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9. ABSTRACT

Corn, cotton, sesame, sorghum, and soya crops in the Santa Lucia region of the Atlantico #3 irrigation district of Atlantico, Colombia, frequently are characterized by erratic growth and low yields. A field study of the heavy soils of the Malambito Experiment Station of the Colombian Agaraian Reform Institute was made to evaluate irrigated rice as an alternative crop for this zone. Uniform, vigorous stands of rice were produced in two preliminary tests, and rice appeared much better adapted to Malambito soil conditions than corn, cotton, sesame, or sorghum when tested simultaneously with them. Yields of rice produced under upland and inundation water management systems were measured at 3951 and 7302 kg/ha, respectively. More grain was obtained from control plots (no nitogen) or plots to which 75 kg/ha had been applied than from plots which had received 225 kg/ha of nitogen, 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. Data from this study indicate that CICA 4 rice could be a profitable alternative to those crops currently grown in the Santa Lucia region. Further research on rice adaptability to the soils, irrigation efficiency, and drainage control should be conducted.

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RICE AS AN ALTERNATIVE CROP IN THE SANTA LUCIA REGION OF THE ATLANTICO #3 IRRIGATION DISTRICT

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INTRODUCTION

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.

Crop stands on heavy soils similar to those found on the Malambito Agricultural Experiment Station of INCORA are frequently characterized by erratic plant growth. Stunted and chlorotic plants with retarded root systems occur in small irregular areas ranging from one to several square meters in size. Yields are severely reduced within these areas which collectively may account for as much as 30% of the total area of some fields. Soybeans appear to tolerate these soils better than corn, sesame, or sorghum but are not widely grown. Only limited success has been attained through cotton production. Sztyglic (8) has emphasized the need for an alternative to sorghum which is generally planted the first semester in rotation with second semester cotton.

Salinity, alkalinity, highly localized soil acidity resulting from degradation of sodic soils, soil compaction, poor drainage, and plant pathogens are most often mentioned as possible causes for erratic plant

growth. Almost no information exists, however, that demonstrates the extent to which each of these factors influence crop yields. Rubink (7) found positive correlations between corn plant heights and increases in both soluble plus exchangeable soil calcium and the Ca/Mg+K+Na ratio on heavy soils of the Malambito Station. These results were interpreted as being of minor importance, however, in explaining the variable plant growth in the area. Depressed corn growth was encountered most frequently in topographical low points of the field where clay content of the soil was slightly greater. Conversely, stunting of corn plants was found more closely related to increases in the sand fraction of the soil within these points. Intensive sampling and analysis by Rubink failed to substantiate the presence of saline, sodic, or strongly acidic soils as a basis for corn stunting. Garcia et al. (2) have considered soil compaction as a factor in reducing crop yields on heavy soils in the Santa Lucia region. More grain was obtained from sorghum plots treated with a subsoiler prior to seeding than from non-treated plots. The best yields were still far below those recognized as normal for sorghum culture. These workers also observed the occurrence of highly non-uniform crop stands on sloping, well-drained soils of the Malambito farm. James and Fullerton (4) concluded that erratic crop growth and poor yields in the Malambito area were the result of a complex of excessive phosphorus and heavy metals in the soil, all of which were of geologic origin. Soil analysis with DTPA indicated that extractable Fe, Cu, Ni, and Zn were 10-fold higher than considered normal. A positive correlation was found between Fe and both extractable Ni and $NaHCO_3$--extractable P. Mn was also involved in the analyses but heat treatment of the soil samples obscured the true effect

of this element. Pelaez[1] has isolated a Fusarium organism from unhealthy sorghum tissue collected in La Isla area and is currently evaluating the implications of this information.

Although a continued and expanded research effort remains as the most promising approach 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 farmer benefits. Rice would be a logical choice for consideration since much of the zone consists of heavy soils formerly in marshes. The objective of this study was to evaluate rice as a possible alternative crop for irrigated sections of the Santa Lucia region.

MATERIALS AND METHODS

The study was conducted on heavy soils of the Malambito Agricultural Experiment Station of INCORA located near the divergence of the Magdalena River and the Canal del Dique in Southern Atlantico. Soil of the study area is dark in color and contains from 45% to 60% clay (7). A sandy-textured layer is encountered at a depth of approximately one meter. Results of soil analysis completed at the Colombian Agricultural Institute (ICA) laboratories at Palmira and Turipana and the INCORA laboratory at El Limon showed the soil to have 3.5% organic matter, 99.4 ppm

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[1]Pelaez P. Alfredo. 1973. Personal communication. Instituto Colombiano Agropecuario, Tibaitata.

phosphorous, and .87 meq. of potassium/100g of soil. The median pH and average electrical conductivity were measured at 6.1 and .89 mmhos/cm, respectively.

Preliminary Observations. Observations from two preliminary tests involving rice provided a basis for the design of a third, more intensive field experiment. Only brief, verbal descriptions of these tests are presented here and in the Results and Discussion since both were confounded by factors beyond experimental control.

The first rice test was initiated on October 2, 1972. 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 and a control were compared in 3x5 m plots arranged according to a latin square design. The treatments consisted of 50, 100, and 150 kg/ha N. Half of each treatment was applied prior to seeding and half again on November 22. The plots were replicated 4 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 due to the lack of rainfall and a breakdown in the irrigation system serving the Malambito farm. The plots were inundated in mid-January following the availability of irrigation water for a brief period. Harvest was accomplished on February 4, 1973. A statistical analysis was not attempted because of variability introduced by outside influences.

A factorial type field test was conducted for the purpose of measuring the relative responses of corn, cotton, sesame, sorghum, and upland rice

to soil-incorporated lime and gypsum treatments. A control was randomized with lime applied at a rate of 5000 kg/ha and with gypsum at 4000 kg/ha in 3x45 m plots on August 22, 1972. There were 4 replications. The crops were seeded on November 14 in 2x36 m strips which extended across the soil amendment treatments. The crop units were also randomized and duplicated 3 times. A population density of 120 kg/ha with 20 cm row spacing was utilized for seeding the CICA 4 rice. The rice plots were observed in relation to the other crops present until early January, 1973, when they were lost due to extreme drought conditions imposed by the scarcity of rainfall together with a non-functional irrigation system.

Field Experiment. A split-split-plot experiment with 3 replications was initiated April 25, 1973. Main-plots were 12x12 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 sprinkler irrigation when tensiometers installed at a depth of 15 cm reached 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. Sub-plots 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 6x6 m. Sub-sub-plot comparisons were comprised of three population densities in 2x6 m plots randomized within each

nitrogen treatment. All plots were planted in rows spaced at 18 cm. Three seeding rates were utilized: 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.

RESULTS AND DISCUSSION

Preliminary Observations. Preliminary tests were conducted to determine if a uniform stand of upland rice could be produced on heavy soil of the Malambito Experiment Station and to observe rice in relation to traditional area crops. Rice in the first of these tests was characterized by even, vigorous growth and responded well to Nitrogen treatments as reflected by greater height and improved color. Several

plots were found to yield up to 3000 kg/ha of grain although exposed to intense grazing by cattle and drought during the latter part of the life cycle. Vegetative growth of corn, cotton, sesame, and sorghum ranged from stunted to normal within short distances in the second preliminary test. In comparison, rice planted in close proximity to these crops displayed normal, uniform growth in all parts of the study area. Visual differences were not apparent as a result of lime or gypsum treatments for any of the crops involved.

Field Experiment. Salinity and shallow water tables have been studied in the Santa Lucia region (9, 5). Defining the minimal irrigation requirement for optimum production would be a prerequisite for rice culture in this area of the district. In addition to evaluating rice as a possible alternative crop, a primary objective of the field experiment was to develop yield data for rice produced under upland and inundation moisture conditions as a basis for future research concerned with water use efficiency. Responses to various management factors as influenced by upland and inundation moisture conditions were also examined.

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 the study was in progress. The infestation did not appear of sufficient magnitude to contribute to yield reduction but would have interfered with combine harvesting. Almost no weeds were present in the inundation plots at the initiation of harvest (Table 1). Differences in the response of rice to the two irrigation treatments were reflected by measurements of root depths when produced under upland conditions. In this experiment, however, average root depths

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 satistically 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 2). Percent lodging data followed a trend consistant with that of plant height. Lodging within the inundated rice ranged from a mean of 7% where no Nitrogen was applied up to 48% 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 2). 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 3).

Crop stands on heavy soils in the vicinity of Santa Lucia are frequently mottled in appearance due to the presence of stunted and chlorotic plants. Contrary to preliminary observations 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 evidenced by decreased tillering, severely retarded root systems, and 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 average 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). Upland rice was normal and vigorous in areas where this layer could not be detected.

Garcia et al. (2) have speculated that root system retardation of crops on heavy soils of the Malambito farm was due to the presence of a shallow hardpan. Presence of a hardpan does not provide a basis of explanation for reduced root systems or the relationship shown here between rice height and depth to a more dense soil layer, however, 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 soil layer but were found only in that portion of the profile with a bulk density of 1.08. These results appear somewhat in agreement with the work of Rubink (7) who reported inferior corn growth where the soil contained a higher percentage of sand particles. The abrupt change to

higher bulk density could probably be explained by an abrupt increase in the proportion of sandy materials. Although roots did not penetrate to this layer, lesser depth to the layer was reflected through increasing suppression of growth. The coarser soil fraction could represent a source of heavy metal imbalances as described by James and Fullerton (4).

All observations indicate that CICA 4 rice is better adapted to the conditions described here than other crops common to the Santa Lucia region. Erratic growth and reduced root systems observed in rice in the upland irrigation treatment also indicate that rice is affected to a lesser degree by those factors which have prevented the attainment of normal yield levels in other crops. Changes in soil chemical and physical properties which accompany extended periods of irrigation by inundation are well recognized. The lack of erratic growth and deeper root penetration recorded for rice of the inundation treatment as compared to that of the upland treatment might be the result of changes in the soil caused by leaching of materials from the root zone. The probability of normal grain production would be much greater under flood irrigation conditions for rice plants affected by poorly developed root systems.

Free ground water may be encountered within a meter of the soil surface in some areas under cultivation near Santa Lucia. Excessive irrigation within these areas could further elevate water tables and intensify salinity problems. Conservative water use combined with maintenance of adequate drainage would be required for rice production in this region of the district.

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 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 the Blaney-Criddle (1) and Hargreaves (3) equations 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 not have been available, 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 under commercial production conditions.

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 4). The data were not interpreted as being 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 directly 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. 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 4). 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 study.

Crops produced for experimental purposes generally received intensive care and management. Test plot yields for a particular crop were frequently much greater than listed variety potentials or yields obtained on a commercial scale under similar soil and climatic conditions. The average of experimental yields for several crops measured by ICA researchers on heavy soils of the Malambito Experiment Station between 1971 and 1973 are presented in Table 5. With the exception of rice, yield levels for all crops were much lower than expected. Production over that required to return investment costs was much greater for inundated rice than other crops studied.

Data developed during the course of this study 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 (6). 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.

SUMMARY

Growing crops of corn, cotton, sesame, sorghum, and soya in the Santa Lucia region of the Atlantico #3 irrigation district of Atlantico, Colombia, are frequently characterized by erratic growth and low yields. A field study was conducted on heavy soils of the Malambito Experiment Station of the Colombian Agrarian Reform Institute in order to evaluate irrigated rice as an alternative crop for this zone. Uniform, vigorous stands of rice were produced in two preliminary tests. Rice appeared much better adapted to Malambito soil conditions than corn, cotton, sesame, or sorghum when tested simultaneously with these traditional crops.

Yields of rice produced under upland and inundation water management systems were measured at 3951 and 7302 kg/ha, respectively. More grain was obtained from control plots (no Nitrogen) or plots where 75 kg/ha

had been applied than from plots which had received 225 kg/ha of Nitrogen, 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.

Data developed during the course of this study indicate that CICA 4 rice could be a profitable alternative to those crops currently included in production systems in the Santa Lucia region. Further research concerned with rice adaptability to the soils, along with irrigation efficiency, and drainage control should be conducted.

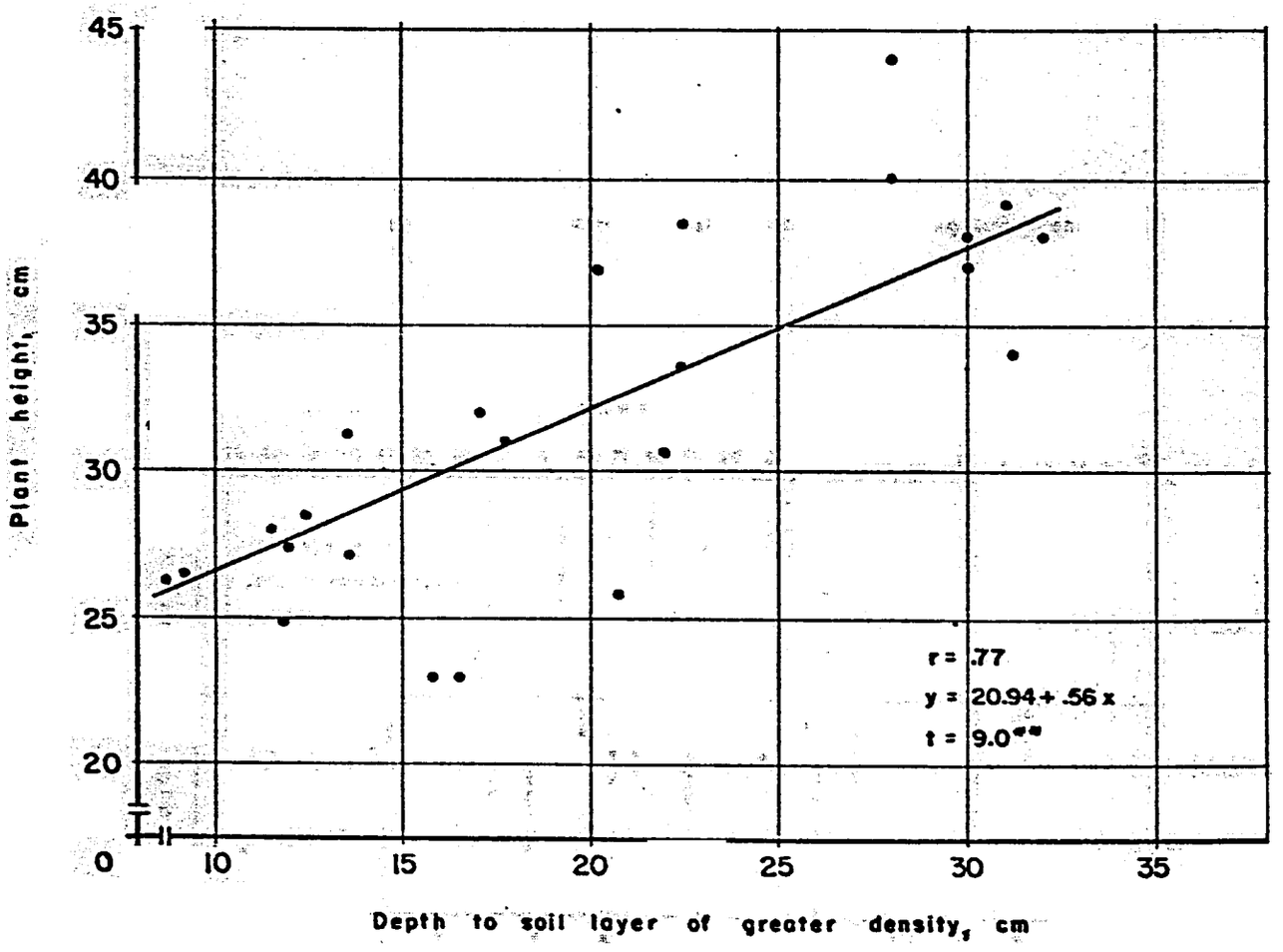

Figure 1. Correlation between plant height and depth from soil surface to soil layer of greater density.

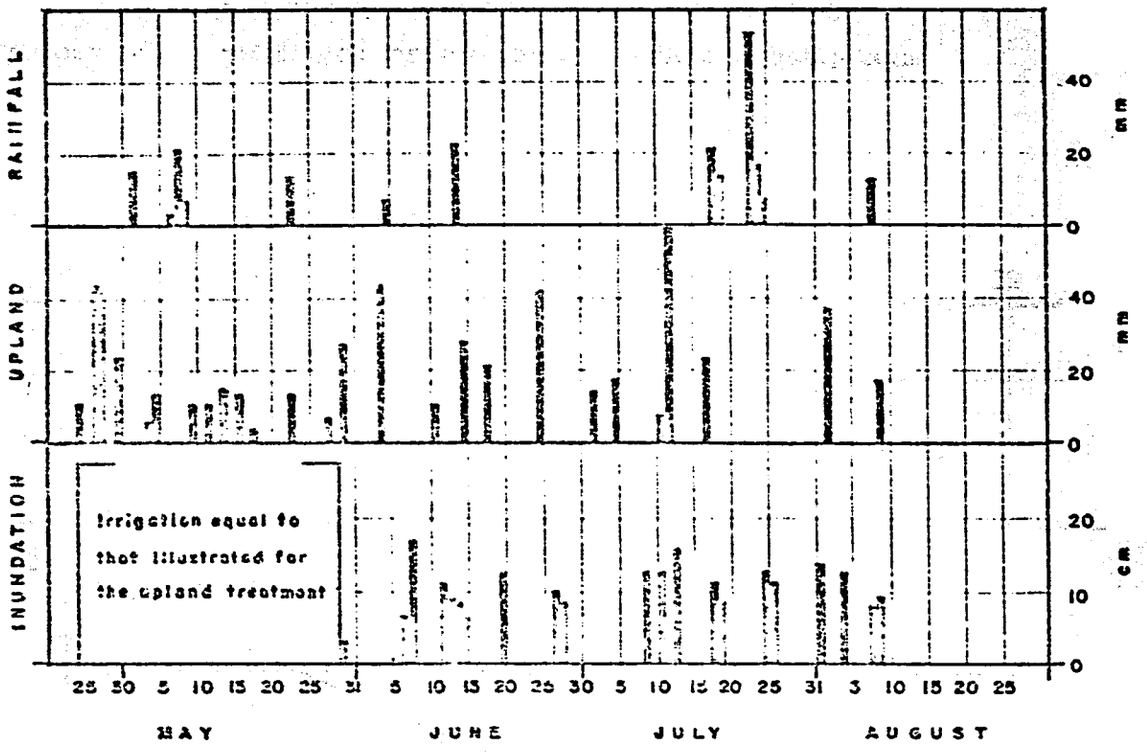

Figure 2. Rainfall and irrigation for the upland and inundation treatments.

Table 1. 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[2]	72 b[1]	0.5 a	4.7 b	67 b	3951 a
Inundation	98 a	28.0 a	6.3 a	94 a	7302 a

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

[2]Upland rice with supplemental sprinkler irrigation.

Table 2. 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

[1]See Table 1. Comparisons can be made only on a horizontal plane.

Table 3. 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 (kg/ha)	5823 a	5638 ab	5422 b

[1]See Table 1.

Table 4. 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	2.64
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

Table 5. 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 investment[1]	Commercial Yields[2] 1968-1972	
				Sta. Lucia region	Atlantico #3
Crop	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 Bolivar #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.

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