17). Water table levels of both treatments were observed to fluctuate simultaneously during August. Measurements from a series of observation wells installed at 3 m intervals across each replication revealed that ground water depths of the upland plots were elevated as a result of water originating from the inundation plots.

The quantity of water necessary for rice culture in the district could be reduced substantially from the amount utilized for the inundation treatment without a corresponding reduction in yield by minimizing percolation losses. This might be accomplished through use of agricultural machinery during **seedbed** preparation or by permitting temporary elevation of the water table. Yields similar to those listed above for the inundation treatment could probably be attained with much less water through intermittent flooding with longer intervals between application dates than shown for this test.

Data of both experiments indicate that rice should receive strong consideration as an alternative to those crops currently included in production systems in the Santa Lucia region of the **Atlantico #3** irrigation district. Acceptable yields for traditional crops of the zone have been difficult to attain. Management-related aspects of the study suggest that substantial yields could be obtained through production of CICA 4 rice according to the normal cultural procedures

recommended by ICA. The adaptability of rice to area soils should be investigated more extensively. Engineering research concerned with irrigation efficiency and drainage control should precede any attempt to produce inundated rice on a commercial basis.

SOILS

Soils of the experimental site are dark in color and contain from 45% to 60% clay. A sandy textured layer is encountered at a depth of approximately one meter. Results of soil analyses completed at ICA laboratories at Palmira and Turipana and at the INCORA laboratory at El Limon showed the soils to have 3.5 percent organic matter, 99.4 ppm phosphorous and 0.87 meq potassium/100 g of soil. The median pH and average electrical conductivity were measured at 6.1 and 0.89 mmhos/cm, respectively.

Topography of the Malambito station is undulating with vertical extremes of 10 to 30 cm. Average slope across the study site is about 0.5 percent. Closed depressions where water collects following rainfall or irrigation contribute to a moisture differential and leaching potential within the field. The surface layer of soil to a depth of 60 cm can generally be classified as a clay loam although texture may change considerably within distances of a few meters due to the presence of silty and sandy lenses.

Crop stands in the Malambito region are characterized by small, irregular areas of retarded plant growth ranging from one to several square meters in size interspersed with areas of normal plant growth.

Yields are severely reduced within these areas which collectively may account for 30 percent of some fields. Retarded crop growth is usually associated with topographical depressions but is also found on sloping, well-drained terrain.

Salinity, alkalinity, highly localized soil acidity resulting from degradation of **sodic** spots, soil compaction, poor drainage, plant pathogens and insect damage are most often mentioned as possible causes for erratic plant growth. Prior to **Rubink's** work, however, almost no information was available that attempted to demonstrate the extent to which each of these factors influences crop yields.

Crop growth and soil physical parameters have been examined. Sorghum yields were increased as a result of subsoiler use, suggesting a shallow compacted layer. However, yields were still far below levels considered normal for culture of this crop under irrigated conditions.

Rubink found a higher percentage of clay particles in soil of topographical depressions where corn heights were reduced. Conversely, stunting of corn was more closely related to increases in the sand fraction of the soil within these points. These results were somewhat substantiated through the study with rice discussed below. Height of upland rice was significantly lower in small areas characterized by a bulk density of 1.08 in the first few centimeters of the soil surface. Rice height was positively correlated with depth from the soil surface to an underlying soil layer with an average bulk density of 1.35. The abrupt change in density of the deeper layer could have represented an increase in the coarse particle fraction of the soil rather than a compacted zone.

Several chemical analyses were conducted by Mr. **Rubink**. Increases in soil organic matter were correlated with increases in corn height. These data were interpreted to indicate that plant development has regularly been deficient over a long period of time in areas where stunting occurs. Dr. Sam **Portch** and Dr. A. A. Hunter at North Carolina State University implied that a high **Mg/K** ratio contributes to poor crop growth on the Malambito station. **Rubink's** investigations indirectly support this contention. Although the correlation coefficient for the **Mg/K** ratio and plant height was considered low ($r = -.35$) a negative relationship between the **Mg/K** ratio and organic matter content was demonstrated ($r = -.88$). **Rubink** also found positive correlations between corn heights and increases in both soluble plus exchangeable soil calcium ($r = .55$) and the **Ca/Mg+K+Na** ratio ($r = .61$). These results were reported as being of minor significance, however, in providing a basis of explanation for variable plant growth of the area. Intensive sampling and analysis by **Rubink** failed to verify the presence of saline, **sodic**, or strongly acidic soils as a cause for plant stunting on the Malambito farm.

More recently soil tests completed at USU strongly indicate that erratic crop growth and low yields are the result of excessive phosphorous and heavy metal toxicity. DTPA - extractable Fe, Cu, Zn, and **Mn** were analyzed in quantities ten times greater than usually considered normal for agricultural soils. Productive soils generally contain from 0.01 percent to 0.1 percent total phosphorous. In contrast, measurements of this nutrient ranged from 0.6 percent to 1.6 percent for heavy soils of Malambito.

Reductions in corn growth were found highly correlated with increasing amounts of both iron and phosphorous. NaHCO_3 - extractable P as well as DTPA - extractable Cu, Zn, Ni and Co were determined to exist in concentrations proportional to soil Fe content. All results tend to indicate a negative interaction between phosphorous and one or several heavy metal ions.

It was speculated that the soil contains geologic minerals which **have** an abundance of heavy metals and phosphorous. Weathering results in the release of these elements in amounts detrimental to crop growth. Malambito soils vary in texture in both horizontal and vertical planes. Irregular growth within crop stands may represent differences in exposure to sources of heavy metals or excessive phosphorous created by sedimentation processes or erosion.

Economically feasible measures are not available for the reclamation of heavy metal affected soils.

OBSERVATIONS

Considerable progress has been achieved in the development of extensive water delivery structures and drainage systems in the Santa Lucia region of the **Atlantico #3** irrigation district.

In addition to water control facilities, modern farm machinery and agricultural chemicals are among the management tools commonly utilized by area producers. More important, both farmers and agronomists of the Colombian Agrarian Reform Institute (INCORA) have accumulated several years of valuable experience in crop production

since district activities were initiated. In contrast to these advances, however, crop yields continue at levels far below those required for obtaining normal agricultural profits.

Lack of success in crop production in the southern sector of the **Atlantico #3** district has been attributed to salinity more than any other factor. While known areas of salinity exist in certain parts of the district, this factor appears of little consequence in those fields neighboring **Malambito** which **are** continually under cultivation. Farmer benefits would certainly increase through improved fertilizer technology, surface drainage, subsoiler use and other innovations.. Nevertheless, data accumulated for this report indicate that yields of those crops currently included in INCORA production schemes will remain at levels considered less than acceptable under the best of circumstances.

Crops produced for experimental purposes generally receive intensive care and management. Test plot yields for a particular crop are frequently much greater than listed variety potentials or yields attained on a commercial scale under similar soil and climatic conditions. The average of experimental yields for several crops measured by LJSU and ICA researchers on heavy soils of the Malambito experiment station between 1971 and 1973 are presented in Table 18. With the exception of rice, yield levels for all crops were much lower than expected. Yield levels above those required to return investment costs were far greater for inundated rice than other crops studied. Commercial yield averages over a five year period for the Santa Lucia region where studies were conducted are much less than averages for

Table 18. Expected yields, average experimental and commercial yields and estimates of production required to return investment in kilograms per hectare.

Crop	Expected yields	Experimental yields Malambito 1971-1973	Production required to return 1 investment	Commercial yields' 1968-1972 Sta. Lucia region	Atlantico #3
Corn	4000	1475	1464	--	--
Cotton	1600	1393	710	1088	1335
Upland rice	3100	3951	--	--	--
Inundated rice	6200	7302	2583	--	--
Sesame	800	569	305	137	220
Sorghum	4000	2445	1470	973	1678
Soybeans	2200	1722	975	30	956

¹ Estimates of production required to cover investment were based on 1970-72 cost data obtained from the INCORA Office of Statistics, -- **Atlantico #3**. The estimate for inundated rice was based on 1970--data of the Boliver #1 district and does not include fixed costs.

² Weighted means representing two to five seasons of production. Growing seasons where complete crop loss was experienced were not utilized in calculating averages.

the **Atlantico #3** district as a whole in spite of large expenditures for irrigation and drainage facilities in this part of the district.

Researchers in Malambito experienced the same difficulties which have prevented producers of the area from attaining high yields.

Certain aspects of crop tests conducted on the Malambito farm tend to confirm the assertion that low yields, erratic seedling establishment and crop development and retarded root growth are the result of excessive soil phosphorous and heavy metal toxicity. For example, plant height and yield of sesame were reduced in plots where phosphorous was applied as compared to control plots. Interestingly, 10-20-10 fertilizer is frequently used for crop production in the southern sector of the district.

A foliar treatment of CuSO_4 was generally detrimental to corn. Application of this material may have compounded an existing toxicity problem. Shallow horizontal growth of primary and secondary roots of sesame, "looping" of soybean roots and extreme angling of cotton seedling roots rather than downward penetration were noted in several fields. Growth abnormalities of this nature could reflect heavy metal toxicity.

Plant response to manganese was variable. A foliar solution of MnSO_4 significantly improved sesame color but resulted in less corn growth. Soil-applied Mn had no effect on sesame. Large quantities of manganese may be presented in Malambito soils but in unavailable forms due to interaction with phosphorous.

Although a continued and expanded research effort remains as the most promising means for increasing yields for a wide range of crops,

immediate solutions are still lacking, Replacement of traditional species by ones better adapted to conditions common to the southern portion of the **Atlantico #3** district probably represents the most rapid means of improving farm profits. Data developed during the course of the Water Management Program suggest that substantial yields could be obtained through production of CICA 4 rice according to the normal cultural procedures recommended by ICA. However, engineering research concerned with irrigation efficiency and drainage control should precede any attempt to produce inundated rice on a commercial basis. Soybeans were also found to yield well but this crop required frequent irrigation due to shallow root growth. The adaptability of rice and soybeans to soils of the zone should be investigated more extensively.

SUMMARY AND CONCLUSIONS

A field research program in on-farm water and soil management was initiated in October, 1971, on heavy soils of the **Atlantico #3** irrigation district in Northern Colombia. Primary objectives were to develop yield functions of soil moisture and fertility and to determine consumptive water use information for economically important crops of the zone. Crops established for experimental purposes were characterized by the random occurrence of stunted and chlorotic plants with extremely shallow root systems interspersed among areas of normal plants. Erratic crop growth prevented the development of valid irrigation data. Depressed and irregular crop growth has tentatively been attributed to excessive soil phosphorous and heavy metal toxicity of geologic origin. Problems encountered in

attempting to conduct research were identical to those commonly experienced by commercial producers of the region.

Sesame, corn and sorghum were found more poorly adapted to the heavy soil conditions than other crops studied. Sesame leaves displayed interveinal chlorosis shortly after germination. Foliar treatments with manganese solutions resulted in the development of a deep, green leaf color but plants remained stunted following these treatments. A significant decrease in both height and yield of sesame was measured where phosphorous treatments were utilized,

In addition to areas of stunted plants, the corn plots were characterized by many plants with blank stalks or barren ears. Fewer plants with blank stalks were recorded where potassium has been applied. A trend of decreasing grain production was noted with increasing amounts of applied nitrogen. Trace element solutions containing manganese or copper generally were detrimental to corn.

All crops studied were characterized by shallow root systems. Sorghum yields were increased in plots where a subsoiler had been utilized prior to seeding over those harvested from control plots. Application of fertilizers resulted in yield increases only in the subsoiled areas. However, yields in the best treatments were still much lower than considered normal for sorghum.

Cotton appeared slightly better adapted to study site conditions than sesame, corn, or sorghum, but was also characterized by irregular development and shallow roots, It was' often noted that the primary root of cotton seedlings penetrated the soil at an angle rather than vertically. A relationship between the soil compaction and this

unusual growth habit was not observed. Use of soil-applied boron failed to improve cotton yields.

Excellent soybean yields were obtained with the varieties ICA Lili and Mandarin, Frequent irrigation was required to maintain soybean growth due to shallow rooting. Irrigation frequencies used during the test would be difficult to carry out on a commercial scale.

Yields of rice under upland and inundation water management were 3951 and 7302 kg/ha, respectively. More grain was harvested from plots that received zero or 75 kg N/ha than from plots which received 225 kg/ha of N, regardless of irrigation management. Small areas containing stunted plants were observed in some of the upland plots but not in the inundation plots, Root depths were considered shallow for all treatments although slightly increased where flood irrigation was utilized.

Agronomic yields have been **consistently** low over a period of years in the sector of the district where studies were conducted. It was concluded that practical measures which would result in immediate and substantial yield increases for traditional crops of the area are unavailable. However, the use of CICA 4 rice could be a profitable alternative to the other crops, Studies concerned with rice adaptability to the heavy soils should be carried out on a more extensive basis. Engineering research regarding irrigation efficiency and drainage control would be prerequisite to commercial production of inundated rice in the district.