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CHAPTER 16

IMPROVED RICE-PASTURES SYSTEMS FOR NATIVE SAVANNA AND DEGRADED PASTURES IN ACID SOILS OF LATIN AMERICA.

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Introduction

In the Savanna Ecosystem of South America there are approximately [illegible] million hectares of acid soils (Oxisols), 16 million of which are found in Colombia (Cochrane et al.,1985), and the majority of these are adequate for annual cropping or for the establishment of improved pastures. As a result of economic and population pressures, there is current need to intensify agricultural production by means of transforming the native savannas into annual crops or into improved pastures. During the last 15 years the International Center of Tropical Agriculture (CIAT), jointly with national research and extension institutions, has been developing improved agricultural systems for this environment (Zigler and Toledo, 1993); however, it is possible for these systems to become non-sustainable. For example after 3 years of continuous cropping of upland rice, the production decreases to non-sustainable economic levels due to weed competition and to a decrease in the soils' nutrients reserve (Seguy et al., 1988). In the same way, continuous cropping of other annual crops such as maize and soybeans, results in erosion problems. On the other hand, pure-grass pastures tend to degrade after several years of grazing, unless adequately fertilized (Buschbaker, 1986; Uhl and Buschbaker, 1985; Vera and Seré, 1985).

Some associated grass/legume pastures perform well under common commercial exploitation conditions in the region. However, there are economic limitations for their establishment or reclaiming once they have become degraded. These pastures require a minimum capital investment --land preparation, fertilizers and seeds-- to adequate establishment and reclaim, and generally, producers are not willing to invest enough in these practices. (Vera and [illegible]) When the pastures include a well managed forage legume among its components, it is to be expected that rice will benefit from converting the increase in oxygen content in the soil into rendering more yield. In the case of degraded pastures the fertilizer added to the rice crop is expected to estimulate the the growth of the seed bank on the soil allowing to incorporate the legume in the ecosystem.

This chapter has been divided into two components: (1) the use of an upland rice crop to establish a grass-legume pasture in the native savanna, and (2) the use of an upland rice crop and a legume component to reclaim degraded pastures.

The first objective consisted in determining whether it would be possible to succesfully and permanently establish an improved grass/legume pasture in an Oxisol when grown in association with upland rice. The second objective was to identify the best method for establishing the grass/legume/upland rice mix in the native savanna or on degraded pastures. The procedure applied consisted of establishing rice monocrop, and also the mix, in plots larger than 2,500 m^2, to compare the yield components of the second (rice grain and dry matter of the pasture) 1 year after planting.

Work Methodology

Location and soils

For the first objective of the study, two trials (Trials 1 and 2) were conducted in the Matazul Farm, located 40 km east of Puerto López Municipality in the Department of Meta, (Colombia). The farm is located at 4° 19' North and 72° 39' West; at an altitude of 160 meters above sea level; the average mean temperature is 27°C and with a 2,200 mm of rainfall. The dry period goes from December to March, followed by a bimodal rainy season. In the months of July and August there are short term duration dry periods - 1 to 2 weeks. The soils are Oxisols (Tropeptic haplustox isohyperthermic) with a pH of 4.5 and low Ca availability (meq/100 g), Hg (0.08), K (Bray 2) (0.1=, and P (Bray 2 (2mg/g) and an Al saturation greater than 80%. In both trials native savanna was burned followed immediately after by the land preparation for the planting of the rice-pasture association.

For the second objective, three Trials were conducted (called Trials 3, 4, and 5, in this Chapter). Trial 3, was performed at the CIAT-Carimagua station, located in the Colombian Eastern Plains at 4° 36' North and 71° 19' West of Carimagua, at 175 meters above sea level. The soil at the experimental site is ultic haplustox, of fine kaolin clay. Trials 4 and 5, were performed respectively at the Santa Cruz and El Trigrillo farms, located approximately at 195 and 200 km West of the CIAT - Carimagua station, under similar ecologic conditions. The values of soil tests for the three sites fall under these ranges: pH 4.2-4.5; Available P 1.5-2.0 mg/g; and K, Ca and Mg (meq/100 g)

= 0.06-0.10, 0.15-020 and 00.6-0.08 respectively. The effective cation exchange capacity has between 80% and 90% of Al saturation.

Planting

In all the Trials for planting rice in monoculture the soil was furrowed at 17 cm distance, and for the planting of the mix it was furrowed at 34 cm distance, in order to prevent competition by the pasture. For the grass and legumes trials (Trials 1 and 2), seeds were applied by broadcasting immediately before planting the rice. In Trials 3, 4, and 5, no grass seeds were used but establishment was attained with the seed bank and stolons present in the soil.

For the planting of Trials 1, 3, 60 kg/ha of the CT 6196-33-11-1-3 rice line were used (Line 3, the most advanced in 1989 for disease resistance). In Trial 2, 80 kg/ha of the CT 6947-7-1-1-1-7-M (Line 6 with similar characteristics to Line 3 of 1990) were used. In Trials 4 and 5, 80kg/ha of the CT 7244-9-2-1-52-1 (Line 23, which turned out to be equally resistant to diseases in 1991) were used.

In Trials 2 and 4, (as a treatment) and in Trial 5, early soil preparation was made by means of burning followed by two passes of chissel plow at 40 cm depth. These practices were performed at the beginning of the dry season (early December), followed by a later land preparation. In the same Trials (2 and 4 - and as a treatment) and in Trials 1 and 3, land preparation consisted of burning the vegetation - unless an earlier preparation had already been done - followed by two passes of disc plow to destroy aggregates in the soil and incorporate the fertilizers broadcasted two weeks before planting at the start of the rainy season in May. The rice was harvested towards the end of August.

Fertilizer application

When nutrients were not applied as a treatment, basic fertilization (kg/ha) was done as follows: application of N (80kg urea: 30 kg at 25 days; 20 kg at 40 days; and 30 at 60 days after planting). P (50 kg) (25 Huila rock phosphate and 25 kg as triple superphosphate, except in treatment 2, in which only the triple superphosphate was used); K (100 kg KCl) split in 3 applications of 30, 50, 20 kg, simultaneous with the N application. Zn (5-$ZnSO_4$) (except in Trials 1 and 3); and 300 kg/ha of dolomitic lime (31.3% Ca and 4.7% Mg, broadcast and incorporated with the last raking 2 weeks before planting. P was broadcast and incorporated before planting in Trials 1 and 3. P and Zn were applied to the seed at the moment of planting in trials 4 and 5. Huila rock phosphate is an apatite having medium solubility in ammonium citrate at pH 7.0, with a P content of 8% (Chien and Hammond, 1986).

Treatment and experimental design

Trials 1 and 3, at each selected site, and Trial 5, had a random block design with 3 replications. Trial 2 and 4, had a split-plot design with three replications.

Trial 1, rice vs. rice/pasture association after native savanna

(1989) included 3 treatments, each of which done in nine plots of 100 m x 100 m. Rice Line 3 was planted in all plots alone or in association with two mixes of grasses/legumes: *Andropogon gayanus* cv Carimagua -1/ *Stylosanthes capitata* cv. Capica or (*Brachiaria dictyoneura* cv. Llanero) *Centrosema acutifolium* cv. Vichada. Planting rates for *A. gayanus*, *B. dictyoneura*, *S. capitata* and *C. acutifolium* were 10, 3, 3, and 4 kg/ha, respectively.

In Trial 2 - about the effect of the time of soil preparation and of the method of fertilizer application on rice establishment and production as monocrop and in association with pastures after native savanna (1990), - the main plots consisted of those with early and late land preparation; the subplots were rice in monocrop (Line 6); rice + (*B. dictyoneura* + *C. acutifolium*); and rice + *A. gayanus* + *S. capitata*); and the sub-subplots consisted of application of fertilizer with the seed by broadcasting.
The size of the main plots were 150 x 150 m, the subplots were 50 x 100 m and the sub-subplots 25 x 100 m. These latter were along the field to facilitate mechanical cultivation, the total area was 9 has. and planting rate was equal to the one used in Trial 1

For Trial 3, - rice in association with grasses and legumes, and in grass-alone pastures (1989), three adjacent sites were selected that had been previously planted with different pasture types:

(1) *B. decumbens* + *P. phaseoloides* 10 years of establishment;

(2) *B. decumbens* alone, 10 years of establishment; and (3) native savanna. In each pasture two levels of P, and three levels of N [illegible] were applied as treatment in 400 m^2 plots. The P levels were 25 and 50 kg/ha (50% TSP + 50% Huila rock phosphate). The N levels (urea), were 0 and 40 kg/ha applied in dosages of 15, 10 and 15 kg/ha at 25, 40, and 60 days after planting, respectively; and 80 kg/ha of N distributed in dosages of 30, 20, and 30 kg/ha, with the same frequency of the prior application.

In Trial 4, reclaiming of degraded *B. Decumbens* pastures with rice cropping and legume based pastures (1990), the *B. decumbens* pastures had 10 years of establishment and had been managed under minimum raking to move the soil and without fertilizers application. The main plots were those of early and late land preparation, and the sub plots - with and without - seed planting of *S. Capitata* (3kg/ha)+ *C. acutifolioum* (4 kg/ha). The main plots sizes were 100 m x 100 m, and the subplots were 100 m x 50 m for a total area of 6 has.

In Trial 5 - reclaiming of degraded pastures of *B. humidicola*.- was done using the rice crop with and without legumes (1991), due to the rusticity and aggressiveness of this species it is seldom found in a degraded state. However, for this experiment it was possible to find a *B. humidicola* sligtly degraded pasture with a high percentage of weeds, due to overgrazing and to the lack of an adequate fallow period. The treatments consisted of planting or not, *Arachis pintoi* (4.5 kg/ha) + *Desmodium ovalifolium* (1.3 kg/ha). The size of the plots were 150 m x 50 m, for a total area de 4.5 ha.

In all the trials plant emergence was measured at 20 days after planting. rice dry matter production (grain and chaff) and biomass in the aerial part of associated pastures (grass + legume + weeds). The measurements were made in eight different sites of 1 m x 1 m, randomly located at each plot. Grain production of commercial rice in the total experimental area, was determined by using a combine harvester. Soil pH and P, K, Mg. Al Zn, Cu, S. B. and M.O soil contents were determined for each treatment prior to fertilizer application and after rice harvesting, by mixing several subsamples of each replication. In a similar fashion the nutrient content was determined: crude protein, P. B. K. Ca. Mg. S. and Zn in plant samples in each treatment.

Results

Trial 1

The new upland rice Line 3. showed good yield (more that 2 t/ha) with a moderate fertilizer application, and did not show a significant yield decrease when planted with improved tropical pastures on low fertility acid Oxisols (Figure 1). Weeds, an important problem in pastures systems, were observed in all treatments, probably resulting from the greater fertility under this new system, or by introduction in either rice or pasture seeds.

Figure 1. Paddy rice production (14% moisture) of Line 3, and pasture biomass in rice monocrop and in the association with pastures. Matazul Farm, Eastern Plains of Colombia, 1989

Treatment[a]	Rice (t/ha)	Grass	Legume (DM t/ha)	Weeds
Rice in monocrop	2.23 a[*]	--	--	0.65a
Rice + Bd- Ca	2.09 a	1.22 a	0.21 b	0-67a
Rice + Ag-Sc	1.950 a	1.77 a	0.44 a	0.43a
$DMS_{0.05}$	0.52	0.59	0.14	0.22

a. Rice line CT 6196-33-11-1-3 (No 3). Bd = *Brachiaria dictyoneura;* Ca = *Centrosema acutifolium;* Ag = *Andropogon Gayanus;* Sc = *Stylosanthes capitata.*

* Averages in the same column followed by similar letters do not vary significantly (P < 0.05) according to Duncan's test.

The absorption of nutrients calculation per unit of area in the aerial biomass, indicates that the rice crop was the main extractor among species, but it also suggests that pastures compete with rice specially for P, K, and Mg (Graph 1), although not affecting grain production. In general the *A. Gayanus + Stylosanthes capitata* pasture absorbed more P, K, Ca, and Mg than the *B. decumbems + C. acutifolium* pasture. Soil analysis showed that the P, K, Ca, and Mg contents were greater after harvest (Figure 2), except for Zn which was significantly reduced. Aside from the Zn, the soils after the first harvest were chemically better than those of the original native savanna, pastures developed well with the residual fertility, and initially they were ready for light grazing, and later for permanent grazing.

Trial 2

Early soil preparation resulted in an increase of 1 ton/ha in rice production in all treatments in comparison with late preparation (Figure 3). Monocrop rice yielded an increase in production when fertilizers were broadcast under early soil preparation conditions, but no differences were observed when fertilizers were applied under late land preparation conditions. In association with pastures, fertilizer application with the seed always resulted in significantly higher rice yields (Figure 3). Weeds' dry matter production was inferior with this latter way of fertilizer application, when compared with broadcasting when the land preparation was late. (Figure 3).

Rice yield after:

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Graph 1. Rice establishment and production when planted in a *Brachiaria decumbens* pasture that had been established for 10 years. CIAT- Carimagua, Eastern Plains of Colombia 1989. Sn= Native savanna; Bd = *B. decumbems;* Bd + Pp = *B. decumbens* + *Pueraria phaseoloides.*

Figure 2. Nutrients availability in the soil (kg/ha, before and after a rice crop in the associated syste or rice-pastures, for pasture establishment. Matazul Farm, Llanos Orientales de Colombia 1989.

Soil status [a]	P	K	Ca	Mg	Zn
Before rice cropping	3.2	54.6	68.0	14.4	0.74
After rice cropping	9.1	67.1	112.0	31.2	0.46
After rice cropping +Bd-Ca	11.8	89.2	124.0	28.8	0.42
After rice cropping +Ag-Sc	19.6	70.2	116.0	28.8	0.42

a. Bd = *B. dictyoneura:* Ca = *C. acutifolium;* Ag=*A. gayanus,* Sc = *S. capitata*

Trial 3

Production of rice planted after *B. decumbens* + *P. phaseoloides* yielded more than 3 t/ha (Graph 1.) in all treatments, including those in which no N was applied, or in those receiving only 25 kg/ha; However, when the dosis was doubled, P (50 kg/ha) no effect was observed on yield. When N applications were increased from 0 to 80 kg/ha, rice production increased in 0.5% t/ha. Poor paddy rice yields 1.3 t/ha) were observed when rice was planted in pastures of *B. decumbens* alone without N application, with 25 kg/ha or 50 kg/ha of P. However, the application of 40 kg/ha of N. increased production to 3 t/ha, and the application of 80 kg/ha resulted in an additional increase of 0.5 t/ha. No difference in rice production was found by applying different doses of P. Rice production when planted after native savanna was low (less than 2 t/ha), being inferior to that obtained by planting rice after improved pastures. The initial soil analysis at the three sites indicated that K, Ca and Mg status was better in improved pastures than in native savanna.

Trial 4

The results of this trial (Figure 4), indicate again a high yield for Rice Line 23 (more than 3.4 t/ha) and a good degraded pasture recovery. No differences were found between early and late land preparation treatments, with or without the introduction of forage legumes.

Figure 4. Rice and DM production (t/ha of pastures and weds in the reclaiming o *B. decumbens* degraded pastures. Santa Cruz Farm Eastern Plains of Colombia, 1990.

Treatment	Rice[a]	*B. decumbens*	*C. acutifolium*	*S. capitata*	*Weeds*
Early preparation					
With legume	3.5[illegible] a*	0.44 a	0.11 a	0.17 a	0.093 a
Without legume	3.64 a	0.68 a	--	--	0.14 a
Late preparation					
With legume	3.46 a	0.53 a	0.11 a	0.17 a	0.25 a
Without legume	3.40 a	0.74 a	--	--	0.19 a
$DMS_{0.05}$	0.57	0.29	0.06	--	0.22

a. Rice Line CT 7244-9-2-1-52-1 (No. 23)

* Averages on a same column followed by same letters do not presnt significant variation (P < 0,05) as per Duncan's test

During the early preparation, grass burning was difficult due to a lack of plant material in the degraded pasture. At the moment of rice harvesting the *B. decumbens* pasture was recovered and ready for grazing. The legumes were found in the same conditions than the grasses and the condition of the grass-legume association was excellent, with a ratio of (M.S.) DM of 1.5:1 and 1.6:1

Soil analysis before the Trial and after the rice harvest (Figure 5), showed that nutrient levels were not affected by fertilizer application to the crop, in contrast with the 10 year well fertilized pasture (see Trial 3, above).

Trial 5

Figure 5. Nutrients availability status in the soil (kg/ha) before and after a rice crop in the reclaiming of degraded *B. decumbens* pastures. Santa Cruz Farm, Eastern Plains of Colombia.

Soil status	P	K	Ca	Mg	S	Zn
Before the crop	6.6	31.2	152.0	12.0	22.7	0.42
After the crop	4.6	46.8	120.0	16.8	21.8	1.12
After rice crop+ *S.capitata&* *C.Acutifolium*	6.6	54.6	176.0	19,2	33.4	0.74

Initially, the rice presented poor growth with foliar symptoms of severe Mg deficiency; despite that *B. humidicola* developed well. The soil analysis results (0.11 amd 0.06 meq/100 g Ca and Mg, respectively) and tissue analysis (0.21% of Ca and 0.04% Mg) confirm the Mg deficiency in the rice crop, as well as the low levels of Ca. When applying 135 kg/ha pf Ca and 160 kg/ha of Mg as chlorides in an additional treatment on a different plot, a good recovery of the rice crop was observed. With this additional treatment rice yields doubled the figure of the non treated plot (Graph 2.) despite the aggressive growth of *B. numidicola*. Both species and the legumes were well established, and evaluation was continued under grazing.

Discussion

High rice yields (2 to 3 t/ha.) can be obtained when planted in association with pastures and with moderate input application. In pastures established simultaneously with rice planting, yields obtained were between 0.41 and 2.54 t/ha of DM for the grasses, and 0.07 and 0.44 t/ha DM for the legumes, without affecting rice yields. The establishment of rice/pastures associations allows to keep a low weed level assuring soil coverage throughout the year. Prior research done (CIAT, 1989) indicated that with early land preparation it is possible to obtain twice the rice production than with a late land preparation. In Trial 2, the effect of early land preparation in addition to the suppression of weeds, was due to the K + NH_4 release from Al--chlorita/Al-vermiculite after the postharvest drying and moisture. (Sanz and Rowell, 1988; Sylvester-Bradley et al., 1988).

In this work, a confounded effect of components occurred when early preparation of the soil was done : burning and chisel plow. Research is being currently conducted to separate the individual effect of these components and to evaluate alternatives to burning. Plant density in the pasture might produce a negative impact on rice development and production, especially if plant density is high at the initial state of the crop. In Trial 1, rice + *B. decumbens/ C. acutifolium* and rice + *A. gayanus/ S. capitata*, the average germination of the pasture components was: 0.6 and 0.9 plant/m^2, 20 days after planting, respectively. In Trial 2, in treatments with late land preparation, this average was 13.9 and 18.2 plant/m^2. In the latter trial, rice production was lower than in the former, and pasture production was not affected by the initial plant density (Figures 1 and 3).

Improved pastures may be plowed and they spontaneously re-establish when planted with rice. Rice yield (3.5t/ha) after the planting of improved pastures can be bigger than after native savanna; this might occur - even without N application - by planting after the grass/legumes association. In all cases re-establishment of associated pastures took place.

Nutrient absorption by rice was reduced when planted in association with pastures on native savanna. However, P, Mg, and Zn competition might limit production under those circumstances. Yet, in both years, after planting rice and rice/pastures, the Ca and Mg levels in the soil remained higher than the initial figures. P and K, were high after the first year of harvest remaining at the same level during the second year. This indicates that after rice harvest there is a significant residual fertility in the soil that pastures can take advantage of. Although low P, K, and S, reserves in the soil suggests that pastures can easily degrade unless the initial competition is reduced. Zn is very low in these soils, was highly absorbed by rice and it was necessary to apply it during the second year.

In this work the contribution of N by the legume refers to a 10 year association of grass/legumes. In CIAT's works at CIAT-Carimagua (CIAT, 1992) using pastures' productivity and legume content in *B. decumbers* alone and in association with *P.*

phaseoloides, it was estimated that 80% to 90% of the potential benefit of this legume in N fixation is obtained betwen years 3 to 5. This indicates that it is not necessary to wait for 10 years to reach such an important economic benefit.

High profit of an annual crop in a short term can be combined with the long term productivity and improvement of soil properties provided by the grass/legume pastures. The rice/pasture system improves the soil nutrients state by the direct application of the most important elements as fertilizers, by the legume N fixation and the O.M. resulting from the abundant biomass of the associated pasture. Production alternatives: annual crop and permanent pasture, might obtain mutual benefit; thus, in cattle raising areas where no cultivation was possible, the new upland rice lines developed and adapted to these acid low fertility soils might be used providing new production options.

The large size plots used in this work in combination with the commercial level production indicate that the system is feasible, and it is also feasible the commercial combine harvesting of rice in the mixture of grasses/legumes. This large scale experiment allows performing long-term studies under the real commercial system conditions in order to estanlish, document and assess the sustainability determining factors in a practical and direct manner.

The wealth of species in the gallery forests of the native savanna (Burman, 1991) and their natural beauty make of them a