Integrated management of itchgrass (*Rottboellia cochinchinensis*) in maize in seasonally-dry Central America: Facts and perspectives

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ABSTRACT

Itchgrass (*Rottboellia cochinchinensis*) is a serious and persistent weed problem in many tropical agricultural and conservation areas. In Central America it is one of the most noxious and serious weeds in several upland crops, causing severe yield losses. Experimentally, pre-emergence control with herbicides, weed elimination during the fallow period and zero tillage reduced itchgrass populations in comparison to conventional practices used by growers (no fallow management, soil preparation by disc harrowing and limited use of in-crop herbicides). Additional improvement in itchgrass management is brought about by inter-sowing legume cover crops. Of several legumes evaluated, mucuna (*Mucuna deeringiana*) and *Canavalia ensiformis* controlled the weed better and covered the soil, especially if planted simultaneously with maize. Itchgrass suppression by mucuna usually corresponded with increased grain yields but competition by the cover crop could reduce yields; a good compromise is to delay mucuna planting by two weeks in relation to maize. Integrated tactics to control itchgrass were evaluated in on-farm validation plots. Pendimethalin controlled itchgrass at the onset of validation plots and facilitated the establishment of the cover crop. Itchgrass densities were lower in validation plots than in grower's fields while infestation levels and the soil seed bank decreased over three years with integrated management. In general, corn yields were also higher in validation plots. Integrated itchgrass management also proved economically feasible for smallholders. A promising alternative is biological control with the itchgrass smut, *Sporisorium ophiuri*, which prevents seed set and is host specific.

INTRODUCTION

Itchgrass (*Rottboellia cochinchinensis* [Lour.] W.D. Clayton) is a pantropical grass weed native to the Old World which probably was introduced to the New World at the beginning of the century. Here, in its exotic range, infestations are considered to be the most severe (Ellison & Evans, 1992) probably as a result of several contributting factors including improved climatic compatibility, mans activity's in disseminating the grass, favourable

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agronomic practices, and the absence of co-evolved natural enemies. It it estimated that itchgrass affects more than 3.5 million hectares in Central America and the Caribbean (FAO, 1992). In Central America itchgrass is found infesting both annual and perennial crops and has been reported causing significant yield loss in maize, sugar cane, upland and rain-fed rice rice, beans and sorghum (Herrera, 1989). Itchgrass infestations can result in up to 80% crop loss, or even abandonment of agricultural lands (Holm *et al.*, 1977). In this paper we address key elements for the integrated management of itchgrass with emphasis on the maize production systems of seasonally-dry areas of Central America.

LOCAL SURVEYS OF ITCHGRASS DISTRIBUTION AND IMPORTANCE

According to surveys in 1994, farmers in the Pacific region of Costa Rica, where most of the research referred to here was conducted, cultivated an average 5.6 ha of monocrop maize or maize-beans, with an estimated 34% of total inputs used solely on itchgrass control. All farmers considered itchgrass to be a troublesome weed, citing its rapid growth and yield reducing effects as the most detrimental characteristics. Control was mainly by a combination of manual (slashing) and chemical methods. Two-thirds used paraquat to control itchgrass and those that relied exclusively on herbicides (23% of the sample) sprayed an average of 2.5 times during the cropping season (Calvo *et al.*, 1996). Similar results were obtained in 1995 in the Atlantic zone of Costa Rica (Merayo *et al.*, unpublished results), where more than three-quarters of the farmers considered itchgrass a problem, the most commonly cited reasons being effects on crop growth (46%), "yellowing" (nitrogen deficiency induced by competition) of the crop (36%) and the large amount of seed produced. All farmers used chemicals to control itchgrass; almost half (43%) additionally rely on physical methods. The most widely used herbicide was paraquat; glyphosate was also used as well as the tank mixture of atrazine plus paraquat. Chemical control of itchgrass accounted for 26% of the income obtained from selling the grain.

Itchgrass is also important in other areas of Mesoamerica. Recent surveys (Valverde *et al.*, unpublished) defined the importance and distribution of the weed in Mexico. Important infestations occur in maize in Campeche state where farmers rely on nicosulfuron and slashing for its control. Serious widespread infestation of maize, rice and sugar cane crops were also found in Veracruz (Tres Valles and Tierra Blanca area) and Oaxaca (around Tuxtepec, Jalapa de Diaz and Nopaltepec). Itchgrass, along with *Sorghum halepense*, is a particular problem in maize production that is now dependent on herbicide use for its control, especially pre-emergence applications of an ametryne/2,4-D ester mixture and directed applications of paraquat, supplemented by slashing if required. In the highlands, maize is grown with a sesame relay crop and here growers have adopted the use of paraquat, followed by two manual weedings, to avoid complete lost of maize yield. Prior to the introduction of itchgrass only hand weeding was used. Moving north in Veracruz itchgrass has already reached Martinez de la Torre where it has become a troublesome weed in citrus production. It seems almost certain that itchgrass was introduced as a contaminant of rice seed and subsequently spread on tillage equipment used for sugar cane grown in rotation with rice or when rice is replaced due to increasing weed pressure.

Most farmers cultivate maize plots of less than 5 ha, and the great majority (about 80%) recognised itchgrass as a troublesome weed. Two thirds of the interviewed farmers use herbicides (nicosulfuron, paraquat and glyphosate) to control itchgrass either alone or in combination with slashing; some rely exclusively on manual (slashing) control.

BIOECOLOGICAL ASPECTS RELATED TO MANAGEMENT

Itchgrass is an erect, strongly tufted, annual grass, characterized as a vigorous competitor and for being able to reach a height of up to 4 m (Holm *et al.*, 1977). It is a weed of warm season crops but its habitat varies widely across the world, being reported as a weed of 18 crops in 28 countries (Holm *et al.*, 1977). Itchgrass reproduces by seeds which are disseminated by water, farm machinery, birds, and, over long distances, as a crop seed contaminant. There are indications of such type of dissemination in rice seed movements from Colombia to Brazil in 1961 (Millhollon & Burner, 1993). Itchgrass seed has been found in rice-seed lots received at the International Rice Research Institute in the Philippines (Huelma *et al*, 1996). In Costa Rica, we estimated a maximum seed production between 7400 and 8900 seeds/m^2 with a single itchgrass plant growing in isolation producing between 700 and 820 seeds. Seed dormancy and germination habits vary substantially across the world (Holm *et al.*, 1977). In a seed burial study, Rojas *et al.* (1994) showed that little viable seed remained after 18 months in the soil, underlining the importance of prevention of seed set in the weed's management. Seed on the surface and buried at 5 and 10 cm substantially lost its persistence; at 20-cm deep less than 10% of seeds remained viable. Itchgrass evolves distinct biotypes. Millhollon & Burner (1993) divided biotypes gathered from 34 countries or territories into five broad groups based primarily on the effect of day length on flowering, but also on general morphology and pattern of growth. Biotypes can also be distinguished by isozyme analyses, particularly esterases (Fisher *et al.*, 1987). In Costa Rica, biotypic differentiation also has been documented (Rojas *et al.*, 1992, 1993c) according to plant morphology (height, tillering, pubescence) and vegetative cycle under comparable conditions.

In the Pacific region of Costa Rica, Rojas *et al.* (1993b) determined that the critical period of interference of itchgrass on maize was from planting to between 45 and 60 days at itchgrass densities between 66 and 74 plants/m^2. When itchgrass was allowed to compete unrestricted with the crop it reduced maize yields between 46% and 54%. Similarly, Bridgemohan *et al.* (1992) determined in Trinidad that the critical period of interference was from 0-63 days after emergence at 55 itchgrass plants/m^2 with yield reductions of about 50% in unweeded plots.

Improved control tactics and their integration for sustainable itchgrass management

A long term trial on the effects of integration of control tactics on itchgrass populations in the seasonally arid zone of NW Costa Rica provided useful information for its sustainable management (Rojas *et al.*, 1993a). There are typically three cropping seasons per year: maize, maize or beans, and a fallow dry season. The four-year study addressed itchgrass management in a maize-beans-fallow rotation begining in 1991. Tactics evaluated were fallow management: handweeding, paraquat application (0.5 kg/ha) and no weeding; tillage practices: zero tillage and conventional tillage (one pass of a disk plough to 20 cm depth plus two passes of a disk harrow) and in-crop control: 1.0 kg/ha pendimethalin plus 2.4 kg/ha alachlor (H1), 1.25 kg/ha pendimethalin (H2), 1.5 kg/ha pendimethalin (H3), and no control (H4). Herbicides were applied pre-emergence following planting in both crops. Fallow management practices were initiated during the dry season of September 1991, prior to the maize planting of a maize-bean rotation in May 1992. Subsequently, maize was planted each year at the beginning of the rainy season in May and beans were planted immediately after the maize harvest in September. Adverse weather conditions resulted in the bean crop being lost every year. Average itchgrass population on the trial site in September 1991 (before implementation of the treatments) was 58 plants/m^2.

Itchgrass density was substantially higher in plots without control in the fallow period but use of in-crop herbicides decreased the weed populations to similar levels regardless of fallow management (Table 1). Lower itchgrass populations also were observed in plots with zero tillage compared with conventional tillage. In-crop control by herbicides had the largest effect on itchgrass populations during the crop cycle and this was greater than the effect of either tillage or fallow management. The lowest itchgrass population was observed in plots with the higher rate of pendimethalin (data not shown). Maize yields were always lower in plots with no fallow and in-crop itchgrass control. When the weed was controlled chemically early in the cropping season, yields were moderately higher in plots with fallow management. However, there was no evidence of maize-yield improvement in plots with zero tillage compared to conventional tillage.

Table 1. Effect of integrated control tactics on itchgrass density and maize yield over four sowing cycles. Guanacaste, Costa Rica, 1992-1994[1]. Maize and beans planted in May and September respectively.

Control tactic	Itchgrass density at 45 DAP (plants/m^2)					Maize Yield (kg/ha)		
	5-92	9-92	5-93	9-93	5-94	10-92	10-93	10-94
With in-crop control by herbicides[2]								
Fallow management								
Zero tillage	14.0	4.8	4.0	3.6	1.6	3525	2908	2996
Conventional tillage	16.4	10.0	6.0	4.4	2.0	3688	2917	3983
No Fallow management								
Zero tillage	12.8	5.2	8.0	3.6	2.4	3708	2617	2267
Conventional tillage	18.0	11.6	8.4	10.0	3.6	3618	2158	2906
Without in-crop control nor fallow management								
Zero tillage	75.6	26.0	41.6	55.6	56.0	2396	650	0
Conventional tillage	74.0	44.4	54.0	69.6	64.4	2146	700	758

[1]Adapted from Rojas *et al.* (1993) and unpublished data.
[2]Data are means for the three herbicide treatments H1-H3 (see text for details).

Legume cover crops as the basis of integrated itchgrass management.

Thirteen legume species were originally screened for their adaptation and usefulness for itchgrass suppression in the Guanacaste region in Costa Rica (de la Cruz *et al.*, 1994). The best cover crops were *Mucuna deeringiana*, *Pueraria phaseoloides*, *Canavalia ensiformis*, *Vigna unguicalta* and *Dolichos lablab*. Of these, mucuna (*M. deeringiana*) was the most suppressive of itchgrass and the species of choice for further development as a cover crop.

Three of the legumes (mucuna, *C. ensiformis* and *V. unguiculata*) were further evaluated as cover crops in 1994. Itchgrass density was reduced about 60% in the presence of either mucuna or *C. ensiformis* and by 55% with *V. unguiculata* compared to the unweeded control, 90 days after planting (DAP). Itchgrass substantially reduced maize yields which were almost ten times higher in the presence of the suppressive legumes. Itchgrass suppression and ground cover was better when the cover crops were planted simultaneously with maize or a week later, compared to two weeks after maize planting but there was no interaction between cover crop and planting time Itchgrass suppression by the legumes corresponded with increased maize grain yields. Of the two most effective legumes, mucuna seemed more suitable for grower's adoption since it is an annual species, easier to manage and with a better growth habit.

Valverde *et al.* (1995) reported reductions of itchgrass biomass at maize harvest between 75 and 95% when mucuna was intercropped with maize at either 50 000 or 80 000 plants/ha. On the other hand, itchgrass density did not affect mucuna biomass nor were differences found between the two mucuna densities. However, both mucuna (planted one week after maize) and itchgrass reduced grain yield up to 40%. These results prompted additional research to better define planting dates and densities for the cover crop in order to minimize negative effects on crop yield.

The interaction between mucuna, maize and itchgrass was further studied in the first cropping season of 1996 and 1997. The locally adapted "*Criollo*" and an improved "*Diamantes*" maize variety were grown in association with mucuna (two varieties differing in the colour of their seeds, variegate and grey seeded, respectively) in presence and absence of the natural itchgrass infestation. Although initial itchgrass densities (15 DAP) were low (3 - 7 plants/m^2) in both years, both mucuna selections supressed itchgrass populations, especially at or after 60 DAP (Table 2). Fresh weight evaluations better described the suppressive effect of the cover crop indicating that itchgrass plants also grew smaller in plots where mucuna was planted than in plots without the legume. By the end of the critical period of competition (45 DAP) mucuna suppressed itchgrass biomass from 60% to 80%. No major differences were observed between the two varieties, except that the variegate-seeded mucuna covered the ground faster than the grey seeded variety and produced more biomass up to 45 DAP in 1996.

Table 2. Effect of maize and mucuna varieties on itchgrass density and fresh weight and grain yields in Guanacaste, Costa Rica, 1996-1997[1].

Treatment		Itchgrass density (plants/m²) at days after planting (DAP)			Itchgrass fresh weight (kg/m²)		Maize yield (kg/ha)
		45	60	90	45 DAP	60 DAP	
1996							
Maize variety	Criollo	9.95 a[2]	10.18 a	7.87 a	0.170 a	0.095 a	2194 b
	Diamantes	10.44 a	9.26 a	6.02 a	0.129 a	0.084 a	3560 a
Mucuna variety	Grey seed	10.07 a	8.68 a	5.56 ab	0.069 b	0.038 ab	2796 a
	Variegated seed	9.72 a	6.60 a	3.47 b	0.063 b	0.022 a	2910 a
	Without mucuna	10.76 a	13.90 a	11.81 a	0.316 a	0.209 b	2926 a
1997							
Maize variety	Criollo	17.13 a	4.17 a	7.87 a	0.269 a	0.227 a	1554 a
	Diamantes	21.99 a	12.96 b	21.99 b	0.310 a	0.418 a	903 b
Mucuna variety	Grey seed	16.67 a	7.90 a	4.20 a	0.179 a	0.090 a	1131 a
	Variegated seed	18.06 a	5.90 a	10.74 a	0.207 a	0.193 a	1148 a
	Without mucuna	23.96 a	11.81 a	29.86 b	0.481 a	0.684 a	1394 a

[1] Partial data from experiments conducted by Valverde *et al.* (unpublished).
[2] Means followed by the same letter within main effect (maize or mucuna variety) within year are not significantly different according to Tukey's multiple range test at 5%.

In the first year the improved variety (Diamantes) yielded more than the local (Criollo) variety and mucuna did not decrease maize yield. However, in 1997 mucuna slightly reduced maize yield and the criollo variety was more competitive with itchgrass and yielded about 70% more grain (1554 kg/ha) than Diamantes (903 kg/ha). This could be associated with a shorter cycle of the local variety that decreased the negative impact of severe water stress late in the cropping season. Yields were lower than normal in 1997 because of drought.

Repeated experiments in 1996 and 1997 studied the impact of mucuna density (25 000 or 50 000 plants/ha) and planting time (0, 5, 10 or 15 DAP) on itchgrass and maize (cv Diamantes). Mucuna was more effective in reducing itchgrass density at 50 000 plants/ha than at 25 000 plants/ha throughout the experiment in both years (Table 3). Better soil cover by mucuna was obtained when it was sown simultaneously with maize than when planted later in relation to the crop, probably because of the competition imposed by maize on the cover crop. At 45 DAP mucuna (planted at 50 000 plants/ha simultaneously with the crop) reduced itchgrass density to 23 and 46% of that recorded in the unweeded controls in 1996 and 1997, respectively (data not shown). Concomitantly, itchgrass biomass decreased between 10 and 15% when mucuna density increased from 25 000 to 50 000 plants/ha, although these differences were not statistically significant. The same tendency was observed as the mucuna planting date was closer to that of maize. Lower maize grain yields were obtained in both experiments when maize was grown in association with mucuna at its highest density and, especially, when the cover crop was planted simultaneously with maize (data not shown). Itchgrass itself decreased maize grain yield by about 46% in both years; yields in 1997 were substantially lower than in 1996 because of drought (data not shown).

Table 3. Effect of mucuna density and planting date on itchgrass density and fresh weight and on mucuna ground cover at 45 days after planting maize. Guanacaste, Costa Rica, 1996-97[1].

Main treatment or Factor		Itchgrass density (plants/m^2)		Mucuna ground cover (%)		Itchgrass fresh weight (kg/m^2)	
		1996	1997	1996	1997	1996	1997
Density	25,000	20.0 a[2]	71.2 a	32.81 a	26.25 a	0.497 a	0.655 a
(plants/ha)	50,000	12.2 b	77.6 a	44.37 b	42.00 b	0.450 a	0.576 a
	0	10.0 b	53.8 a	79.37 a	54.37 a	0.402 a	0.477 a
Planting date	5	14.5 b	82.3 a	33.75 b	35.62 b	0.495 a	0.693 a
(DAP)	10	14.5 b	86.8 a	21.25 c	23.57 c	0.450 a	0.737 a
	15	25.5 a	74.6 a	20.00 c	20.62 c	0.545 a	0.558 a
Unweeded control	-	26.0	111.1	-	-	1.076	0.997

[1] Partial data from experiments conducted by Valverde *et al.* (unpublished).
[2] Means followed by the same letter within main effect (density or planting date) and year are not significantly different according to Tukey's multiple range test at 5%.

Efforts were also made to adapt legume cover crops for itchgrass suppression in the maize monoculture and cassava-maize systems in the Atlantic region of Costa Rica, where itchgrass is also a key weed (Merayo *et al.*, 1998). This region is characterized for a long rainy season (average rainfall at experimental site is 4440 mm) and the absence of severe dry periods during the year. None of four legume species (*M. deeringiana, C. ensiformis, V. unguiculata* and *P. phaseoloides*) gave satisfactory ground cover or provided adequate suppression of the high infestation of itchgrass present at the experimental site. Where maize and cassava were grown in association, these cover crops also failed in suppressing itchgrass probably because of the early emergence of the weed and the poor ground cover obtained. Additionally, cover crops reduced maize yields compared to those obtained in plots with the grower's management (hand mowing at 15 and 30 DAP) and prevented production of the associated cassava crop.

Validation of improved itchgrass management in grower's fields

Integrated tactics to control itchgrass were evaluated for three years in on-farm validation plots (about 1000 m^2 each) beginning in 1995 in small, subsistance growers fields at three locations in Guanacaste, Costa Rica (Valverde *et al.*, 1999). At two of the sites (Arado and Corralillo) maize is grown twice per year; in the third location (Palmira) the cropping system is based on a maize-dry beans-fallow rotation. Validation plots integrated no-tillage, use of the selective herbicide pendimethalin in the first maize crop (to lower the initial density of itchgrass), planting of mucuna between maize rows, and prevention of itchgrass seed set in the fallow period. In grower's plots itchgrass control was based on a combination of slashing and direct applications of paraquat. Pendimethalin effectively controlled itchgrass and allowed the establishment of mucuna during the first maize crop. At all sites, itchgrass densities were lower in validation plots than in grower's fields and infestation levels decreased throughout the years with integrated management (Figure 1). In general, maize and dry beans yields were higher in validation plots at all locations and cropping seasons; however soil fertilization regimes and sometimes maize varieties differed between validation and grower's plots, preventing direct yield comparisons. Soil core samples also revealed substantial reductions in the itchgrass soil seed bank in validation plots (Merayo *et al.*, unpublished results). On average, 1.1 seeds/kg germinated and emerged from soil samples taken from validation plots at 0-10 cm whereas in the grower's plots germinating seeds amounted 5.22, 17.23 and 17.00 per kilogram in 1996, 1997 and 1998, respectively. Germinating seeds at 10-20 cm depth ranged between 0.12 and 0.48 seeds/kg and 0.23 to 2.12 seeds/kg in validation grower's plots, respectively. The sustained depletion of the soil seed bank corroborates the biological suitability of integrated itchgrass management. Partial budget analyses demonstrated that integrated itchgrass management also is economically feasible for smallholders (data not shown). Weed management costs were usually higher in validation plots than using grower's technology; pendimethalin was one of the inputs that increased costs. However, increased yields at most sites and years balanced the higher production costs and improved profitability.

Prospects for classical biological control of itchgrass

A very promising and complementary alternative for itchgrass management is classical biological control. Of several itchgrass pathogens screened as possible biocontrol agents a head smut, *Sporisorium ophiuri* (P.Henn) Vanky (Ustilaginales), has been thoroughly studied (Ellison 1987, 1993, Reeder *et al.*, 1996). The smut is a soil-borne, systemic pathogen, infecting itchgrass seedlings before they emerged from the soil. Experimentally, significant reductions in seed set was achieved when plants were infected. In the endemic range of the weed, natural epiphytotics of the smut are common, often with a high percentage of plants infected within a population. Isolates of the smut were found to be itchgrass-biotype specific but one from Madagascar was found to infect a wide range of biotypes including a number from Latin American, and hence selected for a comprehensive host range screening. The smut was found to be extremely host specific; none of 49 species/varieties of graminaceous test plants other than itchgrass became infected. Screened species included pastures, weedy grasses, gramineous crops (rice, sugar cane, maize, sorghum) and the maize ancestor *Zea (Euchlaena) mexicana* (teosintle).

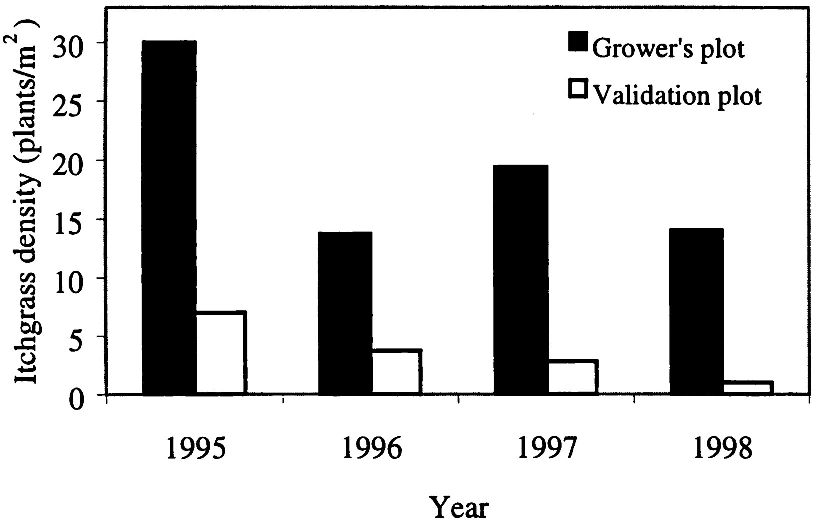

Figure 1. Itchgrass density in validation and grower's plots at 60 DAP (data are averages across three validation sites). Guanacaste, Costa Rica.

The dynamics of the itchgrass-head smut system was explored within a modeling approach (Smith *et al.*, 1997). This work suggested that a very high annual infection rate (above 85%) would be required for the smut to be effective as the sole agent of control. Further refinement of the model and additional simulations suggested that the smut in combination with a cover crop could be highly effective. A low density cover crop plus 50% smut infection rate resulted in 2 plants m^{-2} in each crop. Simulations of a high density crop plus smut predicted a reduction of itchgrass density to 0.1 plant m^{-2} (Smith *et al.*, unpublished).

A leaf rust, *Puccinia rottboelliae* P&H Sydow (Uredinales), also was observed to cause severe damage to itchgrass in the field, particularly to seedlings, and could complement the effect of the smut fungus by reducing the competitive ability of the weed within a cropping system (Reeder *et al.*, unpublished). Unfortunately, none of the rust strains screened proved sufficiently virulent towards any of the South American biotypes that were challenged, therefore, further host range screening was suspended.

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