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Itchgrass (*Rottboellia cochinchinensis*) and its Management

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ABSTRACT

ITCHGRASS (*Rottboellia cochinchinensis*), a C_4 annual grass weed, poses a significant threat to warm-season crops in tropical and subtropical regions. Its invasive nature, exacerbated by its rapid population growth and ability to thrive in diverse habitats, has made it a major problem for at least 18 crops across Africa, Asia, the Americas and Oceania. This weed significantly impacts yields, causing losses between 20-70 per cent depending on crop type and environmental conditions. Itchgrass competes aggressively for nutrients, water and light, making it difficult to manage. It reproduces exclusively through seeds that are spread by water, birds and human activities, contributing to its widespread dissemination. Management strategies for itchgrass include mechanical, cultural, chemical and biological methods, emphasizing an integrated approach. Mechanical controls involve cultivation and hand removal, while cultural controls focus on crop rotation, cover crops and certified seed use. Biological control explores the use of natural enemies, such as fungi and rusts to suppress itchgrass populations. Chemical control, utilizing pre-emergence and post-emergence herbicides, also plays a crucial role in managing this weed. Despite these efforts, control remains challenging and a multifaceted approach is essential for effective itchgrass management.

Keywords : Invasive, Itchgrass, Herbicide, Biology, Chemical control

ITCHGRASS is a C_4 annual grass weed prevalent in rainfed environments, particularly problematic in warm-season crops. Its populations can rapidly build up in various habitats throughout the tropics (Holm *et al*.,1991). Its common names in English and other languages relate to the silicaceous, fragile, irritating hairs covering the leaf sheaths that break off on contact with the skin. It is native to the Old World (Afro-Asian) and probably was introduced to the New World at the beginning of the twentieth century. Here, in its exotic range, infestations are considered to be the most severe, perhaps because of several contributing factors, including improved climatic compatibility, human intervention in disseminating the grass, favourable agronomic practices and the absence of co-evolved natural enemies (Ellison and Evans, 1992).

This weed is a major issue for at least 18 crops across Africa, Asia, Central and South America, the United States, Australia and Papua New Guinea (Table 1). Itchgrass ranks among the three most serious weeds affecting cassava (*Manihot esculenta* Crantz), corn (*Zea mays* L.), peanut (*Arachis hypogaea* L.), sorghum (*Sorghum bicolor* L. Moench), pineapple [*Ananas comosus* (L.) Merr.], banana (*Musa* spp.), cowpeas (*Vigna unguiculata* L.) and rice in countries such as Cuba, Ghana, Jamaica,

TABLE 1

Geographic distribution of *Rottboellia cochinchinensis* and associated major crops

Region	Countries	Major Crops Affected
Africa	Ghana, Nigeria, Zambia, Zimbabwe	Maize, Sugarcane, Cowpea
Asia	India, Philippines, Indonesia, Thailand	Rice, Sugarcane, Maize
Central America	Honduras, Costa Rica, Nicaragua	Maize, Beans, Sugarcane
South America	Venezuela, Brazil	Cassava, Maize
Oceania	Papua New Guinea, Australia	Rice, Sugarcane
North America	USA (Louisiana, Florida)	Maize, Sugarcane

Source : Holm *et al.,* 1991

Venezuela, Trinidad, Tobago and the Philippines (Holm *et al.,* 1991). Additionally, itchgrass thrives along roadsides, in open, well-drained sites, on contour banks and at altitudes up to 2,300 meters (Grace *et al*., 2011).

Although it is a tropical plant, *Rottboellia* can also grow in cooler and drier conditions (Strahan *et al.,* 2000). Considered a very aggressive invasive plant, *Rottboellia* is one of the most noxious weeds known worldwide (Alves *et al.,* 2003). It causes yield losses of 20 to 70 per cent, depending on the crop type, harvest cycle and local ecological conditions, including soil type, fertilization methods and the season in which the crop is grown (Millhollon and Burner, 1993). Itchgrass competes with plants for nutrients, water, space and light for photosynthesis and causes great losses in crop yields (Hall & Patterson 1992; Lejeune *et al.* 1994; Casini *et al.* 1998; Ajmal *et al.,* 2002 and Strahan *et al.* 2000).

Fig. 1 : Itchgrass plant

Fig. 2 : Silica hairs on the leaf sheath

Biology and Ecology

Itchgrass features cylindrical, hollow stems that branch at the upper nodes, where leaves arise (Fig. 1). The leaves, which are flat and 5-20 mm wide with a conspicuous pale mid-vein, appear blue-green when growing vigorously and yellowish otherwise. The base of the stems has prop roots and the plant produces multiple tillers. Silica hairs on the leaf sheath (Fig. 2) can penetrate and irritate the skin (Cope, 2002). The flowers are borne on spikes up to 15 cm long, which can appear singly or in groups of 3-4 from the leaf axils at the top of the stem. As these spikes mature, the cylindrical rice-sized seeds progressively break free from the furthest end and fall to the ground (Jackson *et al.,* 2019).

R. cochinchinensis has evolved distinct biotypes across different areas of its range. Most of these biotypes are diploids with 2n=20 chromosomes, though some are polyploids with 2n=40 or 2n=60 chromosomes (Table 2). The shape of the glume tip on the pedicellate spikelet serves as a reliable marker to distinguish these biotypes: acuminate for diploids (2n=20), acute for polyploids with 2n=40 and obtuse for polyploids with 2n=60 chromosomes (Millhollon and Burner, 1993). The receptor of the photoperiodic stimulus appears to be the expanding leaf. Alves *et al.* (2003) also identified both diploid and polyploid biotypes are differ in seed size, stomatal size and total chromosome length, variability that was confirmed at the molecular level. Cytological and morphological studies of two morphotypes of *R. cochinchinensis*, collected from Kerala State, India, revealed that the short morphotype was diploid (2n=20) and the tall robust morphotype was tetraploid (2n=40). According to Valverde (1999) Amplified fragment length polymorphism (AFLP) studies have identified five major biotype groups closely related to their geographical distribution. Two major groups were comprised of biotypes predominantly collected in Latin America, suggesting that the majority of Latin American biotypes might have arisen from a limited number of introductions, probably from Africa and partially from Asia. The spread of *R. cochinchinensis* in Louisiana has been attributed in part to movement of equipment and road matting materials used during the extensive oil exploration that occurred in the late 1970s and early 1980s. By 1980, the weed infested 38 Louisiana parishes on about 80, 940 ha (Bowen *et al*., 2002).

Itchgrass reproduces exclusively through seeds, which are spread by water, farm machinery and birds. The seeds generally have some dormancy and fresh seeds require 4-5 months after-ripening before they germinate. Factors controlling dormancy include environmental factors and water-soluble phenols which inhibit germination. In warm weather conditions seeds can remain viable for over 2.5 years and at soil depths of 45 cm. Over long distances, the primary method of dissemination has been as a contaminant in crop seeds. Itchgrass seeds have been discovered in rice seed lots received at the International Rice Research Institute in the Philippines (Huelma *et al*., 1996).

Seed germination is influenced by environmental factors such as temperature, light and moisture (Baskin and Baskin 1998, Chauhan *et al*., 2006 and Chauhan and Johnson 2010). Weed seeds that require light for germination normally emerge when close to the soil surface and are dominant in no-till or reduced-tillage systems (Chauhan and Johnson, 2009).

This weed is relatively shade tolerant and also able to grow rapidly under high light exposure. (Strahan *et al*., 2000). The species is usually found at altitudes upto 2300m, with low temperatures often being the

TABLE 2

Morphological and cytological differences among *R. cochinchinensis* biotypes

Biotype Location	Chromosome Number (2n)	Glume Tip Shape	Plant Morphology
India (short type)	20 (diploid)	Acuminate	Short, compact
India (tall type)	40 (tetraploid)	Acute	Tall, robust
Africa	20 (diploid)	Acuminate	Moderate height
Latin America	40–60 (polyploid)	Acute to Obtuse	Highly variable

Source : Alves *et al.,* 2003

limiting factor above this and favours acidic soils (Holm *et al*.,1991 and Bolfrey-Arku *et al*., 2011).

Smith *et al.* (2001) state that in Costa Rica, *Rottboellia cochinchinensis* life cycle is synchronized with the cropping season because its seed germinates and emerges in response to soil moisture and exposure to light after tillage prior to planting. Seeds do not germinate in the dry fallow season, although in practice, senescing *R. cochinchinensis* plants that remain after crop harvest may continue to shed seed during the fallow season (Thomas and Allison 1976). Preventing seed-set within crops should, in theory, substantially reduce *R. cochinchinensis* populations, since this plant's seed bank is short lived, approximately 3 to 5 years (Rojas *et al.,* 1993). Smith *et al.* (2001) continue that, *R. cochinchinensis* seed floats easily and irrigation or floodwater is known to be a source of contamination for other fields (Mercado 1978), this is an aspect worthy of consideration for those managing *R. cochinchinensis*. In addition, the seed is very palatable to some birds, rodents and insects. In studies of seed-feeding birds in the United States, 26 of 345 birds (4 out of 15 species) collected were found to have *R. cochinchinensis* seeds in their guts (Aison *et al.,* 1984). In feeding trials, only about 0.3 per cent of the seed survived passage through the gut. Similarly, Thomas and Allison (1976) found that guinea fowl, mongoose and cattle-but not smaller birds and mammals-could disperse *R. cochinchinensis* seed in Zimbabwe. This evidence from other regions indicates that local fauna could play a major role in destroying *R. cochinchinensis* seed and that they also contribute to local dispersal.

Impact on Crops

Rottboellia infestations pose a serious threat for cultivation of many upland crops such as maize, sorghum, sugarcane, soybeans and rice. A summary of yield losses reported across different regions and crops is shown in Table 3. Infestations presently occur worldwide in the area between 34° north and south latitudes (Sharma and Zelaya, 1986), encompassing regions across North America, South America, Africa, Asia and Australia (Julien *et al.,* 1999 and CABI, 2023). In its exotic range, infestations are considered to be the most severe due to the absence of natural enemies, favourable climatic conditions and anthropogenic disturbances that promote its spread (Ellison & Evans, 1992; Villamagna & Murphy, 2010 and Patel, 2012). Also, a result of several contributing factors including improved climatic compatibility, man's activites in disseminating the grass, favourable agronomic practices and the absence of co-evolved natural enemies. It is 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, sugarcane, upland and rainfed rice, beans and sorghum (Herrera, 1989). Itchgrass infestations can result in up to 80 per cent crop loss or even abandonment of agricultural lands (Holm *et al*., 1977).

R. cochinchinensis is a serious weed of sugarcane in the Philippines, USA and Zambia and a moderate weed in Kenya, Madagascar and Venezuela. The studies in which *R. cochinchinensis* removed at harvest (after 180 days of interference) reduced

TABLE 3

Crop yield losses due to *R. cochinchinensis* infestation

Crop	Location	Yield Loss (%)	Source
Maize	Philippines	85-90	Fisher *et al.,* 1985
Sugarcane	Louisiana, USA	43-72	Millhollon, 1992
Maize	Honduras	80-83	Sharma & Zelaya, 1986
Rice	Philippines	40-60	Holm *et al.,* 1977

sugar yield by 19 per cent. Similar infestations during in the second-year crop reduced sugar yield by up to 72 per cent compared to a 2-year weed-free control. The interference primarily reduced sugar yield by reducing the stalk population, even though full-season interference increased the sugar concentration of the juice by 2-10 per cent. These studies indicate that *R. cochinchinensis* must be removed from sugarcane well before 30 days of interference under Louisiana growing conditions. However, sugarcane stands and yield almost completely recovered when kept weed-free in the second-year crop following full-season *R. cochinchinensis* interference in the first-year crop (Millhollon, 1992).

Alves *et al*. (2003) state that, *Rottboellia cochinchinensis* is an aggressive weed, considered to be one of the 12 worst weeds that infest sugarcane (*Saccharum officinarum* L.) in the world because it obstructs closure of crop rows when densities are above 10 plants m^{-2}. According to Arevalo and Bertoncini (1994), this species is one of the main invaders of sugarcane in Argentina, Cuba, India, Trinidad and the United States, where losses can reach 20 to 70 per cent, depending on the cultivar, cutting cycle and local ecological conditions. The authors continue to state that, the appearance and dispersal of *R. cochinchinensis* worries researchers and sugarcane producers in areas that do not yet have *R.cochinchinensis* because the weed might spread and adapt to their conditions.

R. cochinchinensis is a serious weed of maize in Ghana, Philippines, Zambia and Zimbabwe and a moderate weed of maize in Colombia, Nigeria, Tanzania and Venezuela. Studies have shown that an *R. cochinchinensis* density of 50 plants m^{-2} can reduce maize yields by almost 50 per cent. A density of 142 plants m^{-2} can cause reductions up to 71 per cent (Mercado, 1978). As a direct result of itchgrass competition, corn yield was reduced by 85 per cent in the Philippines (Fisher *et al.,* 1985) and by 80 per cent in Honduras (Sharma & Zelaya, 1986). Sugar cane yield reduction was 43 per cent in Louisiana, United States of America (Lencse and Griffin, 1991).

R. cochinchinensis competes throughout the season and can exert its most damaging effect late in the season. Monocrop maize and the associated cultural practices tend to encourage weed growth. Regional maize-growing farms generally fall in the 3-5 ha range, thus precluding sufficient time or labour to weed the planted area adequately (Richards and Thomas, 1970).

It is a very competitive weed with crops particularly maize and it has irritating hairs on its stem which makes it difficult to control manually in small-scale farms. It is also tolerant to most herbicides that are applied in cotton and maize fields (Rivera *et al*., 2007). The weed is very competitive and over a 3-year period it may reach densities that could prevent crop harvest (Harger *et al*.,1982). Although relatively shade intolerant, *R.cochinchinensis* has the capacity for high photosynthetic activity and growth rates when exposed to light (Pamplona and Imilan, 1977). In Rhodesia, Thomas and Allison (1976) reported a 46 per cent decrease in grain yield of corn when heavy infestations of itch grass were present for the full season. Removal of itch grass by 8 weeks after emergence eliminated the yield loss.

In India, particularly in regions like Karnataka, *R. cochinchinensis* poses similar challenges to crops, especially maize, due to its competitiveness and the difficulty in manual control due to its irritating hairs (Krishi science, 2023). A preliminary survey was conducted during 2022 and 2024 in maize growing districts of Karnataka. The main objective was to study the phytosociology of the weeds. It was observed that *R.cochinchnensis* infested maize plots was abandoned and left without harvesting due to presence of silica hairs, that causes irritation to the skin (yet to publish). Farmers are unable to take up harvest of maize crop and thus abandon the field (Fig. 3).

Field studies conducted at Louisiana, USA, and Trinidad also highlighted the negative impact of itchgrass on maize yield, underlining the importance of timely control (Thomas *et al.,* 1982). Though

Fig. 3 : Maize field abandoned without harvesting in Karnataka state, India

detailed data specific to Karnataka are sparse, the weed's high competitiveness and persistence suggest it may be a serious threat to maize production in the region (Patel and patel, 2014).

Management of Itchgrass

Cost effective methods for controlling weeds could help preserve profits and increase yields. Since the goal of every farmer is to increase production per unit area while minimizing costs, the understanding of weed biology is very important in developing a holistic integrated weed management strategy for itchgrass control (Grace *et al.*, 2011). In preparation for cropping, farmers in many countries (Laos and Ghana) use fire to clear their land of straw or debris before crop planting (Roder *et al.*, 1997). In some areas, farmers seldom practice soil tillage with upland rice, but, instead, 'dibble sow' the crop seed after burning the cut vegetation (Johnson and Kent, 2002). The heat generated by this burning may affect emergence of several weed species. Seed burial depth (buried by tillage or other means) also affects emergence of several weed species (Chauhan and Johnson, 2010). Crop residues left on the soil surface as mulches may also selectively provide weed suppression (Teasdale and Mohler, 1993) and this could be a part of an integrated weed management system.

Successful management of itchgrass relies on depleting its soil seed bank and preventing seed production (Bridgemohan and Brathwaite, 1989). Since no single control method can achieve this goal, an integrated strategy is necessary to steadily decrease itchgrass populations. Available and promising tactics include mechanical, cultural, chemical and biological options (Valverde *et al.,* 1999a). A comparative overview of these control methods is provided in Table 5.

Eradication as a strategy does not seem entirely feasible, even when a new, very localized infestation

TABLE 4

Comparison of itchgrass management methods and its pros and cons

Control method	Description	Pros	Cons
Mechanical	Hand-weeding, shallow tillage	Effective in small areas	Labour-intensive
Cultural	Crop rotation, cover cropping, certified seeds	Preventive, soil improvement	Requires planning and time
Chemical	Pre- and post-emergent herbicides	Quick results	Resistance issues, environmental risk
Biological	Fungi, smut, rust (e.g., Exserohilum, Puccinia)	Eco-friendly	Needs more research for consistency
Integrated	Combination of all above	Sustainable, long-term suppression	Complex to manage, training needed

Source : Valverde *et al.,* 1991a

TABLE 5

Reported herbicide resistance in *R. cochinchinensis*

Herbicide Group	Herbicide Name	Resistance Reported	Country	Reference
ACCase Inhibitors	Haloxyfop, Sethoxydim	Yes	Bolivia	Valverde *et al.* (2001)
Triazines	Atrazine	Partial resistance	Various	Rivera *et al.* (2007)
ALS Inhibitors (Sulfonylureas)	Nicosulfuron	No resistance noted	Mexico, USA	Valverde *et al.* (2001)
Glyphosate	Roundup	No resistance noted	Global use	Griffin (1991)

is detected early at the farm or country level (Pandu *et al.*, 2022). Earlier, eradication efforts began at Wales Estate, one of the major sugar cane-producing units in Guyana, soon after itchgrass was first identified in 1991. Affected areas were designated as restricted and all agriculture-related movement, including that of workers and equipment, required prior approval. The use of planting material from infested sites was also banned. Several tactics were implemented to eliminate the weed, such as roughing, herbicide application, legume cover cropping and flooding during fallow periods (under their production system, flooded fields remain under freshwater for 6-12 months after tillage but before planting). Even though the eradication program did not eliminate the weed after five years, it reduced the density of the infested sites and limited new infestations (Bishun dial *et al.,* 1997).

Mechanical Control

Cultivation has been employed to control itchgrass in row crops and incorporating chemical controls can significantly enhance results in these systems. Small patches of itchgrass can be removed by hand, but precautions should be taken to avoid the stiff hairs, which can irritate or pierce the skin. Deep cultivation during land preparation should be avoided as buried seed may remain viable for several years. Minimum tillage practices lead to more rapid depletion of weed seed (Labrada *et al.*, 1994). Shallow tillage is useful with the aim of promoting seed germination before planting. Usually, this has to be done more than once before planting and then again during crop growth. Often, herbicide is needed after tillage as it may result in extremely high densities of seedlings (Valverde *et al.*, 1999b).

However, after soil preparation, itchgrass seedlings may go out of control and reach extraordinarily high densities, which can significantly reduce crop yields. Interrow slashing and cultivation are common practices in small-scale farming, however they are ineffectual because growing seedlings inside crop rows evade management, contribute to the seed bank and lower crop output Maillet (1991). Damage to crop roots by in-crop cultivation might result in seed being brought to the surface where it can easily germinate and raise the possibility of erosion (Bridgemohan & Brathwaite, 1989). Traditional hand-weeding at three times failed to reduce the *R. cochinchinensis* infestation population in the maize row. Uncontrolled *R. cochinchinensis* reduced maize yields by approximately 50 per cent. Two cultivations using draft animals has controlled *R. cochinchinensis* to some extent but yields were still reduced by 24 per cent. The best control of *R. cochinchinensis* was achieved by two mechanical cultivations plus hand-weeding in the maize row and the best economic return was achieved by inter-cropping maize with mung bean (Fisher *et al.*, 1985).

Cultural Control

Using certified crop seed is essential to preventing the introduction and spread of itchgrass since admixture of weed seed in crop seed spreads the weed easily (Adithya *et al.,* 2022). When itchgrass becomes established, a number of agronomic techniques can also aid in lowering densities of the weed and reducing the soil seedbank. By enabling the deployment of alternate control strategies like flooding and other herbicides, crop rotation may be able to break the close relationship that itchgrass has with some crops such maize and sugar cane (Buckles and Triomphe, 1999). According to Fisher *et al*. (1985), the rapid development of itchgrass as a dominant weed is facilitated by maize monoculture.

In addition to considering the needs of farmers, local conditions and cropping systems should be considered when choosing a species of cover crop. This includes considering the crop's potential for negative competitive effects, additional pest control issues, management costs and the benefits of the cover crop in terms of soil erosion prevention and food supplementation (Kirchhof and Salako, 2000). Allelopathic plants are also included in this group. Velvet bean allelochemicals prevent the growth of weeds (Caamal-Maldonado *et al*., 2001 and Fujii *et al*., 1991). Additionally, legume covers raise the levels of phosphorus and organic carbon in the soil and enhance its cation exchange capacity and calcium contents (Obi, 1999).

Using cover crops is one of the most effective and well-researched methods for suffocating itchgrass plants. Mesoamerica, Africa and Asia have produced cover crops to control weeds and improve the properties of the soil (Buckles and Triomphe, 1999). They can be grown as intercrops or as a component of a rotation plan. Legumes that fix nitrogen have been given preference, including *Cajanus cajan*, *Callopodium mucunoides*, *Canavalia* spp., *Callothalaria* spp., *Poraria phaseoloides*, *Dolichos lablab*, *Mucuna* spp. (velvetbean) and *Stylosanthes* spp. (Tarawali and Ogunbile, 1995). Velvetbean intercropped with maize at either 50 000 or 80 000 plants ha^{-1} reduced itchgrass biomass at maize harvest between 75-95 per cent (Valverde, 1999). Conversely, itchgrass density did not affect velvet bean biomass nor were differences found between the two velvetbean densities. But both velvetbean (planted one week after maize) and itchgrass reduced grain yield up to 40 per cent. 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 (Valverde *et al.,* 1999b).

Biological Control

Biological control of itchgrass involves using natural enemies such as insects, fungi, bacteria or other organisms to manage its population. These biological agents target itchgrass specifically, reducing its growth, reproduction or survival rates. Because itchgrass thrives in exotic ranges, a very promising and complementary management alternative is classical biological control. Isolates of fungi collected from *R. cochinchinensis* have been screened for host specificity and three of them selected for further study as potential biological control agents. An isolate of *Colletotrichum* sp. near *graminicola* from Thailand was tested in the laboratory and in field trials in Thailand as a possible candidate for development as a mycoherbicide. The results were equivocal but a synergistic response was found when a low dose of chemical herbicide was added to the fungal inoculum (Ellison and Evans, 1995). As the sporadia are readily produced in culture, it may be possible to apply them to the soil as a form of mycoherbicide or introduce the fungus as a classical biocontrol agent (Ellison and Evans, 1995). Jimenez *et al.* (1990), described a spike rot disease on itchgrass in Guatemala that was caused by *Fusarium moniliforme*. Infected plants failed to produce viable seed and in preliminary tests, the pathogen showed some specificity towards itchgrass.

In Malaysia, the fungus *Exserohilum longirostratum* has been studied as a possible biocontrol agent. According to Kadir *et al.* (2007), the fungus killed a significant proportion of young itch grass seedlings when it was applied as a post-emergence foliar spray. That didn't was able to kill older plants but reduce biomass by about 56 per cent. Alloub *et al*. (2009) suggest that *Exserohilum prolatum* (*Setosphaeria prolata*) has good potential for biocontrol, especially when applied multiple times. Itchgrass is also highly susceptible to *Exserohilum monoceras*, a fungus being considered for *Echinochloa colona* biocontrol (Zhang and Watson, 1997). There is also potential to use native pathogens as a complement to other control methods for itchgrass (Zuniga *et al.* 2000). In Costa Rica, pathogenic strains of *Curvularia* sp., *Drechslera* sp. and *Fusarium* sp. have been shown infective to itchgrass, their severity being enhanced by stress factors, including the application of sub-lethal herbicide doses (Zuniga *et al.,* 2001).

Puccinia rottboelliae, causes severe seedling infection in the field and preliminary host-range tests with an isolate from Kenya suggest that it is specific to *R. cochinchinensis*. Thus, this rust may have potential as a classical biological control agent in the Americas, perhaps involving a management strategy including early-season augmentation and further research is being carried out on these agents in order to develop a biological control strategy (Ellison, 1993).

The smut fungus is a soil-borne, systemic pathogen that infects itchgrass seedlings before they emerge from the soil. *S. ophiuri* has been recorded as a head smut of itchgrass in Africa and Asia and it is restricted to the Old World (Reeder and Ellison, 1999). Infected plants grown individually in pots grew similarly to healthy plants, but when grown under competitive conditions (8 plants per pot), smut-infected plants produced fewer tillers than healthy plants (Reeder *et al*., 1996). Experimentally, infected plants produced substantially fewer seeds than healthy plants.

Chemical Control

Chemical control of itchgrass involves the use of herbicides to manage and reduce its population. Herbicides can be applied in various stages of itchgrass growth to effectively control its spread.

Chemical control of *R. cochinchinensis* is challenging in many crops due to its resistance to several important herbicide groups including triazines (*e.g.* atrazine), chloroacetanilides and others like metribuzin and terbacil. Additionally, populations of *R. cochinchinensis* in Bolivia have evolved resistance to herbicides that inhibit the enzyme acetyl coenzyme-A carboxylase, such as haloxyfop-R-methyl and sethoxydim (Valverde *et al*., 2001).

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In Louisiana, nicosulfuron (35 g a.i. ha^{-1}) controlled itchgrass in maize better than primisulfuron (39 g a.i. ha^{-1}) when applied at the six-leaf growth stage (Strahan *et al.,* 2000). When formulated as a dispersible granule, nicosulfuron requires the addition of a non-ionic surfactant for its activity. The new post-emergence sulfonylurea herbicide for cotton and sugar cane, trifloxysulfuron-sodium controls itchgrass in sugar cane at 15-50 g a.i. ha^{-1} in mixture with ametryn (Hudetz *et al.,* 2001). In Trinidad, pendimethalin (1.5 kg ha^{-1}) and interrow cultivation at 14 and at 28 days after planting effectively controlled itchgrass in maize during the critical period of interference (Bridgemohan and Brathwaite, 1989).

Selective systemic graminicides that inhibit acetyl-CoA carboxylase, such as aryloxy-phenoxy propanoates and cyclohexanediones, have been employed to eliminate itchgrass. However, the weed has developed resistance to these herbicides, including fluazifop-p-butyl in soybeans in Louisiana, United States (Heap, 2002 and Travlos *et al.,* 2020). Broad-spectrum herbicides, particularly paraquat and glyphosate, are also widely used to control itchgrass.

Sulfonylurea herbicides, which inhibit the enzyme acetolactate synthase (ALS), are now commercially used to selectively control itchgrass. Nicosulfuron is one of the most widely used compounds for this purpose. In Campeche, Mexico, nicosulfuron is commonly applied to manage itchgrass and *Sorghum halepense* which are particularly problematic in maize production (Valverde *et al*., 2001). Post-emergence application of fluazifop-P, haloxyfop, quizalofop and diclofop gave at least 90 per cent control. *R. cochinchinensis* was less well controlled by sethoxydim and clethodim post-emergence, while imazaquin and imazethapyr lacked adequate activity (Griffin, 1991).

In tests in southern Louisiana, overall application of diclofop gave 73-94 per cent control of 10-30 cm tall *R. cochinchinensis*. Diclofop was effective as a follow-up, mid-season treatment whereas dinitroaniline was used pre-sowing and this combination resulted in higher yield increases than those obtained with mid- or late-season applications of diclofop alone (Nester and Harger, 1980). In an earlier study conducted in Louisiana, USA, dinitroaniline herbicides which showed 80 per cent or more control of *R. cochinchinensis* in soybeans were on fine-textured soil: trifluralin, fluchloralin and pendimethalin, prodiamine and profluralin and on medium-textured soil: trifluralin, profluralin and pendimethalin, prodiamine and fluchloralin (Harger and Williams, 1982). In Nigeria, metolachlor, chlorthal-dimethyl and pendimethalin applied as pre-emergence controlled most annual grasses (including *R. cochinchinensis*) in cowpea (*Vigna unguiculata*). None of these herbicides injured the crop so that cowpea yields from the herbicide treatments were as good as those from normal hand-weeding or experimental clean-weeding (Akobundu, 1982).

Integrating Tactics for Itchgrass Management

Integrating multiple tactics for itchgrass management involves combining various control methods to achieve more effective and sustainable weed control.

TABLE 6

Chemical control tactics for itch grass at different time of application of herbicides

Method	Herbicide	Rate (ounces per acre or spot treatment)
A. pre-emergence		
clomazone + diuron	Command 3ME + Diuron, Direx, 4L	32–43 oz/A + 80 oz/A
clomazone + metribuzin	Command 3ME + Sencor, Metribuzin, 4L	32–43 oz/A + 24 oz/A
pendimethalin	Pendulum 3.3EC, Prowl H_2O, Prowl 3.3EC	19–58 oz/A
B. post-emergence		
Asulam	Asulox, Asulam	128 oz/A
Glyphosate	Roundup	32 oz/A of 3 lb ae/gal formulation
Nicosulfuron	Accent	0.67 oz/A
Glufosinate	Liberty, Finale, Lifeline,	28–34 oz/A
Clethodim	Select	6–16 oz/A or 0.5%
Fluazifop	Fusilade II	6–12 oz/A or 0.5%
Sethoxydim	Poast	12–40 oz/A or 1%
Sethoxydim	Vantage, Poast Plus, Sethoxydim, etc	24–36 oz/A or 1.5%
Sulfometuron	Oust, SMS, etc.	4 oz/A
Trifloxysulfuron +asulam	Envoke, Monument + Asulox, Asulam, etc.	0.2 oz/A + 96 oz/A

USDA, NRCS. 2007

This integrated approach helps to reduce the reliance on any single method and minimizes the risk of resistance development. In East Africa, *R. cochinchinensis* is managed through a combination of cultivation and fallowing for at least two years. Initially, the infested site is burned to destroy surface seeds. The area is then ploughed to stimulate the germination of seeds in the topsoil horizon. Subsequent deep ploughing buries the seedlings. The land is then left fallow until the buried seeds decompose, rendering the area clean (Holm *et al.*, 1977). *R. cochinchinensis* densities were also reduced by integrating no-tillage, use of the selective herbicide pendimethalin in the first maize crop (to lower the initial density of itchgrass), planting of a velvetbean cover crop between maize rows and prevention of itchgrass seed set in the fallow period (Valverde *et al.*, 1999b). In soybean [*Glycine max* (L.) Merr.], applications of preplant-incorporated and post herbicides combined with cultivation were necessary to reduce itchgrass biomass at harvest (Harger *et al*., 1982). Research has shown that soil-applied herbicides alone are not adequate for season-long control of itchgrass in corn and a successful itchgrass management program should include post herbicide applications (Bridgemohan and Brathwaite, 1989).

Integrated tactics for controlling itchgrass were evaluated over three years in on-farm validation plots, each about 1000 m², in small subsistence growers' fields at three locations in Costa Rica (Valverde *et al*., 1999a, 1999b). Maize is grown twice a year at two of these sites, while the third site follows a maize-dry beans-fallow rotation. The validation plots employed a combination of no-tillage, the selective herbicide pendimethalin in the first maize crop to reduce initial itchgrass density, planting velvetbean between maize rows and preventing itchgrass seed set during the fallow period. In growers' plots, itchgrass control involved slashing and direct paraquat applications. Pendimethalin effectively managed itchgrass, facilitating the establishment of velvetbean during the first maize crop. Across all sites, itchgrass densities were lower in validation plots compared to growers' fields, with infestation levels decreasing over the years due to integrated management. Overall, maize and dry bean yields were higher in the validation plots across all locations and cropping seasons. Soil core samples also showed significant reductions in the itchgrass soil seed bank in validation plots (Merayo *et al*., 1998). Partial budget analyses indicated that integrated itchgrass management is economically viable for smallholders.

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 with conventional tillage (Rojas *et al.,* 1993 and Valverde *et al.,* 1999b). A low-density cover crop, plus a 50 per cent smut infection rate resulted in 6 plants m^{-2} of itchgrass in each corn crop (Smith *et al.,* 2001).

Itchgrass (*Rottboellia cochinchinensis*) is a highly invasive C_4 annual grass weed that threatens agricultural productivity in tropical and subtropical regions. Its rapid growth, adaptability and prolific seed production enable it to outcompete crops like maize, sugarcane, sorghum, and rice, causing yield losses of 20-70 per cent. Factors such as the absence of natural enemies, favourable climates and human-mediated spread have accelerated its invasion. The weed's tolerance to shade, moisture stress and acidic soils, along with seed dormancy and dispersal *via.,* water, machinery and animals, make it particularly difficult to manage.

Effective management of itchgrass requires an integrated approach that combines mechanical, cultural, biological and chemical control methods. Mechanical control, such as shallow tillage and hand-weeding, can be effective but is often labour-intensive and may not fully eradicate the weed. Cultural practices, including crop rotation, intercropping and the use of cover crops, have shown promise in reducing itchgrass densities and depleting its seed bank. Biological control, utilizing natural enemies such as fungi and insects, offers a sustainable and environmentally friendly alternative, though further research is needed to optimize its efficacy. Chemical control, while effective, is challenged by the weed's resistance to multiple herbicide groups, necessitating the development of new herbicides and application strategies.

Integrated weed management (IWM) strategies that combine these methods have proven to be the most effective in reducing itchgrass populations and minimizing its impact on crop yields. The integration of no-tillage practices, selective herbicide use, cover cropping and fallow management has successfully reduced itchgrass densities and improved crop yields in smallholder farming systems. However, the success of these strategies depends on local conditions, farmer adoption and continuous monitoring to prevent resistance development and ensure long-term sustainability.

In conclusion, itchgrass remains a significant challenge for global agriculture, particularly in tropical and subtropical regions. While no single control method can fully eradicate the weed, an integrated approach that combines multiple tactics offers the best chance for effective management. Future research should focus on understanding the weed's genetic diversity, developing resistant crop varieties and optimizing biological control agents to enhance the sustainability of itchgrass management strategies. By adopting holistic and adaptive management practices, farmers can mitigate the impact of itchgrass and safeguard agricultural productivity in affected regions.

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