*Report/Informe*

# GLOBAL WORKSHOP ON RED RICE CONTROL
# TALLER GLOBAL DE CONTROL DE ARROZ ROJO

***30 August- 3 September 1999,  Varadero, Cuba***

**Plant Production and Protection Division**
**FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS**
**FAO, ROME**

## I. BACKGROUND

One of the major constraint to the production of rice in direct-seeded areas is the incidence of red rice, which is widespread all over the world. Wild rice *Oryza barthi* and *O. longistaminata* are among the four most important weeds in West Africa and Sahel. *Oryza sativa* L. var. *sylvatica* is one of the main weeds in direct-seeded rice in the Mediterranean while in USA, Latin America and the Caribbean its presence currently hinders harvesting process and reduces quality of the obtained produce.

Red rice effectively competes with homologous crop rice and contaminates obtained crop seeds due to its earlier shattering.

Red rice seeds posses dormancy, so its seed bank in the soil becomes a serious permanent problem of weed competition in rice areas.

Crop losses due to red rice incidence may be up to 60% in circumstances of heavy field infestation.

Being rice the major staple in the developing world, there is an urgent need to improve control methods currently used by farmers in order to increase yields.

## I. ANTECEDENTES

Una de las mayores dificultades en la producción de arroz de siembre directa lo constituye la incidencia del arroz rojo, el cual se halla diseminado en todo el mundo. El arroz salvaje *Oryza barthi* y *O. longistaminata s*e hallan entre las cuatro especies más importantes de malezas en Africa Occidental y el Sahel. *Oryza sativa* L. var. *sylvatica e*s una de las especies principales en el arroz de siembra directa en el Mediterráneo mientras que su presencia en EE.UU., América Latina y el Caribe obstaculiza el proceso de cosecha y reduce la calidad de la producción obtenida.

El arroz rojo efectivamente compite con su homologo cultivable y contamina las semillas del cultivo con otras semillas que se desprenden tempranamente en el campo..

Las semillas de arroz rojo también poseen latencia, por lo que su banco de semillas crea un serio y permanente problema de competencia en las áreas arroceras.

Las pérdidas de la cosecha debidas a la incidencia del arroz rojo pueden ser de hasta 60% en condiciones de alta infestación en campo.

Siendo el arroz el producto principal de alimentación en el mundo en desarrollo, existe una urgente necesidad de mejorar los métodos de control usualmente utilizados por los agricultores a fin de aumentar los rendimientos del cultivo.

**II**. **OBJECTIVES.** The present global workshop convened by FAO had the objectives as follows:

- Discussion of the status of the problem in affected countries.
- Update on newly developed methods for red rice control
- Discussion and analysis regarding transgenic rice cultivars resistant to herbicides (HRC).
- Define follow-up activities

The programme of the workshop consisted of three days for presentation of country reports and specific technical papers related to this topic, one day for field visit of a large area of direct-seeded rice under harvest, and the final day for conclusion and recommendation.

**II. OBJETIVOS.** El presente taller global convocado por la FAO tuvo los siguientes objetivos:

- Discusión del status del problema en los países afectados.
- Actualización sobre nuevos métodos de control del arroz rojo.
- Discusión y análisis osbre el arroz transgénico resistente a los herbicidas (CRH).
- Definir actividades de seguimiento.

El programa del taller consistió en tres días de presentación de los informes de los países y otros específicos relacionados con el tópico, un día de visita de campo a un área grande de arroz de siembra directa bajo cosecha, y el día final para discusión y aprobación de conclusiones y recomendaciones.

## III. PROGRAMME/PROGRAMA

### 1ST Day Monday 30 August 1999/1ST Día lunes 30 agosto 1999

9:00 Opening of the workshop/ Apertura del taller: Dr Luis Alemán, Director Rice Research Institute in Cuba and Dr Fernando Robayo, FAO representative in Cuba.
9:30 Technical introduction to the workshop/ Introducción técnica al taller. Dr Ricardo Labrada, FAO Plant Protection Service/Servicio de Protección Vegetal.
10:00 Break/Receso
10:30 **Country Reports/ Informes de los Países**
Brasil (Dr Tarcisio Cobucci)
11:00 Colombia (Mr Gildardo Rodriguez)
11:30 Costa Rica (Mr Hernán Castro)
12:00 Break for lunch/Receso para almuerzo)
13:30 Cuba (Mr Jorge García)
14:00 Guyana (Mr Leroy Small)
14:30 Mexico (Mr. Gustavo Torres Martínez)
15:00 Nicaragua (Mr Marvin Sarría)
15:30 Discussion/Discusión
16:00 Conclusion of the first day/Conclusión del 1er día

### 2nd Day Tuesday 31 August /2do. día martes 31 agosto

8:30 Spain/España (Dr Diego Gomez Barreda)
9:00 Senegal (Mr Souleyman Diallo)
9:30 Surinam (Mr. Mohamed Rashied Khodabaks)
10:00 Break /Receso
10:30 Vietnam **(**Dr. Duong Van Chin)
11:00 Venezuela (Sra Aida Ortiz) Discussion of country reports, main conclusions
11:30 Break for lunch/Receso para almuerzo
15:00 Wild rice in the rice systems of West Africa, its incidence and the scope for control measures/ El arroz salvaje en los sistemas arroceros de Africa Occidental, su incidencia y alcance de las medidas de control. Dr Dave Johnson, WARDA, Ivory Coast/Costa de Marfil.
15:45 Red rice control in rice pre-planting and post-planting/ El control del arroz rojo en tratamientos de pre-plantación y de post-plantación. Dr Aldo Ferrero, University of Turin, Italy/Italia.
17:00 Research Programme on Red Rice control in France/Programa de Investigaciones en el control del Arroz Rojo en Francia. Dr Jean Claude Mouret.
17:30 Post-emergence herbicides for red rice control in Portugal/Herbicidas de pos-emergencia para el control de arroz rojo en Portugal. Ms Maria Lubelia
18:00 Conclusion of the 2nd day/ Conclusión del 2do. día.

**3rd Day Wednesday 1 September/3er día miércoles 1ro. septiembre**

8:00 Red Rice: Problems and Opportunities/ Arroz Rojo: Problemas y Oportunidades.Dr Albert Fischer, Davis University, USA

9:30 Characterisation of red rice biotypes in Venezuela/ Caracterización de biotipos de arroz rojo en Venezuela. Ms Aida Ortiz, Universidad Central de Venezuela, Maracay.

10:00 Discussion on red rice control/Discusión sobre el control del arroz rojo.

11:00 Break for lunch/Receso para almuerzo

15:00 Risk assessment of herbicide resistant rice - a treat or a solution?/ Análisis de Riesgo del arroz resistente a herbicida- una amenaza o una solución? Dr Maria Olofsdotter, University of Copenhagen.

16:00 Discussion on risk and benefits of transgenic herbicide resistant rice/Discusión de riesgos y beneficios del arroz transgenico resistente a herbicidas.

17:00 Conclusion of 3rd Day/Conclusión del 3er día.

**4th Day Thursday 2 September/4to. día jueves 2 septiembre**

4:30 Field visit to areas of rice enterprise Sur del Jibaro in Sancti Spiritus province/Visita de campo a áreas arroceras de la empresa Sur del Jibaro de la provincia de Sancti Spiritus.

**5th Day Friday 3 September/5to. día viernes 3 septiembre**

8:00 Discussion and approval of conclusions and recommendations/Discusión y aprobación de las conclusiones y recomendaciones.

12:00 Closure of the workshop Clausura del taller.

**EL ARROZ ROJO- MALEZA Y CONTAMINANTE DEL CULTIVO DEL ARROZ**
**RED RICE-WEED AND CONTAMINANT OF RICE CROP**

*Introducción al Taller Global* *Introduction to the Global Workshop*

Ricardo Labrada

## I. IMPORTANCE AND CHARACTERISTICS OF RED RICE.

Red rice is one of the major weeds in direct-seeded rice in Arkansas, and Louisiana in USA and Latin America. In the Mediterranean, red rice (*Oryza sativa* L. var. *sylvatica)* is an important weed of rice, while in Asia, countries as Vietnam & Malaysia, where rice is also direct-seeded, red rice has become a major weed.

Other endemic species, not precisely red or weedy rice, exist in other parts of the world. This is the case of annual *Oryza barthi* and perennial *O. longistaminata*, which are among the four most important weeds in West Africa and Sahel.

Normally red rice is identified as *Oryza sativa* L, i.e as the same crop rice. Its main characteristics are as follows:
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- Its pericarp is red and this colour if given by a dominant gen.
- This red pigment is difficult to remove and may bring about breaking of many grains.
- It effectively competes with its similar rice crop.
- It shatters earlier than rice crop and its seeds posses dormancy.
- Its presence in harvested grains reduce their quality and its price.

Not all forms of weedy rice have red pericarp, but they also grow quicker than cultivated rice and shatters earlier.

## II. METHODS FOR RED RICE CONTROL

The methods can be classified as preventative, short and medium terms. Normally control strategies should be towards consistent reduction of soil red rice seed bank and this can only be achieved with a medium term approach.

Preventative methods are planting rice seeds free of red rice seeds. To this end it is important to produce rice seeds completely clean and with no seed of red/weedy rice. In some countries there are tolerances admitting some seeds of red rice per kg of cultivated rice seeds. This practice has shown to be negative in long term.

The short term control methods are:

- Flooding or its combination with puddling during land preparation.
- Stale seed bed preparation including the application of foliar non-selective herbicide before rice planting.
- Planting crop rice at high seed densities.
- Grazing rice areas during fallow period.

- Pre-planting application of herbicide molinate.

The most common medium term method is rotation of rice with upland crops, such as soybean, beans or sorghum to enable the use of other control practices, including the application of herbicides non-selective to rice.. This practice is not possible to be implemented in many cases because soils are not always suitable for planting upland crops and farmers do not often see any economical advantage to plant a crop other than rice.

There is a need to design a strategy for red rice control. To this end basic studies should be carried out, such as:

- Characterization of red rice biotypes and their biological traits.
- Red rice seed bank and ways to substantially reduce it
- Competitive ability of rice cultivars with different red rice biotypes.
- Effect of cropping systems on red rice population.
- Technically effective and economically feasible crop rotation, fully adoptable by farmers.

**III. TRANSGENIC RICE RESISTANT TO HERBICIDES.**

There is an ongoing research towards the development of rice cultivars resistant to herbicides (HRC). In fact, HRCs faciltate weed control procedures and increases in short term the efficacy of the herbicide over the weed flora present in the field. This is an advantage and benefit to the farmers.

However, the use of HRC, specifically of rice, may bring about transfer of gene resistance to red rice, thus creating a *SUPER RED RICE*, which will be extremely difficult to control with existing herbicides.

Therefore the development of using herbicide resistant rice should be previously evaluated through procedures of risk assessment.

**IV. EXPECTED RESULTS FROM THE WORKSHOP**

Through the presentation of country reports and other technical papers related to red rice control, as well as the debates of the participants, the workshop intends to get recommendations for:

1. Improved red rice control measures, including preventative and field ones.
2. Possible ways to adopt and use rice cultivars resistant to herbicides.
3. Defining follow-up and collaborative activities

**I. IMPORTANCIA DEL ARROZ ROJO EN LAS REGIONES DEL MUNDO.**

El arroz rojo es una de las malezas principales en áreas de arroz de siembra directa en Arkansas y Louisiana en EE.UU. y en América Latina. En el Mediterráneo, el arroz rojo (*Oryza sativa* L. var. *sylvatica) e*s una maleza importante del arroz, mientras que en Asia, países como Vietnam y Malasia, donde el arroz también se siembra directo, el arroz rojo es una maleza principal.

Otras especies endemicas, no precisamente arroz rojo o maleza, existe en otras partes del mundo. Este es el caso de la especie anual *Oryza barthi* y la perenne *O. longistaminata*, las que aparecen entre las cuatro malezas más importantes en Africa Occidental y Sahel.

Normalmente el arroz rojo se identifica como *Oryza sativa* L, o sea igual que el arroz cultivable y sus características principales son:

- El color rojo de su pericarpio, que lo confiere un gen dominante presente en el pericarpio. Esta pigmentación es difícil de remover y provoca la fragmentación de muchos granos.
- El arroz rojo compite efectivamente con su similar cultivable.
- Suele desgranarse más tempranamente que su homologo y sus semillas poseen latencia.
- Su presencia en los granos cosechados reduce la calidad de la producción y provoca una reducción de su precio.

No todas las formas de arroz maleza tienen el pericarpio rojo, pero si crecen más rápido que su similar cultivable y se desgranan tempranamente.

**II. MEDIDAS DE CONTROL DEL ARROZ ROJO/**

A corto plazo/ Preventivo:

Siembra de semillas de arroz libre de semillas de arroz rojo.
Inundación o su combinación con el fangueo en el proceso de preparación del suelo.

A corto plazo:
- Siembra de arroz a altas densidades en campos inundados.
- Provocar la emergencia del arroz rojo con riego de pre-siembra y eliminación de las plantas con algún herbicida no residual.

A Mediano Plazo:
- La rotación del arroz con cultivos de secano, como soya, frijol o sorgo permite la utilización de otras prácticas de cultivo y uso de herbicidas no selectivos al arroz.
- Pastoreo de las áreas de arroz durante el período de barbecho.
- Otra práctica reconocida como válida es el uso de pre-siembra del herbicida molinate para control del arroz rojo.

Los estudios esenciales, entre otros, a desarrollar son/
- Caracterización de los biotipos de arroz rojo existentes y sus características biológicas.
- Banco de semillas del arroz rojo y formas de reducir consistentemente su población.
- Habilidad competitiva de las variedades del arroz con los biotipos de arroz rojo.
- Influencia de los sistemas de cultivo sobre la población de arroz rojo.
- Rotación de cultivo factible técnica y económicamente, adoptable por el agricultor.

**III. ARROZ TRANSGENICO RESISTENTE A HERBICIDAS**
Existe investigación en el desarrollo de variedades de arroz resistente a herbicidas (ARH).

- Los CRH facilitan el proceso de control de malezas.
- El uso de CRH, concretamente de arroz, también pudiera provocar la transferencia del gen de resistencia al arroz rojo y crearse un *SUPER ARROZ ROJO.*
- Por lo tanto, este desarrollo debe ser evaluado previo a su introducción mediante procedimientos de análisis de riesgo.
- Trabajos a emprender para el diseño de una estrategia de control del arroz rojo (I)

## IV. RESULTADOS ESPERADOS DEL TALLER

Recomendaciones de/ Medidas de control del arroz rojo, preventivo y en campo.

- Tareas de seguimiento y cooperación.
- .Formas de posible adopción del arroz resistente a herbicidas.

# RED RICE INFESTATION AND MANAGEMENT IN BRAZIL

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**SUMMARY**

Red rice is a common weed in nearly all rice production areas in the Americas. In Rio Grande do Sul, the largest rice production state in Brazil, red rice infestation is very critical. The main factor that has contributed to red rice dissemination is the use of rice seed contaminated with red rice seeds. Red rice also affects the milling industry and the consumers. A red rice control program require the use of several measures, including the use of rice seeds free of red rice, water-seeded or low-tillage rice, the use of herbicides applied pre-emergence, and adequate water management after seeding. Fields infested with red rice should not be plowed immediately after harvest. Red rice seeds buried deep in the soil last longer than the seeds near the soil surface.

**RESUMEN**

El arroz rojo es una maleza común en casi todas las áreas arroceras de América. En Río Grande Do Sul, que es el estado con mayor de producción de arroz en Brasil, la infestación de arroz rojo es crítica. El principal factor que ha contribuido a la diseminación del arroz rojo es la contaminación de las semillas de arroz con semillas de arroz rojo. El arroz rojo también afecta el molinado y a los consumidores. Un programa de control de arroz rojo requiere del uso de varias medidas, incluyendo el uso de semillas de arroz libre de arroz rojo, siembra del arroz en agua, mínima labranza, el uso de herbicidas pre-emergentes y un adecuado manejo de agua después de la siembra. Los campos infestados con arroz rojo no deben ser arados inmediatamente después de la cosecha. Las semillas de arroz rojo enterradas profundamente en el suelo duran más tiempo viable que aquellas cercanas a la superficie del suelo.

## INTRODUCTION

Rice is a very important staple food in Latin America. In 1996, rice production in Latin and North America was 30.5 millions MT grown in 8.5 million hectares, for both upland and irrigated rice. Irrigated rice represented about 55% of the growing area and 80% of the total production in America. In Southern Brazil, irrigated rice yield amounts to 5.0 t/ha in Rio Grande do Sul and 5.8 t/ha in Santa Catarina. The average yield observed in Brazil is still low, considering that all area is planted with semidwarf cultivars, which show high yield potential. Some farmers in Santa Catarina have reached yields more than 12 t/ha. The main reasons accounting for the low yields in most rice growing areas are poor seed quality, high red rice and weed infestation, blast incidence, insects, nutritional disorders, and low fertilizer application.

## RED RICE INFESTATION

Red rice is the most troublesome weed in irrigated rice fields in southern Brazil. In Rio Grande do Sul, the largest rice producer State in Brazil, red rice infestation is critical in more than 80% of the cultivated area (Marchezan 1994, Souza and Fisher 1986). Severe infestation occurs when rice is drill seeded and irrigation is delayed (conventional planting system). Due to red rice infestation and high production costs, farmers have changed their production system from drilled to minimum tillage (Menezes et al. 1994) or water-seeded rice (pre-germinated system).

Red rice is spread basically as a contaminant in rice seeds. Several surveys about rice seed quality have been carried out in Santa Catarina State during the last 20 years. The percentages of seed samples infested with red rice were 98, 89 and 57%, respectively in 1977, 1987, and 1996 (Marques et al. 1990, Noldin et al. 1997, Ramos and Santini 1979). The last survey showed also that only 19% of the seed used by the growers was registered or certified seeds, and 71% of the growers sampled produced their own rice seed or used commercial grains as seeds.

**RED RICE EFFECTS ON RICE**

Menezes *et al.* (1997) reported that as the percentage of grains of red rice increased in the rice samples in the milling process, the whole grain yield and total milling yield decreased linearly for the cultivars tested. In addition, the red rice pericarp is difficult to remove during the milling process, so most red rice grains remain with some traces of the red color after polishing, which is undesirable to consumers.

**RED RICE MANAGEMENT**

Red rice is very difficult to control due to its close genetic relationship to domestic rice. Red rice control requires a program approach that includes several management practices: a combination of preventive, cultural and chemical control (Dunand 1988, Marchezan 1994, Menezes et al. 1994, Montealegre and Vargas 1989, Noldin 1988).

The number one preventive measure to control red rice is the use of high quality rice seed. Use of rice seed free of red rice is important to prevent the introduction or dissemination of red rice in the rice fields. This objective can be accomplished only if a good program of certified seed production is established. Planting a rice field free of red rice with rice seeds containing only two red rice seeds/kg, may result in a soil infestation above 100 kg/ha of red rice, after just three seasons. In most countries in Latin America it is allowed the presence of red rice in some class of commercial seeds. However, in Uruguay, red rice is not allowed in any class of commercial seeds, zero tolerance for red rice in the lab analysis (Zorrilla, personal communication). In Santa Catarina, southern Brazil, red rice is not allowed in most seed class (genetic, foundation, registered, and certified). But, there is a fifth seed class called Ainspected@, which tolerates two red rice seeds/kg. The tolerance level has been brought down year by year, and it is expected that in three years, Santa Catarina will have zero tolerance for all commercial rice seed classes.

Cultural practices for red rice control include the use of stale seedbed technique, water-seeded rice with pregerminated seeds, crop rotation, and management practices to reduce the red rice seed bank. Red rice seed longevity increases when the seed is buried deep in the soil (Noldin 1995, Zorrilla and Acevedo 1996). After harvesting rice fields infested with red rice, the best management practice is to keep the seeds near or at the soil surface during the fallow period. In this environment, red rice seeds will either germinate or lose viability faster than when buried deep in the soil.

Minimum tillage systems are used in many areas with severe red rice problems. In Rio Grande do Sul, about 250,000 ha are cropped every rice season using the low/minimum tillage (Menezes et al. 1994). Soil preparation takes place early in the season, summer or fall, or at least 20-30 days before planting. After seedbed preparation, the area is kept idle, for red rice and other weeds to grow and to form a good mulching cover. Rice can either be drilled or water-seeded after spraying the area with non selective herbicides (glyphosate or sulfosate). Using the minimum tillage system, farmers get good red rice control but some reinfestation may occur, mainly along the rice rows. The crop should be flooded soon after rice emergence, otherwise the degree of red rice control will decrease (EMBRAPA-CPACT/EPAGRI/IRGA 1999).

Water-seeded rice is used in leveled fields with lasting levees. Pre- germinated rice seeds are broadcasted in the water after seedbed preparation. The use of this crop system combined with a good water management is one of the best alternatives to control red rice (Noldin 1988). In this system, the soil is flooded for seedbed preparation. Early flooding, 20-30 days before soil preparation will be helpful to control red rice. After seeding, water management is the most critical point for successful red rice suppression. There are two management strategies for irrigation after seeding: (i) water is maintained at a depth of 5-10 cm until drainage at harvest (continuous flood); or (ii) water is drained, the soil is kept saturated for 3-5 days, and flooding is returned gradually. Excessive drainage exposes the soil to air and increases oxygen concentration in the soil, thus stimulating red rice germination. Studies carried out at Itajaí Experimental Station/EPAGRI have shown that some water-seeded rice genotypes grow and yield well under a continuous flood (Ishiy and Noldin 1997).

Red rice control in water-seeded rice can be improved with the use of the herbicides molinate, thiobencarb, oxadiazon or oxyfluorfen preplant, in combination with specific water management practices (Noldin 1988).

Crop rotation, mainly with sorghum or soybean, is a very effective practice to reduce red rice population in infested fields (Marchezan 1994, Montealegre and Vargas 1989). Sorghum treated with atrazine or soybean treated with metolachlor, alachlor, trifluralin, dimethenamid, applied PPI alone or in combination with POST application of sethoxydim, quizalofop or fluazifop, generally are very effective in controlling red rice. Besides to reduce red rice infestations, crop rotation may also contribute to improve rice yields, resulted of better weed control and improvement in soil conditions. However, the success of soybean or sorghum planted after rice in flat soils is dependent of a good drainage system, since soybean or sorghum cultivars available, generally, do not tolerate high soil moisture.

A plant growth regulator, maleic hydrazide, has been labeled in Brazil for the control of seed production of red rice (Andres and Menezes 1997, EMBRAPA-CPACT/EPAGRI/IRGA 1999). A difference in maturity between red rice and commercial rice is necessary (Dunand 1996). Rice cultivars must be earlier and head at least 10-15 days before red rice. Maleic hydrazide sprayed at the rice milk stage and prior or during red rice heading stage reduce red rice seed production (Dunand 1996). The number of red rice panicles decreases and increase red rice sterility with the use of maleic hydrazide. Also, maleic hydrazide reduce red rice and rice seed viability, so it should not be used on rice seed production fields (Andres and Menezes 1997). Application of maleic hydrazide is a complementary practice to be used associate with other control methods to reduce seed production of the red rice and, consequently, minimize the problem the following years.

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# EL ARROZ ROJO EN COLOMBIA

Gildardo Rodríguez Carroza

**SUMMARY**

The red rice term is applied to various biotypes of *Oryza sativa*, which behave as weeds in rice fields. Red rice invades large cultivations of rice in Colombia. The crop area is equal to 320 000 ha, and its production is affected to some extent by the incidence of red rice. Private and government institutions have conducted experimental work in the field and in greenhouse and laboratory conditions in order to characterize red rice biotypes, their seed dormancy, problems caused by their interference and implementation of cultural control methods, among others.

The results obtained enable us to conclude that there is vast information and data to develop a suitable strategy to control red rice. From the results it is clear that it is necessary to implement a medium or long-term programme for the eradication of the weed. Such a programme should include measures, such as use of clean certified seeds free of red rice, crop rotation, use of green manure such as crotalaria (*Crotalaria juncea*), preventative measures, and others to increase rice yields.

**RESUMEN**

El término de arroz rojo es aplicado a varios tipos de *Oryza sativa*, que se comportan como malezas en los campos de arroz. El arroz rojo invade grandes extensiones de arroz en Colombia. El área del cultivo asciende a 320 000 ha y su producción se ve afectada hasta cierto punto por la incidencia de arroz rojo. Las instituciones privadas y gubernamentales han desarrollado un trabajo experimental de campo, en invernadero y condiciones de laboratorio para caracterizar los biotipos de arroz, la latencia de su semilla, los problemas que ocasiona su interferencia y la implementación de métodos culturales de control, entre otros.

Los resultados obtenidos permiten concluir que existe una vasta información y datos para desarrollar una estrategia de control de arroz rojo. De los resultados existentes queda claro que a mediano y largo plazo la erradicación de la maleza es necesaria llevarla a cabo. Tal programa debe incluir medidas, tales como el uso de semilla certificada libre de arroz rojo, rotación de cultivos, uso de fertilizantes verdees como crotalaria (*Crotalaria juncea*), medidas preventivas y otras para aumentar los rendimientos del arroz.

## 1. INTRODUCCION

El termino arroz rojo se aplica a una serie de biotipos de *Oryza sativa* que son malezas en el cultivo del arroz en muchos países del mundo. Diversos autores clasifican el arroz rojo como una maleza que causa pérdidas en el rendimiento y la calidad del arroz y está distribuida mundialmente tanto en el sistema bajo riego como en el secano.

Craigmiles (1978) definió el arroz rojo como “granos que poseen un pericarpio rojo o una capa externa de color marrón”. En adición a esta característica, el arroz rojo se desgrana fácilmente y las semillas pueden permanecer en el suelo en forma dormante por largos períodos.(1).

## 2. EL ARROZ ROJO EN COLOMBIA

Grandes extensiones de las zonas arroceras de Colombia se encuentran invadidas por esta maleza. En el Tolima, en la zona de Saldaña es donde mejor se ha apreciado el efecto competitivo del arroz rojo. A pesar de lo mucho que se han divulgado los problemas provocados por el arroz rojo, la diseminación y establecimiento se ha extendido a algunas áreas arroceras importantes del país.

Colombia planta anualmente 320 000 hectáreas de arroz, las cuales se encuentran en mayor o menor grado afectadas por ésta maleza.

## 3. INVESTIGACIONES REALIZADAS EN COLOMBIA.

### 3.1. TIPOS DE ARROZ ROJO.

Con el objeto de clasificar y describir los principales tipos de arroces rojos en Colombia, en un estudio de Clavijo (2) y Fedearroz (4) se estableció que existen 30 tipos de arroz rojo, 15 de los cuales fueron estudiados y clasificados en cuatro grupos principales denominados Varietales, Pipones, Mechudos y Rayones.

### 3.2. DORMANCIA DE SEMILLA

De acuerdo a resultados obtenidos de investigaciones, se pudo establecer que la profundidad de la ubicación de la semilla, a 5, 15 y 25 cm en suelo, de un tipo de arroz rojo denominado pipón desgranador, incrementa la dormancia de la semilla en 12, 47 y 41% , respectivamente.

### 3.3. MANEJO CULTURAL DEL ARROZ ROJO

En otros estudios se determinó que:

- Se presentó mayor porcentaje de germinación de arroz rojo en suelo saturados e inundados que cuando se realizaron mojes.
- En el campo, con la quema física sobre tallos y tamo de arroz, se observó menor germinación de semillas donde hubo quema fuerte.
- Con relación a la preparación en seco y fangueo, el menor número de plántulas emergidas se presentó en fangueo.

### 3.4. INTERFERENCIA CON EL CULTIVO

En estudio de interferencia realizado por Clavijo y Baker (1986), citado por Clavijo (1) (2), analizaron y compararon la germinación, la emergencia y desarrollo temprano de la plántula de arroz rojo y dos variedades de arroz con el objeto de establecer las ventajas morfológicas y fisiológicas asociadas con la competitividad del arroz rojo en los primeros estados de crecimiento. Se encontró lo siguiente:

- El porcentaje de germinación de arroz rojo fue significativamente mayor que el de las dos variedades.
- La velocidad de emergencia mostró diferencias significativas entre el arroz rojo y las variedades indicando que el arroz rojo emergió más rápidamente.
- La comparación de los índices de semillas demostró que las semillas de arroz rojo fueron las más pesadas, lo que las capacita para germinar y emerger de una manera eficiente con un extensivo desarrollo radicular.
- La longitud de la radícula en el momento de la germinación, y la longitud y peso seco de las raíces y tallos 10 días después de la emergencia fueron consideradas como características de un

desarrollo temprano y vigoroso de las plántulas. En todos los casos el arroz rojo presentó el mayor valor.

- Existe una óptima relación entre el área foliar expuesta por la planta de arroz rojo y la biomasa total.
- La capacidad de interferencia del arroz rojo está basada su alta germinación, velocidad de emergencia y vigor de la plántula, que posibilitan su rápido establecimiento al inicio del período vegetativo.

**3.5. COMPORTAMIENTO DE LA SEMILLA.**

La capacidad de desgrane de la mayoría de biotipos de arroz rojo implica un potencial de reinfestación del banco de semillas. Las semillas que permanecen superficialmente germinan rápidamente; mientras que las enterradas adquieren latencia y germinan solo ante un estímulo específico.

En un trabajo realizado por Venegas y Clavijo (1996) citado por Clavijo (2), se encontró que:

- En los primeros 10 cm del suelo se consiguen 2.318.000 semillas viables por hectárea.
- La preparación del suelo con rastras y rastrillos, los cuales no profundizan más de 12 cm en el suelo, propicia la mayor concentración de semillas de arroz rojo en los primeros 10 cm del suelo. .
- La preparación del terreno inmediatamente después de la cosecha, propicia la reinfestación del suelo con la semilla desgranada, la cual puede permanecer viable durante varios años.
- La preparación del suelo debe iniciarse 50 días después de la cosecha, lo que evita el entierre de semillas de arroz rojo en el suelo, lo que hace más difícil su manejo y control.

**3.6. EFECTO DE ALGUNAS PRACTICAS CULTURALES SOBRE LA POBLACION DE ARROZ ROJO.**

Otro estudio sobre el efecto de algunas prácticas culturales arrojó lo siguiente:

- La rotación de arroz con sorgo, soya o *Crotalaria* para su incorporación al suelo, tienen un marcado efecto sobre la población de arroz rojo y desde luego aumentó los rendimientos del arroz comercial.
- Cuando se mantienen continuamente la siembra en forma tradicional, los rendimientos tienden a reducirse por efecto del aumento de la población de arroz rojo. Cuando se incorpora la quema, esta práctica ayuda a mantener los rendimientos a un nivel estable, lo mismo que la población de arroz rojo.
- El grado de preparación del suelo y su integración con tratamientos químicos proporcionaron un significativo control de arroz rojo y aumento de los rendimientos. Cuando además de la preparación intensa se realiza una quema con un herbicida no selectivo, los rendimientos aumentan significativamente, mientras la población de arroz rojo decrece en forma dramática. Sin embargo, la integración de las anteriores prácticas con un sistema de rotación con soya y sorgo permitieron recuperar y estabilizar nuevamente los rendimientos.
- Se estableció que las pérdidas de arroz comercial alcanzaron 18.6 Kg./ha de arroz por panícula de arroz rojo presente por $m^2$ .

- Cuando se trabaja en áreas infestadas con arroz rojo, el empleo de una sola práctica no es suficiente para eliminar el arroz rojo y el regreso a un manejo tradicional puede conducir a una reinfestación igual o peor a la anterior.

Linares (5), concluye que se debe implementar el manejo del arroz rojo a través de diferentes labores tales, como pastoreo con ganado, el uso de diferentes implementos para destruir una buena población de malezas, incluyendo al arroz rojo; uso de variedades comerciales precoces, complementadas con el uso de secantes, para obtener cosechas limpias de arroz rojo; uso de semilla certificada y altas densidades de siembra, lo que evita la germinación y establecimiento de altas densidades de arroz rojo; control manual para evitar la floración del arroz rojo; y aplicación de herbicidas no selectivos antes de la siembra, luego de la preparación del suelo.

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# MANEJO DE ARROCES CONTAMINATES EN LAS AREAS PRODUCTORAS DE ARROZ COMERCIAL DE COSTA RICA

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**SUMMARY**

In Costa Rica there are two species of contaminants of rice crop, one is *Oryza latifolia* commonly known as Arrozon and the other is *Oryza sativa* with red a pericarp. Although small amount of seeds of red rice are required to contaminate rice grains it has been found that stands of red rice of equal or less than 10 plants/m² do not affect rice yields. Above such a stand each additional red rice plant per sq. meter may cause a yield reduction of 0.09 t/ha.

The most commonly applied control methods are crop rotation with leguminous crops, such as beans, which should be implemented for more than two years in heavily infested areas. Use of rice seed free of red rice contaminants, cleaning of machinery used in infested areas, stale bed preparation and combination of puddling with flooding to prevent germination of red rice are also practised. Some herbicides are to some extents effective in controlling red rice stands, such as molinate, oxadiargyl and oxifluorfen.

**RESUMEN**

En Costa Rica hay dos especies de contaminantes del arroz, uno es *Oryza latifolia* conocido como Arrozón y *Oryza sativa* con pericarpio rojo. A pesar que pequeñas cantidades de arroz rojo son requeridas para contaminar la semilla de arroz, se ha visto que una infestación de arroz rojo de menos de 10 plantas/m² no afecta los rendimientos del cultivo. Por encima de esa densidad, cada planta adicional de arroz rojo causará la reducción de 0.09 t/ha de los rendimientos de arroz.

Los métodos más practicados de control son la rotación del arroz con cultivos de leguminosas, que debe ser desarrollada por más de dos años en áreas con altas infestaciones. El uso de semillas libre de arroz rojo, la limpieza de la maquinaria utilizada en áreas infestadas, la preparación del terreno provocando la emergencia del arroz rojo previo a la siembra del cultivo y la combinación del fangueo con la inundación para prevenir la germinación del arroz rojo son también de práctica común. Algunos herbicidas son hasta cierto punto efectivos para el control del arroz rojo, tales como molinate, oxadiargyl y oxifluorfen.

## INTRODUCCION

Los arroces contaminantes como *Oryza latifolia* (Arrozón o arroz pato), *O. sativa* (Rojo, voluntarios y otros fuera de tipo), son plagas que causan gran perjuicio a la producción comercial del arroz.

La dificultad en el combate de esas especies o tipos asociados y el daño que causan está relacionado con la cercanía taxonómica con el arroz comercial, ya que esta íntima relación, provoca un mayor costo en el combate (por tolerancia a las prácticas utilizadas) y el mayor daño (por la semejanza en las demandas del medio).

## ASPECTOS BIOLOGICOS DE LOS ARROCES CONTAMINATES

En Costa Rica los arroces contaminantes pertenecen a dos especies del género *Oryza*, *sativa* denominado arroz rojo por el color rojo de su pericarpio rojo. *O. latifolia*, es llamado arrozón por el tamaño que puede alcanzar la planta, aunque su semilla es más pequeña, y achatada que el arroz rojo, y su pericarpio es blanco.

En el cuadro 1 se dan algunas características diferenciales entre los grupos de arroces contaminantes *O. sativa* (arroz rojo) y *O. latifolia* y el arroz comercial blanco.

**NOCIVIDAD DE ARROCES CONTAMINANTES**

Poco se conoce sobre la posible nocividad del *O. latifolia* (arrozón). Sin embargo, en opinión del autor, poblaciones crecientes del arrozón son perjudiciales desde el punto de vista de contaminación de la cosecha, pero fundamentalmente desde la competencia. El uso de herbicidas selectivos para el control malezas causa un aumento de la población de esta maleza, al eliminar la posible competencia de otras.

En el caso de *O. sativa* spontanea (Arroz rojo), su nocividad se atribuye a:

- Su **habilidad para el entrecruzamiento,** con la consiguiente pérdida de las características de la variedad comercial
- La **longevidad y la latencia de su semilla**, lo que le permite sobrevivir en el suelo por muchos años aproximadamente (10-12 años).

Tabla 1. **Características diferenciales entre *O. latifolia* (Arroz pato) y los *O. sativa* spontanea (Arroz rojo) y cultivares comerciales**.

| CARACTERISTICAS | *Oryza latifolia* | *Oryza sativa* ROJO | BLANCO |
|---|---|---|---|
| **VEGETATIVAS** | | | |
| **HOJAS** | Más anchas que las de *O. sativa* | Parecidas a las del blanco verde más pálido. | |
| **TAMAÑO PLANTA** | Hasta 2 m | De mayor porte que el blanco | Menor porte que el rojo y el arrozón. |
| **TIPO CRECIMIENTO** | Erecto | Semidecumbente o decumbente | Erecto |
| **REPRODUCTIVAS** | | | |
| **PERICARPIO** | Blanco | Rojo, púrpura o blanco grisáceo. | Blanco |
| **ARISTAS** | Largas, hasta 3,5 cm | Robustas y largas | No. |
| **DESPRENDIMIENTO DEL GRANO** | Caedizos | Antes de la completa madurez | Variable, pero menos qu anteriores. |
| **REPOSO SEMILLAS** | Variable | Alto | Variable |

**DAÑOS CAUSADOS**

**A. INDIRECTOS**

Al transmitir, de manera dominante, la pigmentación roja del pericarpio, lo que es indeseable durante el proceso de industrialización del arroz, se reduce el valor de la cosecha.

La producción de arroz para semilla se dificulta con la presencia del arroz rojo. Su presencia, en cantidades superiores a los límites de tolerancia establecidos, obliga a desechar lotes con la consiguiente pérdida para el productor.

El hecho de exhibir crecimiento decumbente o semidecumbente, o bien ser de mayor porte, hace al *O. sativa* spontanea (Arroz rojo) sensible al encamado, arrastrando consigo a las plantas vecinas del arroz blanco comercial, dificultando la cosecha y provocando pérdidas de grano durante ese proceso.

La habilidad del arroz rojo para el cruzamiento con cultivares de arroz blanco, rápidamente incrementa la población, lo cual puede obligar al abandono de áreas productivas con costosa infraestructura.

**B. DIRECTOS**

Tanto el *O. latifolia* (Arrozón o arroz pato) como el *O. sativa* spontanea (Arroz rojo) compiten severamente con las variedades blancas.

Se acepta que la competencia por factores del medio: nutrimentos, luz y agua, son más fuertes cuanto mayor es la cercanía taxonómica de las plantas; puesto que los requerimientos son muy similares.

**C. COSTO DE LOS DAÑOS**

En Costa Rica se encontró que cuando existen poblaciones inferiores o iguales a 10 plantas/m² de contaminantes no hay reducción en la población del arroz comercial, sin considerar la posible contaminación de la cosecha. Después de 10 plantas/m², por cada planta de arroz contaminante más, se obtiene una merma de 0.09 t/ha en el rendimiento del arroz comercial. Estas pérdidas son causadas por una reducción en el número de hijos/m² y por lo tanto en la cantidad de panículas /m² del arroz comercial. Se encontró que por encima de 10 plantas/m² de arroces contaminantes cada planta- maleza más mermó la cantidad de tallos del arroz comercial en 12/m² y de panículas en 7/m².

## COMBATE DE ARROCES CONTAMINANTES

El combate del arroz rojo y del arroz pato implica un programa de actividades que tienen como objetivos mantener el suelo libre de semillas de arroces contaminantes y evitar la entrada de esas semillas.

Existen muchas prácticas que permiten alcanzar los citados objetivos: rastreas de desgaste, rotación de cultivos, limpieza de la semilla (certificación), limpieza de maquinaria, etc.

Pretender que un tratamiento herbicida aislado permita la consecución de estas metas, es un error. No obstante, el uso de herbicidas dentro de un programa de manejo es un importante componente del mismo, pues muchos productores no pueden aplicar medidas de control de largo plazo por razones de tiempo.

**A. CONTROL CULTURAL**

**1- Uso de semilla limpia**
Este asunto ha sido muy debatido, la mayoría opina que no deben existir semillas de arroz rojo en semilla certificada de arroz.

**2- Rotación de cultivos**
La rotación permite el empleo de herbicidas sumamente eficaces en el combate de arroces contaminantes. Se estima que para alcanzar un adecuado éxito, la medida debe aplicarse durante 2-3 años, para después volver a un sistema arroz-arroz.

Es posible el uso de cultivos de leguminosas en rotación, como el frijol terciopelo, que también aportan nitrógeno al suelo.

**3- Limpieza de los equipos**
La maquinaria agrícola disemina malezas. Así llantas de tractor, arados, rastras, cosechadoras, etc., llevan semillas de malezas que pasan de los lotes sucios a los limpios, por lo que este trasiego de maquinarias, siempre que sea posible, debe ser evitado.

Otras medidas culturales son el uso de semilla pre- germinada y la siembra de transplante.

**A. COMBATE FISICO**
**1- Medidas promotoras de la germinación**
Aradas sucesivas, generalmente con intervalos de 5-8 días, dependiendo de la germinación de la maleza, destruyen la población emergida de arroz rojo y propicia un desgaste del banco de semillas del suelo, al promover la germinación y emergencia, e impedir la producción de las mismas.

Cuando se emplean herbicidas residuales para el control no selectivo de arroz rojo, como metribuzina, cianazina y alaclor, la promoción de la germinación es crucial para lograr una buena eficacia de estos herbicidas.

**2- Anegamiento**
La condición anaeróbica, por limitación de la disponibilidad de oxígeno, impide la germinación de las semillas.

Por ejemplo, semillas de cuatro tipos de arroz rojo que se pusieron en agua durante 0, 15, 30, 60 y 129 días, mostraron que hubo mayor germinación cuando estuvieron 30 días con agua y la menor con 120 días. No obstante, la semilla no murió, sino que tuvo un reposo más prolongado con inmersión de 120 días.

El mantenimiento de una lámina de agua, después de la aplicación de un herbicida, puede influir sobre el comportamiento del herbicida: reduciendo la población de la maleza, incrementando la sensibilidad al herbicida de esa población y aumentando el efecto residual del herbicida.

Cuando se utiliza el manejo de agua en la producción de arroz, es necesario realizar una labor precisa de nivelación, lo que elevará la eficiencia del control.

**3- Fangueo**

Promueve la adherencia de una capa de barro sobre la semilla de la maleza, lo cual limita el intercambio de gases y mantiene una temperatura menor, que impide la germinación de la maleza.

**4- Fangueo y anegamiento**

En Costa Rica se ha ampliado esta metodología la cual consiste en:

a- Nivelación de los terrenos, de modo que cuando se introduzca el agua, no queden partes del terreno descubiertas, en las cuales se facilitaría la germinación de muchas especies de malezas.

b- Fangueo del suelo previo a la siembra, con lo cual se reducen las pérdidas por percolación de agua, se fomenta un ambiente anaeróbico en el suelo al disminuir los macroporos. Además, muchas semillas de malezas resultarán impregnadas con una capa fina de lodo lo cual disminuye la conducción de calor y el intercambio gaseoso.

c- Se deja el terreno varios días en sedimentación

d- Se saca el agua y de inmediato se siembra a voleo la semilla pre-germinada de arroz. En otros casos la siembra a voleo de la semilla pre-germinada se realiza sobre la lámina de agua y luego se drenan los lotes.

e- El terreno se mantiene sin agua por 2-3 días para favorecer un rápido anclaje de las plántulas de arroz

f- Se introduce el agua para inhibir la germinación de malezas.

g- Luego el agua se maneja de acuerdo con la altura del cultivo.

**5- Mínima labranza**

Con el advenimiento de herbicidas totales, de amplio espectro como el glifosato, esta práctica se ha popularizado.

No obstante, parece que los mejores resultados se han logrado con la combinación con la labranza (estímulo de la germinación, al menos 3 a 4 veces).

**C- COMBATE QUIMICO**

**1- No selectivo**

En este caso es crucial atender las especificaciones del periodo que hay que dejar entre aplicación del herbicida y siembra del arroz blanco (descanso, ventana).

Generalmente se emplean productos residuales, como metribuzina, cianazina, alaclor y EPTC + antidoto (Erradicane), así como el glifosato.

Por lo general se prefieren herbicidas de residualidad intermedia, como metribuzina o bien poco residuales como paraquat o el mismo glifosato.

Los períodos de descanso pueden variar entre un mismo herbicida, dependiendo de varios factores de suelo. Es necesario hacer pruebas de sensibilidad sembrando semilla pre-germinada cada ocho días después de la aplicación para determinar la "ventana" para la siembra del lote con la semilla comercial sin que ésta sufra un daño.

También se usa el glifosato en tratamientos de "quemas", que consisten en la promoción de la germinación de las malezas, mediante el suministro de humedad, unos días después de que ocurre la primera emergencia de malezas, se aplica el herbicida; y se siembra el arroz, (3 a 4 días después de la aplicación con semilla pre- germinada para darle ventaja de competencia al arroz comercial.

**2- Herbicidas selectivos de uso actual:**
En Costa Rica tres herbicidas selectivos se han venido empleando como parte del manejo de arroces contaminantes; molinato, oxadiargyl y oxifluorfen.

En todos los casos se debe tener un control estricto del manejo del agua. Para el caso del molinato, este debe ser incorporado en el suelo dada su volatilidad, pero la aplicación debe hacerse sobre suelo seco en la superficie, pero con humedad en el horizonte A, de tal forma que al momento de la incorporación el suelo húmedo trabaje como un sello y al agregar la lámina de agua, el producto no se pierda por lixiviación a horizontes con menor cantidad de semillas de arroz rojo.

Por su parte, oxadiragyl y oxifluorfen se aplican en la lámina de agua cuando esta tapa por completo tanto las malezas como a los arroces contaminantes. El efecto de "quema" ocurre en el término de 36 horas, ocho días después de deben de iniciar la pruebas de sensibilidad y entre 15 a18 días después de la aplicación es la ventana según investigaciones semi- comerciales y comerciales para la siembra del arroz comercial.

# EL ARROZ ROJO. ESTUDIOS Y PERSPECTIVAS DE SU MANEJO EN LA PRODUCCIÓN ARROCERA CUBANA

Jorge García de la Osa y Luis E. Rivero

**SUMMARY**

Red rice seriously affects the production of rice in Cuba, where mechanized direct-seeded rice is a normal practice in most areas of this crop. In some areas, heavily infested stands of red rice of up to 240 plants/sq. m. have been found. Research conducted has determined the existence of 39 biotypes of red rice widely distributed along the country. Red rice incidence is more serious in short cycle rice cultivars.

The major control measures against red rice are the production of clean certificate rice seeds in areas completely free of red rice, rotation of heavily or medium infested rice areas with *Sesbania rostrata* , grazing only in medium and low infested areas, application of stale bed preparation with the use of glyphosate, and puddling to be combined with alternation of flooding and draining.

**RESUMEN**

El arroz rojo afecta seriamente la producción de arroz en Cuba, la que se realiza a través de la siembra directa mecanizada en la mayoría de los campos. En áreas densamente infestadas los niveles de población de arroz rojo pueden ser de hasta 240 plants/m$^2$. Los estudios desarrollados han determinado la existencia de 39 biotipos de arroz rojo ampliamente distribuidos en el país. La incidencia del arroz rojo es más seria en cultivares de ciclo corto.

Las medidas principales de control del arroz rojo son la producción de semilla certificada en áreas libre de infestación de arroz rojo, rotación de las áreas con infestaciones de moderada a altas con *Sesbania rostrata,* pastoreo solo en arrozales con infestaciones bajas o medias, aplicación del método de provocación de emergencia de arroz rojo previo a la siembra utilizando glifosato para su eliminación, fangueo y también la combinación de riego con drenaje.

## INTRODUCCIÓN

El arroz constituye uno de los alimentos principales en la dieta alimenticia de los cubanos, con un consumo anual per cápita de 44 kg (Castillo et al., 1997).

La producción arrocera en Cuba la conforman un sector especializado constituido por empresas estatales que producen más de 127 000 ton. de arroz en 104 860 ha distribuidas en ocho zonas arroceras en igual número de provincias (UCAIA, 1999), y un sector de producción popular integrado por productores individuales y Cooperativas de Producción Agropecuaria, los que obtienen 128 300 ton. de arroz consumo en 97833 ha dispersas a lo largo de todo el país (Alemán et al. 1999).

Los rendimientos agrícolas actuales en los dos sectores son bajos (2.76 t/ha en el especializado y 2.16 t/ha en el popular) y sus producciones no llegan a satisfacer las demandas de este cereal en el país, siendo necesario importar alrededor de 350 000 ton. anuales de arroz blanco para cubrir el balance nacional.

Una de las principales limitantes para la obtención de altos rendimientos son las malezas, particularmente el arroz rojo, considerado dentro de las cinco primeras especies de malezas de importancia económica, por su amplia distribución, afectaciones al cultivo y recursos empleados para su control (Colón y Antigua, 1992).

Bajo condiciones de siembra directa, el arroz rojo constituye una de las más serias amenazas a la producción arrocera. En Cuba, el sector estatal cultiva el 100 % de las áreas utilizando esta tecnología, mientras que el sector popular lo hace en un 60 %, lo cual favorece la multiplicación de esta maleza.

**ORIGEN Y DISEMINACIÓN DEL ARROZ ROJO**

No se conoce con exactitud el origen del arroz rojo en nuestro país, se supone que pudo ser introducido en la época de la colonia en semillas de variedades procedentes de España o más tarde en semillas de variedades importadas de Estados Unidos durante el proceso de extensión del cultivo del arroz iniciado en 1927 (Arango, 1954). Esto último es más aceptado pues desde 1846 el arroz rojo había sido reconocido como maleza severa en Estados Unidos y reportado como la peor en los campos de Louisiana y Arkansas (Dodson, 1900; Vincenheller, 1906 citados por Diarra *et al*. 1985).

Pérez *et al*., 1973, en recorrido realizado por áreas arroceras y pantanosas de la provincia de Pinar del Río colectaron plantas con características intermedias de *Oryza sativa* y *Oryza perennis* var. *cubensis* de cuyos descendientes obtuvo progenies similares a los arroces negros o barbudos, típicos de nuestras zonas arroceras, considerando el cruzamiento natural de estas dos especies como una posible causa de la aparición de nuevos biotipos de arroz rojo. Oka, (1960, citado por Pérez *et al.*1973), encontró en áreas pantanosas de Cuba , cruces naturales de *O.perennis* con la variedad Century Patna 231.

Aunque el arroz rojo había sido considerado por Arango (1954), como una de las principales malezas que afectaban al cultivo del arroz en esa época, no es hasta 1968 con el desarrollo del programa arrocero y la apertura de nuevas áreas de cultivo, que comienza un período de multiplicación acelerada de las mezclas o arroz rojo, lo cual fue propiciado, entre otras causas, por la utilización de semilla no certificada existente en el país y la introducción procedente de México de semilla de las variedades IR8 e IR160 que contenían biotipos de arroz rojo, luego diseminados por todas las zonas arroceras (Martínez Grillo, 1999, comunicación personal).

Según Antigua y Galano, 1981, el no haber contado con una organización correcta en la producción de semilla, así como la no- aplicación de métodos de control cultural y químico (durante los años 1968 a 1972 aproximadamente), tuvo como consecuencia el incremento de la infestación de esta maleza.

A pesar de los esfuerzos dedicados para su erradicación desde los años 70, el arroz rojo ha ido aumentando su presencia y en la actualidad ocupa el 86 % de las áreas de cultivo con una incidencia ligera en el 53 % , media en el 20 % e intensa en el 13 % del área total.

***Causas de la actual situación de las mezclas (arroz rojo) en Cuba***

1. El empleo de la tecnología de siembra directa en el 100 % de las áreas del sector especializado y el 60 % del sector popular.
2. Poca disponibilidad de áreas para rotar o alternar con otros cultivos (sólo se rotan el 8% de las áreas del sector especializado y el 60% del sector popular).
3. La siembra de 70 % de las áreas de cultivo con variedades de ciclo medio que favorecen la multiplicación de las mezclas.
4. Incumplimiento de los programas de desifección química de campo con infestación intensa.
5. La desinfección química realizada en muchas áreas no ha cumplido con las exigencias previstas para este método de control de mezclas.
6. La selección negativa es inadecuada por falta de personal vinculado a áreas con infestación ligera.
7. Muchas áreas infestadas continúan siendo explotadas sin la aplicación de un programa de desinfección previa.
8. No se limpian adecuadamente las máquinas y equipos de preparación de suelos y cosecha cuando salen del campo con mezcla.
9. El traslado de ganado sin desinfestar de campos con mezcla a campos limpios.
10. No se ha aplicado un programa de manejo integrado de arroz rojo .

**AFECTACIONES AL CULTIVO DEL ARROZ**

La interferencia ejercida por el arroz rojo provoca reducción en los rendimientos agrícolas e industriales del arroz comercial. García y Cordero, 1992, en muestreos efectuados en áreas de producción del CAI arrocero Sur del Jíbaro, cuantificaron pérdidas de hasta un 89.9 % en el rendimiento agrícola de la variedad J 104 con niveles de infestación promedio de 286 panículas/m$^2$ de arroz rojo (Graf. 1).

En ensayos de campo realizados en la Estación Experimental del Arroz "Sur del Jíbaro", García et al., 1998, determinaron que las afectaciones al rendimiento agrícola de la variedad J 104 podrían alcanzar hasta un 91.5 % en la época de lluvias y 94.8 % en la seca en presencia de infestaciones de 200 plantas/m$^2$ de arroz rojo. Los rendimientos agrícolas del arroz comercial decrecieron con el aumento de la densidad de la maleza, siendo menor la afectación en la medida que se aumentó la densidad de población de la variedad cultivable de 50 a 300 plantas/m$^2$ (Tabla 1).

Las pérdidas en el rendimiento agrícola ocurridas en el arroz comercial se debieron a la disminución del número de panículas/m$^2$ y de granos llenos/panícula que provocó la competencia con el arroz rojo (Tabla 2)

Se observó que el arroz rojo en interferencia con la variedad J 104 mostró mayor habilidad competitiva que ésta. A igual número de plantas/m$^{2,}$ el arroz rojo alcanzó un porte mayor, produjo mayor cantidad de panículas/m$^2$ y logró rendimientos agrícolas superiores (Tabla 3).

Estudios posteriores sobre competencia (Tabla 4) demostraron que en la época de seca una planta/m$^2$ de arroz rojo es suficiente para causar una reducción significativa del rendimiento agrícola del arroz comercial con relación al testigo limpio en la densidad de población de 50 plantas /m$^2$ de arroz comercial, mientras que en las densidades de 100, 200 y 300 plantas/m$^2$ se necesitan 3 plantas/m$^2$ de esta maleza. En la época húmeda los rendimientos agrícolas de la variedad J 104 con poblaciones de 50, 100 y 200 plantas /m$^2$ fueron afectadas significativamente con sólo 1 planta/m$^2$

de arroz rojo y en la mayor densidad de población con infestaciones de 3 plantas /$m^2$ (García et al. no publicado).
A diferencia de otras malezas que sólo producen pérdidas, el arroz rojo aporta una producción que aunque indeseable contribuye a atenuar las afectaciones en los rendimientos agrícolas totales de las áreas infestadas (Tabla 5). El aporte del arroz rojo produce un aumento de la cantidad de arroz cosechado/área, pero trae consigo afectaciones en los porcentajes de granos enteros. En la Tabla 6 se aprecian los resultados de dicho efecto, los cuales coinciden con los de Sonnier, 1962 ; Oliveira y Barros , 1986.

**BIOTIPOS DE ARROZ ROJO**

García et al., 1998, determinaron la presencia de 39 biotipos de arroz rojo de acuerdo a sus características morfofisiológicas en la zona arrocera de Sur del Jíbaro, de ellos 16 con glumelas pajizas, 10 con glumelas jaspeadas y 13 con negras. De la población inicial de semillas colectadas el 27 % manifestó segregación en la primera generación. Algunas de las principales características de estos biotipos aparecen en las tablas 7, 8, 9, 10, 11 y 12.

En áreas del CAI arrocero Los Palacios, en Pinar del Río, López y Morejón, 1988, caracterizaron 27 biotipos de arroz rojo. De los biotipos colectados, sólo uno no mantuvo las características por las cuales fue seleccionado. Muchos de los biotipos caracterizados en ambas zonas coincidieron en sus características morfofisiológicas.

**CONTROL DE ARROZ ROJO**

La estrategia de lucha contra las mezclas en Cuba se realiza de acuerdo al grado de infestación con que esta maleza incide en las áreas de cultivo. Estas son evaluadas visualmente según la escala de determinación de intensidad de las mezclas varietales. Antigua y García, 1993.(Tabla 13)

**AREAS LIMPIAS**

El porcentaje de áreas con esta categoría en el país es bajo y se refieren a granjas de producción de semilla y zonas de fomento en su mayoría. En estos campos son aplicadas fundamentalmente medidas preventivas entre ellas se citan :

1. El uso de semilla libre de arroz rojo. Esta medida es la de mayor importancia y uso. Nuestro país tiene organizado un programa de producción de semilla donde la semilla original y básica son obtenidas en las estaciones experimentales, mientras que la registrada y certificada de primera generación son producidas en centros especializados. La certificada de segunda generación es obtenida en las granjas de semilla de la propia empresa. En ninguna de las categorias de semilla se permite la presencia de granos de arroz rojo.

2. Limpieza de los equipos e implementos de preparación de suelos y cosecha.

3. No- utilización de agua de drenaje de campos infestados con arroz rojo en campos libres de esta maleza.

4. Evitar el pastoreo de ganado procedente de áreas infestadas en campos limpios.

Los campos limpios pertenecientes a granjas de semilla se siembran una vez al año por un período de dos años consecutivos (excepcionalmente tres años) al cabo de los cuales son sometidos a procesos de desinfección durante dos años. En el período seco se alterna el pastoreo intensivo de ganado con laboreos mecánicos al suelo y en el período lluvioso es utilizado el pastoreo intensivo con ganado principalmente.

Las plantas de arroz rojo que escapan a estas medidas son extraídas manualmente de los campos (selección negativa).

Areas con infestación ligera

Aunque en estos campos se aplican algunas de las medidas preventivas anteriormente señaladas, en ellos la selección negativa juega el papel fundamental. Las plantas de arroz rojo son extraídas manualmente del campo o tratadas de forma dirigida con una solución del herbicida Glyfosate al 10% (Antigua, 1993).

Este proceso comienza a aplicarse tan pronto se observen diferencias en altura y coloración entre el arroz rojo y el comercial (alrededor de los 30 días de germinado el cultivo).

**AREAS CON INFESTACIONES MEDIA E INTENSA**

Dos métodos de control de mezclas se han aplicado tradicionalmente a partir de los años 70:

a) Método agrotécnico en áreas cuya infestación no es intensa que disponen de suficiente agua y tiempo entre la preparación de suelos y la siembra. Este consiste en :
- Preparación de suelo en seco.
- Construcción de diques.
- Riegos para provocar germinaciones de arroces y malezas.
- Eliminación de las plántulas emergidas por medio de una labor de grada.
- Se repiten los riegos y labores de grada tantas veces como sea posible.
- Aniego del campo por un período de 7 días como mínimo.
- Siembra en aguas claras con semilla pregerminada.

b) Método agrotécnico - químico. Es el más usado y el que mejores resultados ha brindado en la lucha contra esta maleza. Se compone de las siguientes labores:
- Preparación de suelo en seco hasta dejarlo bien mullido y nivelado.
- Levantamiento de los diques.
- Realización de uno o dos riegos para provocar germinaciones de arroces y malezas.
- Eliminación de estas con una o dos aplicaciones de herbicidas no selectivos (paraquat o glifosato).
- Aniego a las 48 horas posteriores a la aplicación.
- De 5-7 días después de la aplicación se efectúa la siembra en aguas claras con arroz pregerminado.
- Riegos con intervalos cortos después de la siembra para evitar que se agriete el suelo.

**RESULTADOS DE LAS INVESTIGACIONES**

A. **ESTUDIO DEL EFECTO DE LAS VARIEDADES DE CICLO CORTO**

En experimentos de campo desarrollados por García et al, 1998, en la Estación Experimental del Arroz Sur del Jíbaro se determinó que la siembra continua de la variedad 4285 en suelo infestado con arroz rojo ocasiona una disminución considerable de las poblaciones de esta maleza en la primera siembra, así como en la tercera y cuarta siembra. Esta variedad, al presentar un ciclo más corto que los biotipos de arroz rojo (86 días en la época húmeda y 100 días en la seca) provoca una interrupción de la reproducción de la maleza, ya que su cosecha se realiza antes que el arroz rojo comience a desgranar. Las variedades comerciales de ciclo corto Perla (100 días en húmeda y 125 en seca) y J 104 de ciclo medio (121 en húmeda y 126 en seca) facilitan la multiplicación de las poblaciones de arroz rojo en los campos de producción y por consiguiente el aumento de las pérdidas en el rendimiento agrícola. Los potenciales productivos de estas dos variedades son mucho mayores que los de la 4285. Sin embargo, en el transcurso de cuatro campañas, la suma de los rendimientos agrícolas logradas por la 4285 superó a la obtenida por la Perla y la J 104.

El rendimiento en pulidos totales y granos enteros se vio afectado a su vez por el incremento de las cantidades de arroz rojo dentro del arroz comercial a medida que aumentó el número de siembras de estas variedades en suelos infestados.

B **ESTUDIO DE CULTIVOS ALTERNANTES**

El uso de la *Sesbania rostrata* como cultivo alternante combinada con labores agrotécnicas ha brindado resultados promisorios en el control del arroz rojo. Esta planta es una leguminosa de rápido crecimiento adaptada a las condiciones de aniego y capaz de producir entre 40 y 50 t/ha de biomasa en sólo 45 días de germinada, aportando al suelo entre 40 y 85 kg/ha de nitrógeno, de 4 a 12 kg/ha de fósforo y entre 90 y 115 g/ha de potasio. Su incorporación facilita el aumento de la capacidad de cationes cambiables, incrementa la disponibilidad de P asimilable en el suelo y el contenido de materia orgánica (Cabello et al., 1990). Además, con la incorporación de esta leguminosa se destruye el arroz rojo y otras malezas que germinaron junto con esta y que aún no han llegado a producir semillas. El arroz sembrado con posterioridad a la siembra de sesbania mantiene una coloración verde intensa que se mantiene durante el transcurso del ciclo del cultivo así como una tendencia a alcanzar una mayor altura.

La realización de un riego de germinación a los 45 días posteriores a la cosecha de los campos, combinado con la preparación de suelo en seco y uso del aniego o la aplicación de herbicidas no selectivos mostraron buenos resultados en el control del arroz rojo.

C **ESTUDIO DE PROTECTANTES DE SEMILLA**

Con el propósito de lograr mayor selectividad de algunos herbicidas al cultivo del arroz, fueron realizados en condiciones da casa vegetativa del CIAT ensayos con tres protectantes de semilla (oxabetrinil, flurazole y carbón activado) y siete herbicidas (molinate, EPTC, butylate, alaclor, diuron, metribuzina, oxyfluorfen). Los resultados preliminares demostraron que la utilización de molinate a 7.2 kg de i.a./ha y butylate a 4.26 kg de i.a./ha aplicados en presiembra e incorporados realizan un excelente control del arroz rojo, lográndose una mayor selectividad al cultivo cuando la semilla del arroz fueron recubiertas con oxabetrinil a 1.5 g de i.a./kg de semilla y flurazole a 2.5 g de i.a./kg de semilla en siembras superficiales. Frente al butylate se logró la mayor protección cuando la semilla seca fue peletizada con carbón activado y sembrada a 2 cm de profundidad.(García y Fisher, no publicado).

D **METODOS DE CONTROL DE ARROZ ROJO EN ESTUDIO BAJO CONDICIONES DE PRODUCCIÓN**

**Variante 1**

- Preparación de suelo en seco (roturación, cruce y dos pases de grada).
- Riego para estimular la germinación del arroz rojo y otras malezas.
- Aniego del campo a los 15 días de la emergencia de estas.
- Fangueo del campo.
- Siembra de arroz comercial en lámina de agua.

**Variante 2**

- Aniego de los campos de doblaje con infestación ligera o media.
- Fangueo.
- Drenaje de los campos y espera de la germinación del arroz rojo .
- Aplicación de herbicidas no selectivos.
- Aniego y siembra del arroz comercial.

**Variante 3**

- Pastoreo intensivo con ganado vacuno en campos con infestación ligera o media cosechados en época seca.
- Riegos para provocar la germinación del arroz rojo .
- Aplicación de herbicidas no selectivos (dos aplicaciones).
- Siembra del arroz comercial.
- Pase de rodillo compactador.
- Riego de germinación.

# RED RICE INCIDENCE IN GUYANA

Leroy Small

**SUMMARY**

Red rice infestation is evident in areas with poor water management. 46% of 129 452 ha (1998) present a low level of red rice stands, while 15 and 5%, respectively, show moderate to high infestation.

The main control method is preventative consisting of the production of certified rice seed. Land preparation is done by ploughing and harrowing several times, a practice that eliminates various red rice flushes. This can be easily done when weather is favourable. Water management is another effective measure. Puddling is usually implemented for red rice control. Another procedure very common in fields with low infestations of red rice is roguing (when red rice plants are tall) in order to avoid their seed setting and to avoid the increase of red rice seed in soil.

**RESUMEN**

Las infestaciones de arroz rojo son evidentes en áreas con pobre manejo del agua. El 46% de un área de 129,452 ha (1998) tiene una baja infestación de arroz rojo mientras que un 17 y 5%, respectivamente tienen niveles de infestación moderados y altos.

La mayor medida de control es la preventiva mediante la producción de semilla certificada de arroz. La preparación del terreno se hace con pases multiples de arado y de grada que normalmente eliminan varias emergencias de arroz rojo. Esta practica es habitual cuando las condiciones del tiempo son favorables. El manejo del agua es otra medida efectiva. El fangueo es bastante practicado para este propósito. Otro procedimiento en campos con menores infestaciones es la de arrancar manualmente las plantas de arroz rojo en estadios tardíos de su ciclo para evitar el incremento del banco de semilla de la maleza en el suelo.

## INTRODUCTION

Agricultural production is mainly confined to the coastal strip of land which varies in width from 16 to 64 km. Rice and sugar are the two most important agricultural products contributing nearly 50% of the foreign exchange earnings. It is estimated that approximately 295,000 ha along the Coastland are available for agricultural production. Of this, 178,000 ha are under production , 51% being utilized by rice.

## RICE PRODUCTION

During 1998 , 129,452 ha were harvested from the two rice crops which yielded 522,907 MT of paddy from which 339,890 MT of rice were obtained. Average paddy yield / ha was 4040 kg. Rice export for the year was 249,755 MT or 73.5% of the production. Export earnings amounted to US$73.26 million.

The entire rice crop is direct seeded using pre-germinated seed. About 62% of the area under cultivation benefit from varying combinations of drainage and irrigation. However , poor maintenance of the canals has resulted in poor water control in some of these areas.

## AREA INFESTED BY RED RICE

Red rice infestation is more evident in areas with poor water control . Of the 129,452 ha harvested during the 1998 growing seasons 46% had a low redrice infestation while 17 and 5% respectively had moderate and high infestation levels (Table 1). As water availability and control improve, the incidence of red rice decreases.

**CONTROL MEASURES**
Red rice control is achieved by a combination of the following measures:

- **Preventative Control**

This is mainly achieved by the use of certified seed . The seed production programme managed by the Guyana Rice Development Board releases Basic Seed to private seed growers for multiplication into Certified - II seed which is used to produce the grain crop.

Basic seed is also released to farmers who multiply this to satisfy their own seed requirements. Excess seed from this process is sold to other farmers.

In 1998 , 10,404 bags (661MT) of Basic Seed and 25,500 bags (1556 MT) of Certified I & II seed were released to seed producers and farmers.

Certified seed is generally red rice free and it represents an important component in the red rice control programme.

- **Cultural Practices**

Several cultural practices when properly managed contribute to red rice control . These include land preparation , water management and roguing.

- **Land Preparation**

During the interval between harvesting and the commencement of the growing season , multiple ploughing and harrowing operations usually result in the removal of successive flushes of red rice seedlings and other volunteer vegetation , thus reducing the potential red rice population that will infest the rice crop . This practice is widely used by farmers when weather conditions are favourable .

- **Water Management**

The most effective and widely used cultural practice for the control of red rice is the management of water.

Wet cultivation followed by under water cropping generally suppresses the germination of red rice seed.

On the other hand pre-germinated rice seed will continue growth and development in a flood of 7.5 to 10 cm. Fields must be relatively level and aquatic pests such as water weevils and snails must be controlled in order to permit the establishment of a good plant stand.

Most rice farmers who are located in areas with good drainage and irrigation facilities employ water management as the primary means of controlling red rice.

- **Roguing**

Farmers with low populations of red rice either in their seed or grain crop remove these plants during the late vegetative or reproductive growth stages . Plants escaping detection are removed during the ripening growth stage .

**RED RICE RESEARCH**

No active research is being conducted on red rice control because of the satisfactory results obtained by farmers when field conditions permit the implementation of the preventative and cultural control measures.

Earlier research on red rice control (E.G. Giglioli , Red Rice Investigations 1951 - 1956) indicated that deep ploughing (20 cm) of a 19 ha field heavily infested with red rice and traditionally ploughed to a depth of 10 cm reduced red rice population by 57.6% as well as increased grain yield by 38.9% . Subsequent shallow ploughing resulted in an increase in the incidence of red rice. He also found that wet cultivation and underwater cropping (10 - 15 cm) using pre-germinated seed reduced the incidence of red rice by 74% providing the soil was not allowed to dry out during the growing season .

**CONCLUSION**

During the past ten to fifteen years the infestation levels of red rice has shifted from predominantly high infestation levels to predominantly low infestation levels. This reduction is mainly due to the use of cultural practices such as wet cultivation followed by under water cropping and the increased use of certified seed by rice farmers .

Un-levelled fields and poor availability and control of water have limited the impact of water management on red rice control in some areas .

Improvement in water control systems and on - farm levelling will further contribute to a reduction in the incidence of red rice.

New approaches need to be developed to supplement the existing control measures to further reduce the incidence of red rice.

**TABLE 1**

**AREA HARVESTED AND RED RICE INFESTATION LEVEL DURING THE 1998 GROWING SEASONS.**

| **LOCATION (ha)** | **AVAILABLE AREA (ha)** | **AREA (1) HARVESTED (ha)** | **AREA INFESTED BY RED RICE (ha)** | | | **TOTAL AREA INFESTED (ha)** |
|---|---|---|---|---|---|---|
| | | | Low (2) Infestation | Moderate (3) Infestation | High (4) Infestation | |
| Region 2 | 13947 | 24210 | 19610 | 3390 | 1210 | 24210 |
| Region 3 | 9820 | 10984 | 2105 | - | - | 2105 |
| Region 4 | 2227 | 3250 | 2834 | - | - | 2834 |
| Region 5 | 31338 | 61086 | 29555 | - | - | 29555 |
| Region 6 | 34099 | 29922 | 4935 | 19173 | 5004 | 29112 |
| Total | 91431 | 129452 | 59039 | 22563 | 6414 | 87816 |
| % of Harv. Area | - | - | 46% | 17% | 5% | 68% |

1- Area harvested represents the sum of 2 rice crops.
2- Low infestation represents an infestation level of less than 2 plants per m2.
3- Moderate infestation represents an infestation level between 2 and 6 plants per m2.
4- High infestation level represents an infestation level greater than 6 plants per m2.

# EL ARROZ ROJO EN MÉXICO
# RED RICE IN MEXICO

Gustavo Torres Martinez


## SUMMARY

Rice in Mexico is sown on about 118 037 ha but yields are limited because of red rice. Infestations are due to contaminated seed, irrigation water and livestock moving from infested land to non-infested rice areas. Control measures currently used in the country, such as use of clean rice seed free of red rice, hand pulling and glyphosate application are described. The selection of the appropriate control measure has been proposed, and is based on the number of ears of red rice per square meter.



## RESUMEN

El arroz en México es cultivado en 118 037 ha, cuyos rendimientos son bajos debido a la incidencia del arroz rojo. Las infestaciones se deben al uso de semilla de arroz contaminada con arroz rojo, la diseminación de la maleza por el agua de riego y el movimiento de los animales de áreas infestadas a otras aun no infestadas. Las medidas de control más usuales en el país, como el uso de semilla libre de arroz rojo, el desyerbe manual y la aplicación de glifosato se describen. La selección de medidas apropiadas de control se propone, la cual se basa en el conteo del número de espigas de arroz rojo por metro cuadrado.


## INTRODUCCION

En México el arroz se cultiva en 113,492 hectáreas de las que se obtiene una producción anual de 469,455 toneladas. Esta producción ha ido en aumento en los últimos años. Sin embargo, no se logra satisfacer la demanda de la población. Para lograr esto se debe incrementar la superficie cultivada o los rendimientos. Uno de los factores que limitan los rendimientos son las malezas, entre las cuales destaca el arroz rojo.

El arroz rojo es una maleza de difícil control y ocasiona grandes problemas al cultivo del arroz. Dentro de los daños más importantes se encuentran la disminución del rendimiento y la calidad del arroz comercial. Se han identificado disminuciones en el rendimiento de entre 40 y 60% dependiendo de la densidad de panículas por hectárea. Por otra parte, la calidad del arroz comercial se ve mermada cuando éste se contamina con los granos de arroz rojo y esto le ocasiona al agricultor una pérdida en el precio por tonelada.

A pesar de lo anterior la investigación sobre arroz rojo en México es escasa, aquí se resumen algunos resultados de investigación obtenidos en México. Sin embargo se debe seguir trabajando en este problema si se desea lograr un control satisfactorio de esta maleza.

## FUENTES DE CONTAMINACION

Se desconoce como llegó a México esta maleza, pero se cree que llegó como contaminante en semilla de arroz proveniente de Estados Unidos.

Las principales causas de infestación de terrenos con arroz rojo son: siembra con semilla contaminada, maquinaria agrícola, agua de riego y pastoreo de ganado proveniente de lotes infestados.

Lo anterior ha propiciado que el número de terrenos infestados con arroz rojo se esté incrementando, y en los terrenos donde ya existe el problema, el grado de infestación aumenta, al grado de que algunos agricultores han tenido que dejar de sembrar arroz.

**METODOS DE CONTROL**

La manera tradicional de controlar el arroz rojo por parte del agricultor, es la eliminación manual. Esto, sin embargo, no evita las disminuciones en el rendimiento.

Recientemente se han realizado algunas investigaciones para el control de arroz rojo y se hacen esfuerzos para que el agricultor cambie al sistema de trasplante, aunque este método es de difícil adopción.

Una opción es dar un riego y rastrear antes de la siembra para eliminar la nacencia de arroz rojo. Se ha encontrado también que la rotación de cultivos más la aplicación de herbicidas es una de las mejores prácticas para el control de arroz rojo. De este modo, se han tenido controles hasta de 95%.

En el cuadro 1 se muestran las opciones que existen dependiendo de la densidad de población de arroz rojo. Esto ha sido recomendado por el Instituto Nacional de Investigaciones Forestales y Agropecuarias para el estado de Nayarit, lugar donde más se ha trabajado en este problema.

Cuadro 1.-**PROPUESTA DE MANEJO PARA EL ARROZ ROJO EN MEXICO.**

| ESPIGAS POR METRO CUADRADO | PROPUESTA DE MANEJO |
|---|---|
| 0 | * Semilla de calidad |
| 1 a 10 | * Semilla de calidad.<br><br>* Riego fitosanitario y eliminación de nacencia de malezas comunes y de arroz rojo mediante control químico o cultural.<br><br>* Limpia manual de arroz rojo en etapa de floración.<br><br>* Rotación de cultivos: En el ciclo de primavera-verano: arroz y en otoño-invierno cualquier cultivo de escarda que se adapte a la región (maíz, sorgo, cártamo, girasol, frijol o tabaco) de acuerdo a la preferencia del productor. |
| 11 a 20 | * Semilla de calidad.<br><br>* Riego fitosanitario y eliminación de nacencia de malezas comunes y de arroz rojo mediante control químico o cultural.<br><br>* Limpia manual de arroz rojo en etapa de floración.<br><br>* Rotación de cultivos: En el ciclo de primavera- verano: arroz y en otoño- invierno cualquier cultivo de escarda que se adapte a la región (maíz, sorgo, cártamo, girasol, frijol o tabaco) de acuerdo a la preferencia del productor.<br><br>* Trasplante a distancia máxima de 30 x 30 entre plantas. |

# EVALUACIÓN DE LA MALEZA ARROZ ROJO (*Oryza sativa*), EN LAS PRINCIPALES ZONAS ARROCERAS DE NICARAGUA

Marvin Sarria Fletes

**SUMMARY**

Red rice is an important weed in rice. It is present in all rice producing areas of the country with infestations of up to 89 panicles/sq. meter. In Altamira rice enterprise red rice and *Oryza latifolia are* present in 10% and 40%, respectively of a rice area of more than 2400 ha.

There is no specific method to control red rice. Normally farmers either apply glyphosate pre-planting over the weed or simply rogue the plants.

Nicaragua needs the implementation of a research programme on red rice control as well as other practical recommendations of specific control measures for immediate adoption by rice growers.

**RESUMEN**

El arroz rojo es una maleza importante del arroz, la que está presente en todas las áreas productoras de arroz del país, con niveles de infestación de hasta 89 panículas por metro cuadrado. En la empresa arrocera de Altamira el arroz rojo y *Oryza latifolia* están presentes en 10 y 40%, respectivamente, de un área de arroz de más de 2 400 ha.

No existe método dirigido al control del arroz rojo. Normalmente los agricultores bien aplican glifosato en pre- siembra sobre la maleza o simplemente realizan desyerbes manuales.

Nicaragua necesita implementar un programa de investigaciones sobre control del arroz rojo, así como de otras recomendaciones prácticas de medidas específicas de control para su rápida adopción por los productores de arroz.

## INTRODUCCION

El arroz (***Oryza sativa*),** representa una de las principales fuentes de alimentación de las familias nicaragüense. El consumo per capita es de 43.18 kg anualmente. (ANAR, 1998).

En Nicaragua se siembran alrededor de 77,000 hectáreas de arroz, de las cuales 50,400 hectáreas se cultivan bajo condiciones de secano (lluvia) y 26,600.00 hectáreas bajo condiciones de riego (MAG.1998). Los rendimientos obtenidos bajo las condiciones de secano son generalmente menores en comparación con los obtenidos bajo condiciones de riego, esto es debido a que dependen de las condiciones climáticas que prevalecen durante el cultivo.

Las principales zonas arroceras en Nicaragua son el valle de Sébaco (Matagalpa), Malacatoya (Granada), Nandaime (Granada) y Altamira (Tecolostote - Boaco).

La producción nacional de arroz no se corresponde con la demanda, ya que su producción se ve seriamente afectada por diferentes problemas fitosanitarios, entre los cuales podemos mencionar las malezas y dentro de éstas el Arroz Rojo, que se encuentra presente en no menos del 60 % de las áreas sembradas**.**

El arroz rojo (*Oryza sativa),* presenta las características siguientes: su testa (cáscara) es de color marrón, presenta una arista (filamento) que se proyecta más allá del ápice del grano, razón por la cual se le conoce también como barbudo; alcanza una mayor altura y generalmente florece primero que las variedades de arroz comercial. Durante el proceso de trillado (proceso para separar el grano de la testa), si hay mezcla de arroz rojo con el grano comercial, se observa la semilla de color rojizo, por lo que se le llama arroz rojo o arroz manchado, esto ocasiona pérdidas de calidad y por ende pérdidas económicas al ser rechazado en el mercado.

**CAUSAS DE DISEMINACIÓN DE LA MALEZA ARROZ ROJO**

- Uso de semilla de siembra contaminada.
- Falta de limpieza de la cosechadora combinada.
- Falta de conciencia de los productores que venden semilla.
- Desconocimiento del productor que compra la semilla.
- Falta de capacitación por parte de las asociaciones de productores.
- Falta de material de divulgación que de a conocer el problema y como enfrentarlo.
- Falta de asistencia técnica dirigida.

**METODOLOGÍA para el muestreo del arroz rojo en Nicaragua.**

a) Para el muestreo de la maleza Arroz Rojo se utilizan cuadrantes de 50 cm X 50 cm. En cada cuadrante se contabiliza el número de panículas de Arroz Rojo y en cada lote se muestrean 20 cuadrantes, al final se obtiene un promedio de panículas de Arroz Rojo por 0.25 metros cuadrados, para finalmente obtener un promedio de panículas de Arroz Rojo por cada zona evaluada.

b) En la Empresa Arrocera Altamira la evaluación del Arroz Rojo fue visual y los resultados se expresan en porcentaje.

En la **zona del Valle de Sébaco,** se encontró que existe una variación dentro en una misma zona e incluso dentro de los diferentes lotes de una misma finca. Por ejemplo, en la finca “Filimón Rivera”, un lote presentó una densidad promedio de 69 paniculas/$m^2$ de arroz rojo, mientras que el lote No. 2 presentó una densidad de 6 paniculas/$m^2$ de arroz rojo. Se puede afirmar que en todos los lotes evaluados se encontró presencia de la maleza Arroz Rojo, lo que es un problema que irá creciendo paulatinamente de no tomarse las medidas necesarias para su control.

En la **zona de Malacatoya,** concretamente en la Finca San Antonio, lote No.1, se encontró una densidad de 37 paniculas/$m^2$ de arroz rojo y la menor densidad se obtuvo en el lote No. 2 con 2 paniculas/$m^2$ de arroz rojo. En todos los lotes muestreados se detectó la presencia de la maleza arroz rojo.

En la **zona de Nandaime**, se muestreó una finca que presentó un promedio de 3 paniculas/$m^2$ de arroz rojo. Aunque la densidad es relativamente baja, el arroz rojo está presente en la zona.

En la **Empresa Arrocera Altamira**, con un área de 2,450 hectáreas destinadas al cultivo de arroz bajo riego, se determinó una infestación de arroz rojo del 10 % del área sembrada mientras que el arrocillo (*Oryza latifolia)* está presente en 40 % de las áreas.

La **zona de Nandaime** fue la que presentó la menor densidad de Arroz Rojo en comparación con las zonas arroceras tradicionales como son Sébaco y Malacatoya que presentan promedios similares entre si, 80 y 84 paniculas/$m^2$ de Arroz Rojo, respectivamente.

## MEDIDAS DE CONTROL

Tradicionalmente no se realizan medidas de control dirigidas específicamente a la maleza Arroz Rojo, si no que se llevan a cabo aplicaciones de herbicidas y algunas prácticas culturales. Algunos productores realizan la limpieza de Arroz Rojo de forma manual.

En la Empresa Altamira, en lotes con altas densidades de Arroz Rojo, se realiza una quema después de la cosecha, posteriormente se nivela el área por donde pasó la cosechadora, se aplica riego para estimular la germinación del Arroz Rojo y otras malezas. Una vez emergidas las malezas, se aplica glifosato a 4.28 litros/ha, lo que reduce en un 70 % la densidad de Arroz Rojo en esa cosecha. (Rafael Reyes com. Personal).

## INVESTIGACION

Hasta la fecha no se han realizado trabajos de investigación formal relacionados al manejo del Arroz Rojo.

## CONCLUSIONES

En todas las fincas productoras de arroz, la maleza Arroz Rojo está presente. Esto sucede, incluso en zonas relativamente nuevas de arroz.

La diseminación del Arroz Rojo es debida principalmente al uso de semilla no certificada por la Dirección de Semillas del MAG- FOR, y por falta de limpieza de la maquinaria utilizada.

## RECOMENDACIONES

- Usar semilla de siembra certificada.
- Realizar limpieza de la maquinaria agrícola utilizada antes de su traslado a otros lotes.
- Capacitar a los productores de arroz sobre el manejo del Arroz Rojo.
- Elaborar material divulgativo que enfoque este problema.
- Realizar estudios de investigación sobre métodos de control de esta maleza.
- Identificar los tipos de Arroz Rojo presentes en Nicaragua.
- Realizar estudios sobre la bio- ecología del Arroz Rojo.

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## PROBLÈME POSÉ PAR LE RIZ ROUGE EN RIZICULTURE AU SÉNÉGAL

Souleymane Diallo

**SUMMARY**

Weed management in rice is one of the most important activities. The major red rice species in Senegal is *Oryza barthii* A. Chev. Red rice biotypes may also come from cultivated *Oryza glaberrima* Steud. Red rice infestation is mainly due to the use of non-clean rice seed

There no data concerning the actual rice area infested by red rice, but some observations indicate that nearly 55% of an area of about 40 600 ha of rice is infested by red rice. Major incidence of this weed is found in direct-seeded areas.

At present no specific methods are implemented to control red rice. Stale bed preparation is a good practice, but is still to be adopted by farmers. Hand weeding is the main control method practised in the country.

**RESUMEN**

El manejo de malezas en arroz es una de las actividades más importantes en el cultivo. La especie principal de arroz rojo en Senegal es *Oryza barthii* A. Chev. Existen otros biotipos de arroz rojo que pueden descender de la especie cultivable *Oryza glaberrima* Steud. Las infestaciones de la maleza son mayormente debidas al uso de semilla arroz contaminado.

No hay datos sobre el área real de arroz infestado con arroz rojo, pero algunas observaciones indican que el 55% de un área de 40 600 ha de arroz se halla infestado por el arroz rojo. La mayor incidencia se encuentra en las áreas de siembra directa de arroz.

En la actualidad no hay métodos específicos de control de arroz rojo. La preparación del terreno provocando la germinación de la maleza es una buena práctica, pero aun no adoptada por los agricultores. De forma similar ocurre con la rotación de cultivo. El desyerbe manual es el principal método de control practicado en el país.

### INTRODUCTION

La maîtrise des mauvaises herbes constitue l'une des principales contraintes auxquelles est confronté le développement de la riziculture au Sénégal. Les riz sauvages annuels ou pérennes figurent parmi les adventices les plus importantes et les plus nuisibles qui envahissent les rizières. L'infestation des périmètres par ces espèces et la difficulté que rencontre les paysans à les maîtriser entralîne souvent l'abandon de certaines rizières. Le riz rouge est, avec le riz à rhizomes, l'une des deux principales espèces spontanées de riz connues comme mauvaises herbes des rizières en Afrique de l’Ouest et au Sénégal en particulier.

Le riz rouge est connu par les riziculteurs sénégalais déplus fort longtemps, probablement déplus l'introduction de la riziculture. Mais cela ne constituait pas, outre mesure, une gêne pour la riziculture traditionnelle, soit parce que sa présence dans les rizières était faible ou rare, donc tolérable en terme de concurrence pour le riz cultivé, soit parce qu'il pouvait être consommé et qu'il était aussi bien apprécié que le riz blanc. C'est assez récemment, avec les efforts d'intensification de la riziculture, que le problème est devenu une contrainte majeure. L'expansion du riz rouge a été favorisée par le passage progressif du système traditionnel à une culture plus ou moins intensive avec de nouveaux objectifs de production plus exigeants et nécessitant de nouvelles technologies (nouvelles variétés, irrigation, mécanisation). Déplus quelques années avec le développement de la commercialisation du riz locale, la notion de qualité s'est imposée comme un facteur important de performance et de compétitivité par rapport au riz importé. Cela a contribué à rendre encore plus aigu le problème posé par le riz rouge.

**IMPORTANCE DE LA RIZICULTURE AU SÉNÉGAL**

Deux principaux types de riziculture se rencontrent au Sénégal : la riziculture traditionnelle essentiellement vivrière, très ancienne, est pratiquée en condition pluviale dans les zones de bas fonds inondables et sur le plateau dans la partie sud du Pays, principalement en Casamance ; la riziculture irriguée a été introduite à partir des années 1950 dans la vallée du fleuve Sénégal, mais assez timidement ; son développement engagé avec la création de la Société d'aménagement et d'exploitation des terres du delta (SAED) créée en 1965, s'est mieux affirmé après la construction de barrages de régulation sur le fleuve Sénégal dont le fonctionnement a débuté en 1986.

Le riz est l'une des céréales, avec le mil, le sorgho et le maï s, qui constituent la base de l'alimentation des populations au Sénégal. Il n'occupe que la troisième place dans la production vivrière derrière le mil et sorgho. Mais le riz a une importance toute particulière dans l'économie agricole sénégalaise, car la production nationale couvre à peine 25% des besoins de consommation qui s'élèvent à environ 600 000 tonnes. Pour combler cet énorme déficit, l'état a recours aux importations (400 000 t/an) qui constituent une lourde charge dans la balance commerciale. Cela justifie que le développement de la riziculture soit un objectif prioritaire de la politique agricole et les efforts importants consentis pour promouvoir la culture irriguée.

**SUPERFICIES CULTIVÉES EN RIZ**

Les superficies occupées par la riziculture pendant les 15 dernières années sont indiquées sur le tableau 1. En 1998 elles étaient estimées à 73 600 hectares dont 52 900 hectares pour le riz pluvial et 21 700 hectares pour le riz irrigué (MA. /D.A., 1999). Elles ont sensiblement diminué par rapport aux années d'avant le cycle de sécheresse des années 1970 et 1980, années pendant lesquelles les surfaces en riz s'évaluaient entre 80 000 et 100 000 ha Cette régression concerne surtout la riziculture en condition pluviale du fait de deux facteurs essentiels : la baisse drastique des précipitations annuelles qui a entraîné une réduction importante des terres inondables et une augmentation du taux de salinité des rizières situées dans le domaine de la mangrove ; l'insécurité qui s'est progressivement installée en Casamance deplus plus de dix ans à cause du conflit qui y règne entrave les activités agricoles dans plusieurs zones de cette région à forte tradition rizicole. La riziculture irriguée, par contre, a connu dans l'ensemble, une augmentation significative des surfaces cultivées, passant de 10 000 hectares environ dans la période 1970-1980 à 20 000 - 30 000 hectares pour 1990-1998. Mais cette croissance est largement inférieure aux prévisions. La tendance à la stagnation ou à la baisse des surfaces en riz irrigué observée déplus 1995 est due, d'une part, aux effets de la dévaluation de la monnaie locale (le franc CFA) qui a entraîné la hausse des prix des intrants et des équipements dépendants dans une large mesure des importations, et d'autre part, à une certaine désorganisation de la filière à la suite du désengagement de l'Etat.

**LA PRODUCTION**

La production nationale de riz paddy, malgré une certaine progression, reste faible par rapport aux besoins de consommation et aux objectifs fixés dans les plans de développement. Elle varie actuellement entre 150 000 et 220 000 tonnes. Le faible rythme avec laquelle la production évolue est due à la régression des surfaces et le niveau faible des rendements (0,75 - 1,2 t /ha) en riziculture pluviale, et à la lenteur de la progression de la riziculture irriguée en terme de superficies exploitées.

## IMPORTANCE DE L'INFESTATION DES RIZIÈRES PAR LE RIZ ROUGE

### Le type de riz rouge en question

Le terme de riz rouge est utilisé pour désigner les espèces de riz dont le caryopse est plus ou moins coloré de rouge. Ces espèces peuvent provenir des riz sauvages mais aussi des variétés ou des sous-espèces des riz cultivés *Oryza glaberrima* Steud. Et *0. satíva* L. (G. B. Boeken, 1971). La principale espèce de riz rouge infestant les rizières au Sénégal est *Oryza barthii* A. Chev. C'est une espèce native d'Afrique occidentale appartenant à la série Giabnima dont elle est descendante.

Tableau 1 : Evolution des superficies en riziculture au Sénégal entre 1990 et 1998 en comparaison avec la période 1970-1975 - en ha (Source : SAED, 1996 ; MA/DA, 1996, 1997, 1998, 1999)

| Types de riziculture | Années | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1970-75** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** |
| Riziculture sous pluie | 80 000 á10 0000 | 47 400 | 45 100 | 45 000 | 48 000 | 52 000 | 44 500 | 52 900 | 51 600 | 51 900 |
| Riziculture Irriguée | 8 000 á 10 000 | 32 500 | 33 700 | 32 100 | 34 600 | 28 200 | 24 900 | 20 900 | 23 100 | 21 700 |
| Total | 88 000 á 110 000 | 79 900 | 78 800 | 82 600 | 75 500 | 75 800 | 69 400 | 73 800 | 74 700 | 73 600 |

Une autre espèce de riz rouge rencontrée au Sénégal et dans la Région est *0. glaberrima*, espèce cultivée, mais pouvant devenir un adventice nuisible dans les cultures d'Oryza *sativa*.

Mais plusieurs auteurs ont rapporte la possibilité de croisement les espèces cultivées et les espèces sauvages de riz rouge. Il y a aussi la possibilité que d'autres espèces de riz rouge soient introduites par le biais de semences importées. Il y a eu un problème de «riz rouge dans la vallée du fleuve Sénégal (1990) pouvant avoir une origine de cette nature qu'on a désigné sous le terme de problème de «riz à caryopse rouge » pour le distinguer du riz rouge (*0. barthii*).

Tableau 2 : Evolution de la production en riz paddy au Sénégal de 1990 à 1998 en comparaison avec la période 1970-1975 (X Mille Ton)

| Types de riziculture | Années | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1970-75** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** |
| Riziculture sous pluie | 75 á 100 | 45 | 49 | 53, 5 | 54 | 52 | 56, 7 | 61, 4 | 60 | 69 |
| Riziculture Irriguée | 10 á 20 | 164 | 17, 4 | 145 | 165 | 164, 7 | 98,3 | 48 | 114 | 86 |
| Total | 85 á 120 | 209 | 223 | 198, 5 | 219 | 216, 7 | 155 | 109, 4 | 174 | 155 |

## DEGRÉ D'INFESTATION DES RIZIÈRES PAR LE RIZ ROUGE (SURFACES INFESTÉES)

Le riz rouge, notamment *0. barthii* existe dans toutes les zones rizicoles du Sénégal. Mais l'importance de l'infestation varient suivant les conditions de culture et atteint des niveaux dommageables avec l'introduction des pratiques d'intensification. Ce sont principalement les rizières dans les périmètres irrigués qui sont affectés. L'introduction de nouvelles variétés, les échanges de semences, la circulation du matériel agricole et l'irrigation communautaire sont des facteurs importants de dissémination du riz rouge.

Des données d'évaluation exhaustive des superficies infestées par le riz rouge ne sont pas disponibles. Mais les renseignements fournis parles services d'encadrement permettent de dresser les estimations suivantes (tableau 3 ) : les superficies infestées par le riz rouge sont estimées à environ 40 600 hectares, soit près de 55% des surfaces cultivées en riz. Les taux d'infestations les plus élevés concernent la riziculture irriguée avec la pratique du mode de semi-direct (plus de 80% des surfaces).

## LES MÉTHODES DE LUTTE PRATIQUÉES CONTRE LE RIZ ROUGE

### Le désherbage manuel

Dans les périmètres irrigués, il est pratiqué en complément du désherbage chimique sélectif. Son efficacité contre le riz rouge est très limitée en raison de la similarité de morphologie avec les riz cultivés qui rend difficile la distinction aux stades juvéniles. A cela s'ajoute l'insuffisance de disponibilité en main d'œuvre pour la majorité des exploitations.

### Le repiquage et la gestion de la submersion

Le repiquage associé avec le maintien d'une lame d'eau dans la parcelle, contribue de façon significative à limiter l'infestation par le riz rouge. Mais ce mode de plantation n'est pratiqué que par un faible nombre de riziculteurs dans les systèmes irrigués avec possibilité de maîtrise de l'eau.

Tableau 3 : Infestation des rizières par le riz rouge *(Source : résultats d'enquête (non publiés))*

| **Niveaux d'infestation** | **Riz irrigué** | | **Riz en condition pluviale** | | | |
|---|---|---|---|---|---|---|
| | Semi-direct | repiquage | Semi-direct | repiquage | Total | En % |
| **Total Superficies en riz (moyenne/an)** | 21 600 | 2 000 | 35 500 | 15 000 | 74 100 | 100 |
| **Superficies non infestées(riz rouge absent)** | 2 600 | 1 400 | 16 500 | 13 000 | 33 500 | 45.2 |
| **Superficies faiblement infestées (riz rouge rare)** | 11 500 | 600 | 15 500 | 2 000 | 29 600 | 39.9 |
| **Superficies plus ou moins fortement infestées** | 7 500 | 0 | 3 500 | 0 | 11 000 | 14.8 |

**La rotation culturale**
Dans la vallée du fleuve Sénégal, le développement des cultures de diversification offre de réelles opportunités de pratiquer la rotation des cultures qui commence actuellement à bien s'installer. Cependant, l'enherbement dans ces cultures est encore assez mai maîtrisé, la méthode utilisée étant essentiellement le désherbage manuel.

**La pré-irrigation suivie de la destruction du riz rouge par travail du sol ou traitement chimique**
Cette recommandation est en voie d'adoption par un nombre croissant de riziculteurs, notamment ceux confrontés à de fortes infestations.

**L'utilisation de semences propres**
C'est l'une des principales recommandations pour la lutte riz rouge, car elle est indispensable, en combinaison avec les autres méthodes, si l'on veut maîtriser les infestations de façon durable. Dans certains périmètres tels que ceux de la cuvette de Boundourn (vallée du fleuve Sénégal), des résultats encourageants ont été obtenus grâce à une organisation des paysans.

# RED RICE IN SPAIN

D. Gómez de Barreda, J. Sendra, R. Carreres, A. del Busto and E. Biendicho.

**SUMMARY**

The area of the main rice scenarios in Spain and the relative importance of red rice in Extremadura, Sevilla, Tarragona and Valencia are described as well as the main weed species in the crop.

It has been found that red rice is an important weed in rice and that there are biotypes of wild rice that do not have a red pericarp, therefore the use of the word wild rice seems more appropriate than red. Various cultural practices are normally used to control red rice.

During 1999 an experiment on red rice control was carried out in a rice field of the Albufera Natural Park. The seed bank in the soil of the experimental plot was very variable with an important presence of shallow seeds. This research in different biotypes, seed bank characteristics and control methods is still going on.

From research results the herbicide cycloxydim (2 l/ha) has given the best results for the control of red rice.

**RESUMEN**

Se describe la superficie de los principales escenarios del arroz en España. También, se describe la importancia relativa del arroz rojo en Extremadura, Sevilla, Tarragona y Valencia así como las principales malas hierbas de los arrozales.

Se ha encontrado que el arroz rojo es una maleza importante del arroz y que hay biotipos de ésta que no tienen el pericarpio rojo, por lo que se sugiere el uso del termino arroz salvaje como más apropiado al efecto. Varias prácticas culturales son normalmente usadas para el control del arroz rojo,

Durante 1999 un experimento para el control del arroz rojo fue llevado a cabo en un campo de arroz del Parque Natural de Albufera. El banco de semillas en el suelo de la parcela experimental se encontró muy variable y con semillas muy superficiales. Esta investigación de diferentes biotipos, características del banco de semillas y en métodos de control está aun en desarrollo.

De los resultados experimentales se ha encontrado que el compuesto cicloxidin (2 l/ha) ha sido el mas efectivo en el control el arroz rojo.

## 1. THE RICE CROP IN SPAIN

The total surface of rice crop in Spain is around 110.000 ha. Crop area is divided in seven main areas.The Guadalquivir marshes area (GMA)[(**)] in Sevilla (32.000 ha), The Ebro Delta Natural Park (DENP) in Tarragona (25.000 ha), The Orellana and Zujar Canal Area (OZCA)[(**)] in Extremadura (20.000ha), The Albufera Natural Park(ANP) in Valencia (18.000 ha), The Aragón Area (5.000 ha)[(**)], The Navarra Area (2.000 ha) and the Calasparra área in Murcia(500); this last one only devoted to biological growing rice crop.

In 1999 we visited four rice growing areas and the level of red rice infestation there is variable from one site to another. The results are shown below.

| Intensity of red rice presence | |
|---|---|
| GMA.-Sevilla | *0* |
| *DENP.-Tarragona* | *5* |
| OZCA.-Extremadura | *1* |
| ANP.-Valencia | *3* |

*0= almost unknown; 5 = very important*

**2. WEEDS IN RICE IN SPAIN**

There are several publications devoted to weed control in rice in Spain (Batalla 1994,1989, Carretero, 1987, Marquez 1998) as well as with red rice (Catalá , 1997, 1998a, 1998b) and *Echinochloa* (Asins *et al*. 1999, Carretero 1981).

**3. RED RICE**

Integrated management is required for effective control of red rice. All available techniques must be applied to achieve an effective control of this weed. Application of a single method will not be sufficient to reach an aceptable control level.

The measures to be used are as follows:

1.-Preventive measures

The rice seed must be free of red rice seeds. The quality of the rice seeds is a key factor in the development of the weed. The legislation allows a maximum of 3 or 5 grains per kg of seed rice, depending if it is an R1 or R2 quality source of seed.

The key factor is to provoque an early emergence of the red rice seedlings, during April, and then to cultivate or make an herbicide application well before the rice sowing periode.

2.-During the rice cropping season

2.1.- Hand-pulling of red rice plants.

2.2.-Application of glyphosate or sulfosate over the red rice plants with an applicator rope.

3.-Cleaning measures

3 .1.- Cleaning the machinery to reduce weed spread.

3.2.- Avoidance of the use of red rice as a source of food for ducks.

4.-Use of short-cycle rice varieties, that allow the rope application system. For example, with Senia variety it is more dificult to distinguish red rice than with cv. Fonsa of shorter cycle.

5.-Use of higher rice seed densities. The application of double density reduces the appearance of red rice.(Catala 1997)

6.-Crop rotation. In certain rice areas, it is possible to grow another crop enabling the control of red rice.

7.-Postharvest applications. After the rice harvest, the field is irrigated to promote the growth of red rice. Then a herbicide treatment is applied over the emerged plants.

8.-Use of herbicides. As a general rule it is almost impossible to control red rice with the herbicides selctive to rice.

**4. RED RICE SEED BANK**

The result of the soil sampling in an experimental plot of a farm (Tancat de Caro of the Albufera Natural Park ), to determine the number of red rice seeds in soil bank, showed that there is a great spatial variability in the distribution of these seeds in soil. Number of seeds are usually higher in deep soil layers than in shallow ones.

**5. Experimental results of different measures for the red rice control in Valencia.**

| **Treatments** | **Number of red rice Plants** |
|---|---|
| **1**.-Check | 52 |
| **2**.-dimethenamid (90% w/v) at 2 l/ha, in dry soil | 11 |
| **3**.-Seeding at double rate than normal one (200 kg/ha) | 55 |
| **4**.-cycloxydim (10%) at 4 l/ha, red rice 2- leaves stage, in moist soil | 4 |
| **5**.-oxadiazon (25% w/v) at 2 l/ha in dry soil | 41 |
| 6.-glyphosate (36% w/v) at 3 l/ha + oxadiazon at 1 l/ha, red rice 2- leaves stage in moist soil | 43 |
| **7.-**Cultivatión at red rice 2 leaves stage, in humid soil | 22 |
| **8**.-cycloxydim (10%, w/v) at 2 l/ha, red rice 2 leaves stage, in moist soil. | 3 |
| **9**.-glyphosate(36% w/v) at 3 l/ha, red rice 2- leaves stage in moist soil. | 22 |

As shown above, cycloxidim application seems to be promisory. The growth of red rice seedlings is reduced by the application of glyphosate or sulfosate. in April (i.e. before rice seeding) and B. in September (postharvest).

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# RED RICE CONTROL IN SURINAME

Rashied M. Khodabaks


## SUMMARY

Red rice is a widespread weed in Suriname. Ten percent of rice fields show infestation of red rice higher than 6%. Every 1% of red rice reduces the yield by 6%. These results are based on a crop production survey that was conducted by ADRON from 1996 to 1998.

The most common practice used by farmers to control red rice is sowing under water. After seed bed preparation the field is not drained. A water layer of 10 –30 cm above the soil surface is maintained, depending on the evenness of the field. Pre-germinated seed (24 hours soaking in water and 24 hours incubation period) is sown in the flooded field. The flood is maintained until grain ripening with intermittent draining periods. Water availability and good levelling, the latter quite common, are required for the best results of the method. Another control method is the use of high plant densities, sowing with rice seeds free from red rice. Seedbed preparation is very common in order to destroy emerged red rice plants mechanically or chemically.

## RESUMEN

El arroz rojo es una maleza ampliamente distribuida en Suriname. Un 10% de los campos de arroz muestran una infestación superior al 6% de arroz rojo. Cada 1% de infestación de esta maleza reduce el rendimiento del arroz en un 6%. Estos resultados están basados en la encuesta de producción del cultivo llevada a cabo por ADRON de 1996 a 1998.

La práctica más común de control de arroz rojo es la siembra del arroz bajo el agua. Después de la preparación del suelo provocando la emergencia de la maleza, el campo no es drenado. Una capa de agua de 10-30 cm sobre el nivel del suelo se mantiene, lo que depende de la uniformidad del terreno. Semillas pre-germinadas (24 horas inmersas en agua y 24 horas de incubación) son sembradas en los campos inundados. La inundación se mantiene hasta que el grano madura intercalada con períodos ocasionales de drenaje. La disponibilidad del agua y buena nivelación, esto último no muy común, son los requerimientos para una buena efectividad del método. Otro método de control es el uso de altas densidades de arroz, pero sembrando semillas libres de arroz rojo. La preparación del terreno con provocación de emergencia de arroz rojo seguida de su destrucción mecánica o química es también practicada.


## INTRODUCTION

Suriname has approximately 50.000 ha of irrigated rice, most of it in Nickerie. The percentage referring to farm size distribution for small-scale farms, medium size farms and large farms is in the proportion of 29%, 43% and 28%, respectively. Continuous rice mono -cropping is practised, in 2 crops per year. The rice production is characterised by low labour input and heavy dependence upon machinery and chemicals. The farming systems of the large and small farms are similar, only the small farmers rely more on manual labour, whilst the larger farms use hired aeroplane services for fertiliser and chemical application.

Tillage is generally carried out by weed cutting, followed by puddling with disc harrows and smoothing the soil surface with wooden beams. The evenness of the paddy fields surfaces is not very good (average height differences 10 – 30 cm) which combined with direct –seeding has led to an increase in red rice infestation.

Pre-germinated seed is sown onto flooded paddy fields. In the past, fields were drained immediately after sowing to encourage early emergence and stand development, with reflooding at 10 – 15 days after sowing but nowadays many farmers are maintaining the flood from sowing to the first fertiliser application four weeks later as a mean of reducing red rice infestation. Standing water is maintained on the paddy fields from sowing till grain ripening with occasionally draining periods for fertiliser application, and application for herbicides and pesticides.

The variation in yield is very high. Data from a crop production survey that was conducted by ADRON from 1996 to 1998 in which 430 farmers were involved showed that the average yield of the 30% least producing fields was 2.4 ton/ha, whereas for the 30% highest yielding fields this was 5.5 ton/ha.

**AREAS INFESTED BY RED RICE**

Almost in every field in the district Nickerie red rice can be observed. The average percentage of red rice is 2.7%, while 10% of the fields have more than 6% of red rice. Every 1% red rice reduces the yield with 6%. These results are based on a crop production survey that was conducted by ADRON from 1996 to 1998.

**METHODS CURRENTLY USED FOR THE CONTROL OF THESE WEEDS**

The most common practice used by farmers to control red rice is sowing under water. After seed bed preparation the field is not drained. A watertable of 10 –30 cm above soil surface is maintained, this depends on the evenness of the field. Pre-germinated seed (24 hours soaking in water and 24 hours incubation period) is sown in the flooded field. The flood is maintained until grain ripening with occasionally draining periods. The pre-requisites of this method are a well-levelled field and the availability of sufficient irrigation water. Most of the fields are poorly levelled (differences up to 30 cm exist within one field) and also irrigation is not always available. Farmers that have good levelled fields and access to irrigation water are successfully controlling the red rice.

One method that farmers also use is establishing high plant densities. However, the utilised seed should be free from red rice.

Also the method of false seedbed preparation is being used. In this case the primary tillage is carried out by disc harrowing or ploughing. The field is irrigated, which allows the weed seed to germinate. The seedlings of the weeds are then being destroyed mechanically or chemically. This is repeated several times. This is an effective method to deplete the seed bank. However, in the farming system of Suriname the majority of the fields are severely contaminated with red rice that this method is not likely to be effective. Also the period between crop seasons is too short to carry out this method.

<u>Research on this topic</u>

From 1994 to 1995 a study was carried out on the polymorphism of weedy rice in Nickerie, Suriname (Baumgart, 1997). The objective was to make an inventory of the weedy rice types that can be found in Nickerie and record the distribution of their characteristics. Weedy rices were collected throughout the district, measurable characteristics were recorded and the seeds of these plants were sown. The characteristics of the offspring were also recorded. Baumgart (1997) speaks

of weedy rice rather than of red rice because it is often observed that red rice has a normal coloured white pericarp.
The experiment showed 179 different weedy rice types, based on 8 characteristics (plant height, presence of awns, grain length and shape, leaf and grain texture, colour of the glumes and of the pericarp). The experiment also suggested, that weedy rices are often very heterozygous for various measured characteristics. The offspring of the weedy rice panicles showed high segregation indicating heterozygosity of the parent panicle. Out-crossing between weedy rice and the commercial varieties could be an explanation for the cause of this heterozygosity. An example of this suggested introgression is the frequent occurrence of typical characteristics of the Surinamese cultivated rice varieties, such as extra-long grains and smooth leaves, in weedy rice. Add to this picture the high heterogeneity of the weedy rice, expressed in the 179 types found, than it can be assumed that the introgression between weedy and commercial varieties is driving the weedy rice polymorphism through a steady gene flow of cultivated-rice traits into the weedy rice population.

Weedy rice may have higher out-crossing than the usual 1% rule of thumb. This estimate has been obtained for natural out-crossing of regular, fertile rice varieties. The occurrence of high sterility in ± 15% of the weedy rice leads to the suspicion that the effective out-crossing in weedy rice should be much higher. This is an area that needs more research to establish the nature and extent of sterility in weedy rice.

Studies were also carried to evaluate the effect of water table manipulation and pre-germinated seed on emergence, growth and competitive ability of rice and red rice (Khodabaks, 1998). This was a preliminary study to evaluate the use of water table (underwater sowing) and pre-germinated seed in order to improve this method.

The use of a water table (under water sowing) had a great effect on the emergence pattern of red rice, it decreased the number of emerged plants and increased the time of 50% emergence. Non-pre-germinated cultivated rice was affected in a similar way as red rice. It was shown that by using pre-germinated sowing material the negative effect on rice could be reduced to acceptable levels.

The relative competitive ability between non-pre-germinated cultivated rice and red rice was not affected by the use of a water table (underwater sowing). By the use of pre-germinated sowing material the competitive ability of rice could be increased. With pre-germination the emergence of rice plants was accelerated, enabling it to compete better with weeds. The favourable competition position of cultivated rice changed when the infestation was through contaminated sowing seed. In this case red rice was pre-germinated together with cultivated rice and this resulted in a relatively more competitive red rice compared to cultivated rice.

In the rice district Nickerie mostly 120 days varieties are being cultivated. Before the crop is harvested most of the red rice plants are fully mature and have shattered already all of their seed in the field. As red rice originated from the soil is more of economical interest than red rice originated from contaminated seed the following hypothesis was formulated: If the field is sown by a 100 days variety, the crop can be harvested before the red rice reaches maturing stage and can be harvested before shattering its seeds.

From 1996 to 1998 experiments were carried out at “Anne van Dijk” Rice Research Centre Nickerie to evaluate whether the 100-day variety is a part of the solution against the red rice problem

(Wildschut et al, 1999). In these experiments a 100-day variety was compared with a commonly used 120-days variety (Eloni). These experiments showed that yield reduction by red rice in a 100-days variety is not higher than in a 120-day variety. The total number of red panicles in the 100 days variety was higher than in the 120 days variety. However the number of mature red rice seed in the 100 days variety was lower. An even amount of mature red rice seed was observed in both the 100 days and the 120 days variety.
In these experiments also the effect of seed density was evaluated. Usually a seed density of ± 130 kg/ha is being used. This experiment showed that by increasing the seed density to 200 kg/ha, the yield reduction by red rice could be minimised (fig.3). Finally, it could be concluded that a 100-day variety would not contribute to the reduction of red rice seeds that remain in the field after harvest.

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# SITUACIÓN DEL ARROZ ROJO EN VENEZUELA

Aída Ortiz Domínguez

## SUMMARY

Rice is a cereal ecologically adapted to Venezuela's conditions and one of the main staples in the country. In 1998 there was a production of 652 495 tons of rice paddy in an area of 143 500 ha. with an approximate yield of 4 547 kg/ha. From this production 82 250 tons were set aside for export. The main production areas are in Portuguese, Guárico (Calabozo), Barinas, Cojedes, and Delta Amacuro; the first two states produce 85% of the total rice in the country.

Red rice is among the major constraints to rice production in the country. Three species of red rice have been identified in areas of Portuguesa, Guárico, Barinas and Cojedes. These are *Oryza sativa* L. (with red pericarp), *Oryza rufipogon* Griff. and *Oryza latifolia* Desv., which is common in adjacent areas to the "melgas" (irrigation system).
It seems that red rice was introduced to Venezuela with rice seed coming from the United States in 1948. By 1988, red rice was already considered one of the major weeds in lowland and irrigated rice in Venezuela. It is considered to be the third weed of economical importance after *Echinochloa colona* and *Ischaemun rugosum*. There is even a classification of rice producing areas according to red rice incidence. In the states of Guarico and Cojedes, red rice is of low incidence, low to intermediate in Portuguesa and high in Barinas.

Main methods for the control of red rice are: use of certified seed free of red rice (the main source of red rice infestation is the use of rice seed contaminated with red rice), puddling during land preparation, occasional use of some herbicides 1. Pre-planting treatments with glyphosate or paraquat, 2. Pre- planting with soil acting using pretilaclor, molinate, oxadiazon or oxyfluorfen, 3. Applied over the water layer (oxadiazon, oxyfluorfen or molinate). The expenses for weed control, including puddling is about 147 $/ha (17,5% of the total production costs).

## RESUMEN

El arroz es un cereal bien adaptado a las condiciones de Venezuela y uno de los alimentos principales de la población. En 1998 se produjo 652,495 ton de arroz en una área de 143,500 ha. Con un rendimiento aproximado de 4,547 Kg./ha. De esta producción 82 250 ton se destinó a la exportación. Las áreas principales de producción el país son: Portuguese, Guárico (Calabozo), Barinas, Cojedes, y Delta Amacuro**;** las dos primeras mencionadas producen el 85% del total de arroz en el país.

El arroz rojo es una de las principales limitantes de la producción de arroz en el país. Tres especies de arroz rojo se han identificado en las áreas de Portuguesa, Guárico, Barinas y Cojedes. Estas son *Oryza sativa* L. (con pericarpio rojo), *Oryza rufipogon Griff.* y *Oryza latifolia* Desv., esta última más común en las zonas adyacentes a las melgas en los sistemas de irrigación.
Parece ser que el arroz rojo fue introducido en Venezuela con semilla de arroz proveniente de EE.UU. en 1948. En 1988, ya el arroz rojo era considerado una de las principales malezas del arroz en tierras bajas e irrigadas. Se considera que el arroz rojo es la tercera maleza del arroz después de *Echinochloa colona* y *Ischaemun rugosum*. Existe incluso una clasificación de las áreas productoras

de arroz según su nivel de incidencia de arroz rojo. Guarico y Cojedes muestran una baja incidencia, Portuguesa de baja a intermedia mientras que Barinas es alta.

Los principales métodos de control del arroz rojo son: uso de semilla certificada libre de semillas de arroz rojo (la principal fuente de infestación del arroz rojo es la semilla contaminada), el fangueo en el proceso de preparación del terreno, uso ocasional de algunos herbicidas: 1. Tratamientos de pre-plantación con glyphosate o paraquat, 2. Otros de pre-plantación con el uso de pretilaclor, molinate, oxadiazon u oxyfluorfen , 3. Igualmente en pre- plantación y aplicado sobre la capa de agua (oxadiazon, oxyfluorfen o molinate). El costo del control de malezas, incluyendo el fangueo, es de cerca de 147 $/ha (17,5% del total de los costos de producción).

## INTRODUCCIÓN

En Venezuela, el arroz es uno de los cereales importantes dentro del rubro agrícola. En 1998, se produjeron en el país 652.495 toneladas de arroz en 143.500 ha, lo que equivale a un rendimiento aproximado de 4.547 kg/ha, De este total se exporta alrededor de 82.250 toneladas a Colombia (Aproscello, 1999).

En el país se produce arroz en los siguientes estados: Portuguesa, Guárico, Barinas, Cojedes, y el Delta Amacuro, de los cuales los 2 primeros aportan el 85 % de la producción nacional.

El arroz rojo es una maleza difícil de controlar debido a que posee iguales mecanismos de detoxificación de los herbicidas selectivos al cultivo de arroz.

Se han encontrado 3 especies interviniendo en el complejo de malezas arroz rojo en los estados venezolanos, Portuguesa, Guárico, Barinas y Cojedes, las cuales se pueden identificar como: *Oryza sativa* L., *Oryza rufipogon* Griff., dentro del arrozal y *Oryza latifolia* Desv., en áreas adyacentes a las melgas (canales o muros) (Peña, 1999).

## INCIDENCIA DE ARROZ ROJO EN VENEZUELA

Se cree que el arroz llegó a Venezuela con la semilla proveniente de Estados Unidos en el año 1948 cuando comenzó la siembra comercial de arroz en Portuguesa y posteriormente en Calabozo (Guárico) (Lanz (1979).

El gobierno venezolano contrató a Efferson y Walker (1953) para elaborar un diagnostico de las causas de la baja producción del cultivo del arroz. En el informe presentado, estos consideraron al arroz rojo como la limitante más seria para la producción de arroz de alta calidad. También describieron varios tipos de arroz rojo, siendo los de cáscara pajiza (claro) y negra los de mayor incidencia en las zonas de producción de arroz.

El batido (fangueo) del suelo se hizo una práctica rutinaria para el control de arroz rojo en Calabozo debido a que el 60 % de las parcelas del sistema de riego Río Guárico (Calabozo) en el año 1968, se encontraban invadidas por arroz rojo (Castillo 1990).

Ohep (1988) reportó al arroz rojo como una maleza importante en las siembras de arroz de riego y secano en Venezuela.

Más recientemente, Martinez (1998), realizó un diagnóstico sobre la situación del cultivo del arroz en Venezuela, en el cual describe que el arroz rojo ocupa el tercer lugar de las malezas de importancia económica después de ***Echinochloa colona*** e ***Ischaemun rugosum..*** También clasificó a los estados productores de arroz según la incidencia de esta maleza en: Portuguesa (baja a media); Guárico (baja); Barinas (alta incidencia) y Cojedes (baja).

Ortiz y Budowski (1998) realizaron un muestreo sobre la incidencia de arroz rojo y otras malezas en el cultivo del arroz en la etapa de maduración del cultivo (período norte verano1996) en 4 estados productores de arroz en el país y encontraron que Barinas tuvo el mayor número de malezas (152 pl/$m^2$) que el resto de los estados evaluados, además, también este estado tuvo pocas plantas de arroz (142 pl/ha) comparada con la densidad de siembra utilizada (180 kg/ha), lo que podría indicar que el manejo de malezas fue deficiente. Así mismo, se encontró que el número de plantas de arroz rojo fue mayor en Cojedes y Guárico, con 18 y 17 pl/$m^2$, respectivamente, mientras que Barinas (13 pl/ha) y Portuguesa (11 pl/m2) mostraron menor población de arroz rojo. Sin embargo, al relacionar el número de plantas de arroz rojo en cada estado con la cantidad de malezas encontradas (Figura 2), se observó que Portuguesa (38 %), Guárico (33 %) y Cojedes (33 %) tuvieron mayor porcentaje de incidencia de arroz rojo que Barinas (9 %).

Las evaluaciones realizadas muestran que en Guárico el mayor porcentaje de arroz rojo se encuentra en Camaguán, Uverote y El Frío, mientras que en Portuguesa, Pimpinela, Payara y Turén resultan ser las más afectadas. En Cojedes la zona con mayor arroz rojo fue Cojedito y en Barinas, Punta Gorda.

**IMPACTO ECONÓMICO DEL ARROZ EN VENEZUELA**

El rendimiento promedio del arroz en el país esta por debajo de las 5 ton/ha, sin embargo el potencial de las variedades mejoradas es de aproximadamente 8 ton/ha, indicando esto que todavía existe una brecha de rendimiento que no se ha cubierto y que podría aumentarse aplicando un manejo agronómico adecuado y dentro de este el control de malezas es importante para lograr un retorno económico positivo del productor.

El gasto del control de malezas (incluyendo el batido del suelo) en el país se ha estimado en 147 $/ha lo que representa el 17,50 % de los costos totales directo de producción, Pulver (1999).

En el país no se han realizado investigaciones orientadas a cuantificar el detrimento económico ocasionado por el arroz rojo, sin embargo, los productores estiman que pierden entre 1 a 2 ton/ha cuando tienen una incidencia de esta maleza mayor del 30 %.

Sin embargo, se realizó un trabajo (por publicarse) para evaluar el impacto del arroz rojo sobre la calidad molinera de las variedades en Venezuela, encontrándose que los ecotipos Portuguesa 2 y Calabozo redujeron el rendimiento en molino (% de granos enteros) de las variedades de arroz (Figura 3).

De manera general se puede considerar que el arroz rojo produce 2 tipos de daños, el primero debido a la interferencia con el cultivo de arroz que ocasiona una reducción del rendimiento del paddy y el segundo deteriora la calidad molinera del arroz y por ende el valor comercial del producto final.

## MÉTODOS DE CONTROL DE ARROZ ROJO UTILIZADOS EN VENEZUELA

El manejo que se realiza en el país para el control de arroz rojo son los siguientes:

### Cultural

**Uso de semilla libre de arroz rojo**

El uso de semilla certificada es lo más recomendado para evitar la diseminación de arroz rojo en el país, sin embargo esta limitada por cuanto la oferta de semilla de esta categoría no abastece a la demanda de los productores por lo tanto se estima que un 48 % de la superficie sembrada en Portuguesa y 50 % de Guárico se siembra con semilla **no certificada**, Martinez (1998).

La principal fuente de contaminación con arroz rojo es la semilla utilizada, en el país la reglamentación oficial sobre la semilla certificada permite hasta 3 semillas de arroz por kilogramo de arroz. Los productores de semilla de arroz están conscientes de la necesidad de llevar esta clase de semilla a cero arroz rojo por kilogramo, pero aducen que tienen limitaciones con la utilización de áreas nuevas libres de esta maleza y también la continua hibridización del arroz rojo con las variedades de arroz en el país ha ocasionado el surgimiento de ecotipos denominados varietales que son muy difíciles de diferencial morfológicamente de los cultivares de arroz por lo cual no se detectan al realizar el roguing. Los actores del circuito de semilla de arroz han planteado que en el mediano plazo se pueda producir la clase certificada sin arroz rojo.

**Batido (fangueo) del suelo**

La preparación del suelo en la modalidad de batido fue la práctica recomendada en los años 60 para contrarestar la alta incidencia de arroz rojo en el país, y todavía sigue siendo una herramienta estratégica para el control de arroz rojo.

La mayoría de los productores en Guárico, Portuguesa y Cojedes baten el suelo, con excepción de Barinas cuyos productores alquilan maquinarias e implementos y realizan poco esta práctica.

Debido a la utilización del batido del suelo, el método de siembra que más se utiliza en el país es el voleo manual de la semilla pregerminada (Ortiz y Budowski 1998).

En Guárico, el batido del suelo se realiza con un tractor que lleva acoplado un implemento llamado yona (rastra pesada en "V"), que realiza un corte profundo al suelo inundado volteándolo e incorporando la soca y malezas para su descomposición, además dispersa la fracción de arcilla para disminuir la percolación del agua y evita la emergencia del arroz rojo, Martinez (1998).

En Portuguesa y Cojedes el batido del suelo se realiza en 3 modalidades:

- **Tractor con ruedas de caucho con rodillo batidor y alisador:** por lo general se realiza 2 pases

- **Tractor con cesta o ruedas de hierro con alisador:** las ruedas traseras del tractor se sustituyen por unas de hierro, el número de pases depende del tipo de suelo

- **Tractor con ruedas 3 aros:** las ruedas traseras del tractor se sustituyen por unas similares a las anteriores pero conformadas por 3 aros en paralelos. Conjuntamente se realiza el pase de rodillo batidor y de alisador, los cuales se acoplan al tractor en este mismo orden. Por lo general se realizan 2 o 3 pases, Martinez (1998).

**Trasplante:** como una opción para controlar el arroz rojo un productor empresario con una alta incidencia de arroz rojo en su finca en portuguesa (2000 ha de arroz) ha introducido la práctica de transplante con máquinas.

**Químico.** El uso de herbicidas para el control de arroz rojo en el arrozal esta restringido debido a que los gramínicidas utilizados en el país en su mayoría no controlan esta maleza, sin embargo, los productores que tienen en sus fincas problemas con arroz rojo utilizan diferentes métodos de manejo, los cuales se pueden resumir de la manera siguiente:

**Quemas**

**Glifosato o Glyfosato trimesio**: previamente se prepara el suelo, bien sea con batido o en seco, y se aplica alguno de estos herbicidas cuando la malezas tienen aproximadamente 10 cm de altura. La dosis utilizada es de 2 a 3 l/ha. Se pueden realizar varias quemas en un mismo ciclo de producción, con la intención de reducir el banco de semilla de arroz rojo en el suelo, pero es costoso. Estos herbicidas son los más utilizados por los productores para realizar las quemas en el país

**Paraquat**: este herbicida se aplica de manera similar al caso anterior y las dosis recomendadas son de 1,5 a 3 l/ha .

**Herbicidas presiembra incorporado, preemergentes, postemergentes o en lámina**

**Pretilacloro**: Este herbicida preemergente se recomienda en mezcla con Glifosato. Se prepara el suelo con batido o en seco (rastra pesada), se riega las melgas, cuando la maleza alcance los 10 cm de altura se aplica la mezcla a razón de 5 l/ha + Glifosato 2 l/ha, se realiza un moje complementario. Luego se puede realizar una segunda quema con Glifosato o Paraquat y finalmente se siembra con semilla certificada pregerminada transcurrido un mínimo de 10 días después de la primera quema.

**Oxifluorfen :** Se prepara y nivela muy bien el suelo, se deja una lámina de agua y se drena para permitir la germinación del arroz rojo, cuando la maleza tenga 10 cm de altura se inundan las melgas e inmediatamente se aplica el herbicida, mantener la lámina de agua por 5 días sembrar la semilla seca o pre-germinada dependiendo de la preparación del suelo, Rohm Haas (1998).

**Molinate: Presiembra incorporado (PSI)**: en suelo preparado en seco o batido con óptima humedad. La dosis recomendada es de 5-6 l/ha y posteriormente se siembra semilla pregerminada. **Pre-emergente:** este herbicida también puede ser utilizado en forma preemergente mezclado con Glifosato cuando la maleza tenga 10 cm de altura y luego se siembra semilla pregerminada. **Lámina de agua:** una vez realizado el batido se deja estabilizar una pequeña lámina de agua que cubra todo el lote, posteriormente se realiza una aspersión de 5-6 l/ha de molinate con avión, al consumirse el agua (de 3 a 5 días) se realiza la siembra con semilla pregerminada, Peraza (1995).

**Oxadiazon**: para el control de arroz rojo se recomienda la aplicación en lámina de agua, se prepara el terreno y se induce la emergencia del arroz rojo, cuando esta alcancen 10 cm de altura se introduce una lámina de agua que sobrepase las plantas de malezas y se impide el movimiento de agua entre los planos, se aplica el herbicida y se deja consumir el agua durante 6 a 8 días, se drena el suelo y posteriormente se siembra semilla pregerminada, (Rhône- Poulenc 1998).

**Regulador de crecimiento:** Actualmente se está estudiando la factibilidad del uso de la Hidracida Maleica (FAZOR) para reducir la viabilidad de la semilla de arroz rojo con pruebas semicomerciales en fincas de productores interesados en cambiar el sistema de preparación del suelo (Portuguesa), donde se ha planteado la necesidad de cambiar el batido por la labranza reducida debido a la presencia del síndrome de la raíz negra y superficial en el cultivo del arroz.

Para usar la Hidracida maleica es necesario que exista una diferencia al menos de 7 días entre el arroz rojo y la variedad de arroz, es decir que el cultivar sea precoz y la maleza tardía (Brandi y Clari 1997).

**Uso de variedades resistentes a herbicidas**

En el país todavía no existe el marco legal para el uso de organismos modificados genéticamente, pero ya se vislumbra que en un futuro se puedan comercializar estos cultivares. Sin embargo, la resistencia a herbicida obtenida por mejorameinto tradicional (Ej. Clearfield, resistencia al imazapir) puede tener lugar a mediano plazo.

De cualquier modo la resistencia a los herbicidas no es la panacea del control de arroz rojo, sino más bien es una estrategia dentro del manejo de malezaa.

## INVESTIGACIONES REALIZADA EN VENEZUELA SOBRE ARROZ ROJO

El arroz rojo en el país como problema se podría decir que tiene el mismo tiempo que la siembra comercial de arroz. Sin embargo, desde que fue definido como tal por Jefferson y Walker (1953) y por otros autores en años posteriores, no se había estudiado la biología de esta maleza.

La investigación realizada en arroz rojo ha contado con el apoyo de la Universidad Central de Venezuela (UCV) y la Fundación del Servicio para el Agricultor (FUSAGRI), así como el financiamiento del Consejo de Desarrollo Científico y Humanístico (CDCH), Consejo Nacional de Ciencia y Tecnología (CONICIT), Fundacite Aragua, Asociación de Productores de Semilla Certificada de Los Llanos Occidentales (APROSCELLO), AgrEvo-Venezuela y Uniroyal Chemical.

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# WEEDY RICE SITUATION IN VIETNAM

Duong Van Chin, Chu Van Hach,Nguyen Cong Thanh and Nguyen Thanh Tai

## SUMMARY

Rice is the most important crop in Vietnam. Transplanting rice is popular in the North whereas more than 90% of sown areas in the South Vietnam is direct seeding. There are four major types of direct seeding namely: (i) traditional wet seeding, (ii) dry seeding, (iii) zero - tillage seeding and (iv) water seeding. Weedy rice infestation is highest under dry seeding followed by wet seeding and zero - tillage seeding. The highest severity is observed in summer – autumn. The typical characteristics of weedy rice as compared with popular modern rice varieties in Vietnam are shorter duration, taller plants, weak culm, smaller seeds, easy shattering and red pericarp. The average yield loss due to weedy rice ranges from 15% to 17%. The quality of milled rice is reduced due to the contamination with red pericarps from weedy rice. Some feasible methods of weedy rice control in Vietnam are: using clean seeds, good land preparation and water management, sowing in lines, seedling broadcast, and rotation with upland crops. Some herbicides which show positive results on weedy rice control are thiobencarb, molinate, oxadiazon and oxadiargyl.

## RESUMEN

El arroz es el cultivo más importante en Vietnam. El arroz trasplantado es la modalidad más popular en el norte del país mientras que el 90% del cultivo en el sur es de siembra directa. Hay cuatro formas de siembra directa: (i) siembra húmeda tradicional, (ii) siembra en seco, (iii) cero labranza y siembra y (iv) siembra en agua. La infestación del arroz salvaje o maleza es altísima en condiciones de siembra en seco, le siguen por este orden la siembra húmeda y la mínima labranza. Los mayores efectos se observan en el verano- otoño comparado con otras estaciones del año. Las características del arroz maleza son: corto ciclo de vida, plantas más altas, tallos débiles, pequeñas semillas, fácil desgranado y pericarpio rojo. El promedio de pérdida de rendimiento a causa del arroz maleza es entre 15 y 17%. La calidad del arroz molinado se reduce debido a la contaminación con pericarpios rojos del arroz maleza. Algunos métodos factibles de control de esta maleza en Vietnam son: el uso de semillas limpias, buena preparación del suelo y manejo del agua, siembra en líneas, siembra de plántulas al voleo y rotación con cultivos de secano. Algunos herbicidas han mostrado resultados positivos en el control del arroz maleza como: thiobencarb,molinate,oxadiazon y oxadiargyl.

## INTRODUCTION

Rice is the most important crop in Vietnam. The annual sown areas of 1997 are 7.09 millions ha with the production of 27.65 millions tons. In the North of the country, there are only two crops of rice namely spring and summer - autumn seasons. The temperature there is too low in winter for planting rice. In the South, double rice cropping system is popular but triple cropping area has been increasing. These rice-cropping seasons are winter - spring, spring - summer and summer - autumn. Along the bank of Mekong river, in some pocket areas, four crops of rice have been practised with two transplanting and two broadcastings using 90 - day short duration varieties. Transplanting rice is popular in the North whereas more than 90% of sown area in the South is direct seeding. There are four major types of direct seeding: (i) traditional wet seeding: pre - germinated seeds are sown onto well puddled soil without excess water, (ii) dry seeding: dry seeds are sown, incorporated under soil surface and wait for rain, (iii) zero - tillage seeding: rice straws of previous crop are scattered throughout the field, dried for few days and burnt, pre - germinated seeds are sown on wet ash layer, (iv) water seeding: flood recedes, weeds are removed by hands and nets, pre - germinated seeds are sown onto water at the depth about 10 - 40 cm. Weedy rice infestation is lowest in transplanted rice. The severe infestation of this special weed has been observed in dry seeding followed by wet seeding and zero - tillage seeding. Summer - autumn rice is strongly affected by weedy rice as compared to other cropping seasons in a year. Weedy rice is dangerous because there are very few selective herbicides, which can control it properly. Their seeds accumulated in the soil seed bank and infest rice fields from time to time.

**ORIGIN OF WEEDY RICE**

There is no scientist working on this subject to find out the origin of weedy rice in Vietnam so far. Wild rices infested floating rice fields more than 20 years ago when the area under this rice is approximately 0.5 million ha in the Mekong Delta. The remaining area now is only about 30,000 ha. Wild rice species have been collected to preserve the gene pool biodiversity for rice. The major ones are : *Oryza glanulata, O. officinalis, O. rufipogon*. The species *O. nivara* existed in the Mekong Delta before but now it is under extinction in the region. In 1995, for the first time, a group of Vietnamese and IRRI scientists found out *O. nivara* in upland area of Ho Lac, North Vietnam. *O. nivara* is an annual species and has the same AA genome with cultivated rice. *O. rufipogon* exists from the North to South Vietnam. It has both annual and perennial types with plenty of accessions and possesses the same genome AA with cultivated rice. The cultivated rice (*O. sativa*) hybridized with *O. rufipogon* or *O. nivara* then the hybrids backcross in either direction and produce integrates. These are known as *O. sativa f. spontanea* types. They invade the cultivated fields and pose problem as weeds. (Buu, 1998)

**FARMERS' PERCEPTION ON WEEDY RICE**

Two important surveys were conducted in Vietnam in the last few years. The first one is Regional Farmers/ Interview (R.F.I) with 4397 respondents in 128 districts of 18 provinces in the South of Vietnam. The second one is Provincial Farmers' Interview (P.F.I) with five hundreds farmers. Results from RFI revealed that 88.2% farmers practice rice monocrop. They use herbicides to control weeds (82.2%) but hand-weeding method continues to be popular (67.7%). A majority of farmers (80.7%) prepares the seed stock for themselves from rice products (67.8%). Farmers (63.8 %) said that they observed weedy existence in their fields. The most severe period is summer - autumn season. Weedy rice causes yield loss and reduces the quality of milled rice (79.8%). The average loss ranges from 15 - 17% and the highest one reaches 70%. The farmers recognized weedy rice by some characteristics such as: taller plants (90.6%), awned seeds (89.5%), easy shattering seeds (73.6%), dark colour husks (77.2%) and small seeds (76.8%). They rogue weedy rice plants during booting to flowering stages (80.6%) (PPD,1996).

The PFI was conducted on 500 farmers in summer - autumn season of 1996 in two provinces namely Binh Thuan and Long An. Most of farmers do dry seeding during this season (76.5%) followed by wet seeding (20%) and transplanting (3.5%). Weedy rice infestation is highest in this season as compared to other time in a year. Farmers said weedy rices evolve from cultivated rice (36.5%), emerge from soil seed bank (32.3%), and come from contaminated rice seeds (13.7%).

They recognized that dry seeding leads to more weedy rice infestation in rice fields (61%). Farmers' perceptions about some characteristics of weedy rice as compared to cultivated rice are taller plants (81.9%), weak culm (60.2 %), fewer tillers (58.5 %) and easy shattering (78.3%). Yield loss due to weedy rice in dry - seeded rice was 22.5% and 13.8% in Long An and Binh Thuan, respectively (Chin, 1997).

## BIOLOGY AND ECOLOGY OF WEEDY RICE

One hundred weedy rice lines in Binh Thuan province were measured directly in the fields during summer - autumn season of 1996. There are 34.3 weedy rice plants/$m^2$ and 252.2 plants of cultivated rice /$m^2$. The corresponding tillers are 86.9 tillers/$m^2$ and 519.6 tillers/$m^2$ respectively. Some characteristics of weedy rice, which have higher magnitude than cultivated rice, are taller plants (112.5cm/74.3cm), longer flag leaves (30.8cm/21.9cm), longer panicles (20.1cm/17.2cm), and higher number of grains per panicle (53.1/34.4). Normally, cultivated rice has no awn whereas the average awn length of weedy rice lines is 2.57 cm (Binh, 1997).

Ten typical lines of weedy rices have been studied experimentally in detail at the CLRRI since 1995 as compared to two varieties of cultivated rice namely IR 64 and OMCS 94. Their names are: BT 20 -1, BT 41 - 2, LATA 10, LATA 14, LATA 16, LATA 18, LATA 20, LATA 23, LATT 11 and HCM BC 3. The average measurement of characteristics was recorded. They are: growth duration (97.1 days), plant height (99.6 cm), percentage of shattered seeds (25.7%), panicle length (21.6cm), number of tillers/plant (5.6), number of seeds/ panicle (46.4) and 1000- grain weight (20.8 g). The corresponding data of cultivated rice var. IR 64 are 101 days; 93.8 cm; 0.0%; 22.6 cm; 4.1; 67.8 and 25.2 g. (Table 1). The lines having high percentage of shattered seeds are LATT 11 (77.9%), LATA 10 (59.6%), LATA 14 (55.7%) and HCM BC 3 (45.3%). There are 4 awnless lines in 10 lines studied. The average awn length of 6 awned lines is 3 cm. The colour of husks ranges from straw yellow, dark yellow to black. All have red pericarps. Five lines out of 10 are continued to study recently. The results are presented in table 2 .The dormancy period of weedy rice is about 50 days after harvest. A study done recently shows that the dormancy is little latter .The germination percentage reaches 93-98.3 % at 65 days after harvest (DAH) whereas at 50 DAH the corresponding data range only 69 to 91.3 % (Table 3). Both weedy rice and cultivated rice seeds lose their seed viability faster in case of moist soil condition as compared to submerged one. The percentage of viable seeds of weedy rice after 4 - month burying is higher than that of cultivated rice in both moist and submerged conditions. The lines having high percentage of viable seeds under moist soil are LATT 11 (51.3%), LATA 10 (63%) and LATA 23 (78%). The corresponding data in submerged soil are 76%, 43.3% and 55.7% (Table 4).

## DAMAGE CAUSED BY WEEDY RICE

Most of weedy rice lines in Vietnam have red pericarp therefore they caused the reduction in quality of milled rice for domestic consumption and export.

Rice seeds contaminated with weedy rice seeds will spread the infestation in rice fields through high seed rate of direct seeding. Normally, farmers use 200 to 250 kg rice seeds per ha (Luat *et al*., 1998). Majority of them (81.3%) prepares seed stock by themselves and 18.7% of them exchanges rice seeds with neighbours or buys certified seeds from companies. Results from analysis of 351 samples in 18 provinces of the South Vietnam showed that the number of weedy rice seeds per kg of rice seeds is as high as 314 seeds/ kg. Vinh Long province has the highest number with 500 seeds/kg (Mai *et al*., 1998). The experiments studied on the competition between weedy rice and cultivated rice were conducted in Tien Giang and Cantho provinces during winter - spring season of 1997 - 1998. Results revealed that the number of tillers of weedy rice produced in the fields is not correspondent with seeds sown. Under treatments of 10 seeds/$m^2$, the number of tillers is only 14 and 10.3 tillers/$m^2$ in both locations. The corresponding data for the treatment of 1000 seeds/$m^2$ are 487 tillers/$m^2$ and 422.8 tillers/$m^2$ respectively. Yields of cultivated rice start to reduce at the average level of 12.2 tillers/$m^2$ . The competition of weedy rice from 1 to 5 tillers/$m^2$ is not strong enough to cause yield reduction. Under the average level of 454.9 tillers/$m^2$ or 552.2 grams/$m^2$ of weedy rice, yields of cultivated rice are only equal to one sixth of those in weedy rice free check (Table 5)

**CONTROL MEASURES**

- Farmers have the tradition of removing weedy rice plants during cropping season. A proportion of farmers (23.2%) practices it during vegetative stage but majority of them (80.6%) does the work at booting to flowering stages. This activity minimizes the contamination of weedy rice seeds into rice seeds and reduces dropped seeds onto soil seed bank. However this method is only partly effective.
- The level of contamination by weedy rice is extremely high (314 seeds/kg rice seeds) in the country .One national program for production of large amount of certified seeds to satisfy the demand of farmers will be needed urgently in the future.
- Water management is very important for weed and weedy rice suppression. Water at the depth of more than 5cm can suppress the germination and emergence of grasses including weedy rice. Adoption of water seeding in acid sulphate soil area during winter - spring season leads to low infestation of weedy rice.

In Ca Mau peninsular, traditionally, farmers practice dry seeding in summer - autumn season. Recently some of them have shifted to water seeding by keeping rain water in the field at the beginning of monsoon season to the depth of 10 - 15 cm and puddled the soil before broadcasting. The other method namely modified water seeding has been introduced .In this method, pre-germinated seeds are sown onto well-puddled soil without excess water but the field will be watered as soon as possible after sowing. The introduction of water at 4 days after sowing (DAS) results in less weed infestation than that of 12 DAS (Hach ET al., 1998).

- Farmers in the Mekong delta have adopted the method of sowing in lines by modified IRRI seeder gradually. The application of this method can save above 100 kg of rice seeds and minimize the damage due to insects, diseases, rats and lodging. Weedy rice and volunteer rice plants grown between two rows of cultivated rice can be differentiated easily by farmers to remove during vegetative stage (Luat *et al* . 1998). This work could not be done before in randomly broadcasting rice. Weedy rice plants grown in the same lines with cultivated rice face strong competition and produce limited number of seeds. Moreover farmers can remove these plants at flowering stage. Fishes and shrimps raised in rice fields sown in lines grow better with more spaces to live as compared to that of randomly broadcast wet seeding (Quan, 1999). Companies in the Mekong Delta to meet the demand of farmers manufactured seven hundreds and eight seeders. In Song Hau, the most prestigious state farm of the country, sown areas under row seeding have been increased tremendously from 5 ha in Winter - Spring season of 1997- 1998 to 2,300 ha in Summer - Autumn season of 1999. Rice yields increase from 0.5 to 1 ton/ha particularly in summer - autumn season (Quan, 1999).

- The method of seedling broadcasting was introduced into Vietnam from China recently. Pre-germinated seeds are sown on mud and put in holes of 2-cm diameter of plastic plates. The 12 - to 15- day old seedlings are broadcasted by hand in fields submerged by water at 5 - 7 cm depth. This layer of water suppresses weeds and weedy rice at the beginning of crop establishment .The method is adopted by farmers faster in the North than to the South of Vietnam.

- The stale seed bed preparation by rotovation many times before sowing is not effective because the situation of too dry or too wet is not suitable for the emergence of weedy rice. Growing an upland crop in rotation with rice is good method to check the menace. Suitable moisture in the soil for upland crop encourages weedy rice seeds to germinate, emerge and be killed by herbicides used for upland crops or by other weeding methods. Farmers, who introduced mungbean cropping in the dry season, found that weedy rice decreased a few years after serious infestation. They found that many weedy rice plants had emerged and died due to insufficient soil moisture during the mungbean season. (Watanabe. 1998).

- There are very few selective herbicides, which can be used to control weedy rice. In weedy rice population, varietal variation is very high and they response to herbicides differently. Thiobencarb, oxadiazon, oxadiargyl molinate are four herbicides which are already registered for use in rice in Vietnam. Application of thiobencarb @ 300 g a.i./ha within 3 - 5 days after drainage and before reintroduction of water results in good weedy rice control (Sadohara *et al*., 1998).Thiobencarb @ 2,100 g a.i./ha and oxadiazon @ 240 g a.i./ha applied 6 days after rice seeding controlled weedy rice with slight rice injury under drain conditions ( Pyon et al.,1998) .Moline @ 4,500 g a.m./ha incorporated into the soil right before sowing gave satisfactory control of weedy rice in wet seeded rice ( Armies et al., 1998) .Experimental results at CLRRI showed that oxadiazon @ 250 g a.i./ha, oxadiargyl @ 72 and 100 g a.i./ha caused significant reduction in dry matter accumulation by weedy rice plants .Rice yields under treated plots are higher than those of untreated check significantly .

**ACKNOWLEDGEMENTS**
We wish to thank the Plant Protection Department (MARD) and the Vietnam National IPM Programme for support this research and helping us to attend the Global Workshop on Red Rice Control held in Cuba.

**Table 1:** Characteristics of weedy rice as compared to cultivated rice, CLRRI Summer - autumn season, 1997

| Varieties | Growth duration (day) | Plant height (cm) | Shattered seeds (%) | Panicle length (cm) | 1000 - grain weight (g) |
|---|---|---|---|---|---|
| - 10 weedy rice lines (Average) | 97.1 | 99.6 | 25.7 | 21.6 | 20.8 |
| - OMCS 94 | 97.0 | 87.3 | 0.0 | 21.7 | 25.0 |
| - IR 64 | 101.0 | 93.8 | 0.0 | 22.6 | 25.2 |

**Table 2:** Characteristics of 5 weedy rice lines as compared to cultivated rice var. IR 64. CLRRI. Winter - spring, 1998 - 1999.

| Varieties | Growth duration (day) | Plant height (cm) | Shattered date (DAF)(*) | Shattered seeds (%) | Pan. length (cm) | 1000 - grain weight (g) |
|---|---|---|---|---|---|---|
| 1. LATA 10 | 96 | 92.7ab(**) | 15 | 19.3 | 21.6b | 23.4c |
| 2. LATT 11 | 98 | 104.4abc | 14 | 94.3 | 21.2b | 21.1b |
| 3. LATA 18 | 92 | 116.5cd | 10 | 38.0 | 16.7a | 19.2a |
| 4. LATA 20 | 98 | 110.9bcd | 8 | 56.4 | 23.7b | 19.4a |
| 5. LATA 23 | 92 | 129.1d | 7 | 24.6 | 22.9b | 21.3b |
| 6. IR 64 | 99 | 85.5a | Not shattered | 0.0 | 24.0b | 23.8c |

Remark: (*) DAF = days after flowering

(**) Data in one column followed by the same letter are not different significantly by DMRT.

**Table 3:** Seed dormancy of weedy rice varieties as compared to cultivated rice var. IR 64. CLRRI. Winter - spring, 1998 - 1999.

| Varieties | Germination percentage (%) | | | | |
|---|---|---|---|---|---|
| | 5 DAH (*) | 35 DAH | 65 DAH | 95 DAH | 125 DAH |
| 1. LATA 10 | 8.7d(**) | 82.0b | 93.0a | 97.7b | 65.3b |
| 2. LATT 11 | 0.7a | 53.3a | 98.0b | 97.3b | 61.0b |
| 3. LATA 18 | 23.3e | 96.3d | 97.3b | 98.7b | 65.3b |
| 4. LATA 20 | 8.0cd | 85.7c | 94.7a | 92.7a | 56.0a |
| 5. LATA 23 | 3.7ab | 86.7c | 98.3b | 98.0b | 55.7a |
| 6. IR 64 | 5.3bc | 88.7c | 99.0b | 97.7b | 73.0c |

Remark: (*) DAH = days after harvest (**): Data in one column followed by the same letter are not different significantly by DMRT.

**Table 4:** Average of viable seed percentage after burying under two soil water regimes. CLRRI. Winter - spring, 1997 - 1998.

| Group of rice | After 1 month | After 2 months | After 3 months | After 4 months |
|---|---|---|---|---|
| A. Moist condition | | | | |
| Weedy rice | 69.7 | 48.9 | 35.1 | 27.4 |
| Cultivated rice | 59.5 | 31.5 | 27.4 | 27.2 |
| Average | 64.6 | 40.2 | 31.3 | 27.3 |
| B. Submerged condition | | | | |
| Weedy rice | 81.5 | 68.0 | 64.9 | 56.8 |
| Cultivated rice | 59.4 | 38.8 | 34.9 | 33.3 |
| Average | 70.5 | 53.4 | 49.0 | 45.1 |

**Table 5:** Dry weight of weedy rice at 56 DAS and yield of cultivated rice var. IR 64 under competition CLRRI. Winter - spring season, 1997 - 1998.

| Treatment (seeds/$m^2$) | Weedy rice dry weight (g/$m^2$) | | | Yield of cultivated rice (T/ha) | | |
|---|---|---|---|---|---|---|
| | Tien Giang | Can Tho | Average | Tien Giang | Can Tho | Average |
| 0 | 0.0 f(*) | 0.0e | 0.0 | 4.53a | 5.27a | 4.90 |
| 1 | 3.2e | 5.5d | 4.4 | 4.50a | 5.40a | 4.95 |
| 3 | 13.7d | 16.4c | 15.0 | 4.35ab | 5.23a | 4.79 |
| 10 | 29.4c | 23.4c | 26.4 | 4.05b | 4.80b | 4.43 |
| 100 | 91.8b | 97.6b | 94.7 | 2.75c | 3.36c | 3.06 |
| 1000 | 552.9a | 491.5a | 522.2 | 0.43d | 1.18d | 0.81 |

Remark: (*) Data in one column followed by the same letter are not different significantly by DMRT.

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# OTHER TECHNICAL REVIEWS

**PROBLEMS AND OPPORTUNITIES FOR MANAGING RED RICE IN LATIN AMERICA**

Albert J. Fischer

**SUMMARY**

Weed management in Latin American rice is strongly affected by agroecosystem diversity. We have discussed here management options in irrigated rice, where red rice is a serious problem. Relevant factors affecting red rice control in the field, are: (i) the type of land preparation (dry or puddled soil); (ii) the planting method used (transplant, using dry or pre-germinated seed, broadcast or drilled into rows, no-till); and (iii) the availability and control of irrigation water (rainfed, flooded or intermittently irrigated).

Red rice is a serious problem in LAC, especially in the tropics where fields must be drained after direct-seeding rice, and anaerobic conditions to prevent red rice germination cannot be maintained due to poor water control and inadequate soil levelling. Rice monocrop (two or more crops each year in tropical LAC) prevails, mainly due to market prices and poorly drained soils not allowing for rotational crops. Given the widespread use of red rice-contaminated seed, monocrop results in perpetual field reinfestation, and ever worse red rice problems. Fields are often abandoned when red rice infestations become unmanageable, particularly among farmers who work leased land and do not feel bound by long-term concerns. Therefore, in spite of sophisticated technologies to control red rice in the field, or its removal in the mills, the problem persists because reinfestations persist almost everywhere.

Direct seeded rice in LAC can involve seeding on a dry seedbed or on wet soil. After seeding, wet soils are drained, and flooding can only be resumed until rice seedlings are well established. During this period without flooding, red rice can germinate and establish. When rice is transplanted (as it is in Asia), and the flood water maintained, there are no opportunities for red rice establishment. Transplanting provides efficient red rice control. Competitive and submergence-tolerant rice cultivars should become relevant components for managing red rice in direct-seeded systems.

Red rice control relies heavily on herbicides, which under the current levels of reinfestation seem to provide an economic alternative. Use of economic thresholds (including long-term considerations) can assist in the choice of economically favourable practices for combining into integrated red rice management strategies.

Selective red rice control is difficult to implement in rice, and a weed for which preventive control in LAC is often hampered by socioeconomic constraints and agricultural policies. The introduction of herbicide-resistant rice cultivars could offer a breakthrough if spread of resistance into red rice populations, and weeds in general, can be controlled.

Red rice is difficult to eradicate, even with good field control, or when sophisticated devices are used to remove it from bulk seed. There is red rice in the US, in spite of all the technology developed in that country. A key element for success is clearly the integration of measures to prevent reinfestation with those for direct control in the field; emphasis on the former has been quite weak. Efforts to control red rice in the field are defeated by contaminated seed. Decisive action is needed, even at the policy level, to ensure the availability of red rice-free seed to farmers, and to

provide economic incentives for its use.  Red rice reinfestation and high herbicide use, will persist unless progress is made in this area, particularly where climate, soils and crop prices lead to continuous rice monocrop.


**RESUMEN**

Las opciones de manejo en arroz irrigado, donde el arroz rojo es un serio problema, son aquí discutidas, por ejemplo (i) el tipo de preparación del terreno (seco o enfangado); (ii) el método de plantación utilizado (trasplante, usando semilla seca o pre- germinada, a voleo o en hileras, sin laboreo); (iii) la disponibilidad y control del agua para riego (siembras de temporal, inundadas o irrigadas intermitentemente); (iv) los sistemas de tenencia de la tierra; y (v) la disponibilidad de semilla libre de arroz rojo.

El arroz rojo es un serio problema en América Latina, especialmente en los trópicos donde los campos deben ser drenados después de la siembra directa del arroz y las condiciones anaerobicas para prevenir la germinación del arroz rojo no pueden ser mantenidas debido a un pobre control del agua y nivelación inadecuada del terreno.

La siembra directa del arroz en América Latina puede ser mediante la siembra en suelo seco como húmedo. Después de la siembra, los suelos húmedos son drenados y la inundación puede ser terminada cuando las plántulas de arroz están bien establecidas. Durante el período sin inundación, el arroz rojo puede germinar y establecerse.

El control de arroz rojo se apoya fuertemente en el uso de herbicidas, los que parecen ser la mejor opción económica para el control de las reinfestaciones. El control selectivo del arroz rojo es difícil de implementar en el arroz. La introducción de cultivares resistentes a los herbicidas puede ofrecer la mejor salida si la diseminación de la resistencia a las poblaciones de arroz rojo, y a las malezas en general, puede ser controlada.

Un elemento clave para el éxito es claramente la integración de medidas para prevenir las reinfestaciones con aquellas que se desarrollan para el control directo de la maleza en el campo. De extraordinaria importancia es la disponibilidad de semillas puras para los agricultores; los esfuerzos para controlar el arroz rojo en el campo son sistemáticamente obstruidos por el uso de semillas contaminadas. Una acción decisiva se necesita, aun al nivel de políticas, para asegurar la disponibilidad de semillas de arroz libre de semillas de arroz rojo, así como garantizar incentivos económicos para su uso.


## INTRODUCTION

Red rice is a serious weed of direct-seeded irrigated and lowland rainfed rice  (Baker & Sonnier, 1983 González, 1985; Smith, 1991; Antigua, 1985).  In Brazil about 40% of the area planted to rice in Rio Grande do Sul is infested (De Souza, 1989).  Red rice is taxonomically classified as *Oryza sativa* L. like commercial rice (Craigmiles, 1978), and as many as seven *Oryza* species have been listed as weeds (Holm *et al.*, 1979).

There is considerable morphological diversity in red rice, and it can often mimic rice varieties in response to selection pressures resulting from commercial rice farming (Galli, 1992;  Montealegre & Vargas, 1992).  Differences in red rice competitiveness can be related to its morphological diversity (Fischer and Ramírez, 1993a). Hybridization with commercial rice (Smith, 1992; Galli, 1992) may be responsible for the morphological variability and crop mimicry of this weed.

The pigmented aleurone pericarp can be removed by intense milling, but this results in a high proportion of broken grains and lower head rice yields (Smith, 1991; Gonzalez 1985; Oliveira & Barros, 1986). Red rice is usually taller, leafier, and more tillered than rice, and thus very competitive with rice. Losses are also high in Latin America, where 60 red rice plants per m² lowered rice yields and productivity in southern Brazil, by 50% and 20%, respectively (De Souza, 1989). In Colombia, the early competition (first 40 days after rice emergence) of 24 plants per m², reduced yields by 50% (Fischer & Ramírez, 1993a). The value of yield losses due to red rice competition far outweighs the value of quality losses (Baker & Sonnier, 1983). Other weedy features, such as its short cycle, easy shattering before rice harvest, and prolonged dormancy, ensure field reinfestations, making its eradication very difficult.

## MANAGEMENT OPTIONS

The different red rice control strategies available in Latin America reflect the diversity of rice agroecosysytems and socio-economic conditions in the region, and should be seen as components for integrated red rice management programmes.

### *Preventive, Cultural, and Physical Control*

Preventing the flow of red rice seed can help contain the spreading of this weed into new areas, and to reduce field reinfestations. Chronic reinfestations have lead to herbicide abuse and high production costs. The most relevant measure is the use of red-rice-free seed (Smith, 1992). Most tropical countries allow for some red rice contamination in their certified rice seed. Five hundred grams of certified rice seed in Brazil may contain up to 15 red rice grains, ensuring continuous field reinfestations (De Souza, 1989). Farmers not always find the use of pure, certified, seed economical, therefore, they often interchange red rice contaminated seed, or keep their own seed from one year to the next. However, there are success cases: Uruguay exports about 80% of their rice, and high quality seed is the way to good prices (Posada, 1992). Today, through pure seed supply and legal control, this country is virtually free of red rice. Nevertheless, in most rice areas of Latin America it is increasingly difficult to find red rice-free fields where pure seed can be grown.

Machinery and equipment should be cleaned when moving out of infested fields (Smith, 1992; De Souza, 1989), and irrigation water coming from such fields should not be used. Also, commercial airplane seeding should not get closer than 200 m from fields intended for quality seed production.

Among cultural practices, tillage should be used to encourage the emergence of red rice seedlings for their elimination. However, tillage should be shallow not to store this long-dormancy-prone seed in the soil (G.Antigua, 1993, personal communication). In some cases delaying the first tillage after harvest leaves red rice seed exposed to temperature extremes, and to predation by birds and mice. In Southern Brazil, a successful practice has been developed (De Souza, 1989; EPAGRI, 1992), whereby an annual pasture (usually *Lolium multiflorum*) is established following rice harvest and grazed during winter, thus considerably preventing red rice establishment in the early spring. Shortly before planting rice, the *Lolium* sward is killed with a non-selective herbicide application, and rice is drilled into the sod using reduced or no-tillage.

Anoxia by flooding prevents red rice germination (Diarra *et al.*, 1985b). Therefore, puddling and transplanting into flooded fields has been a very successful practice, allowing to recover severely infested fields, where rice could no longer be grown. A thin film of water left over the soil after broadcasting pre-germinated seed, can maintain anaerobiosis in the top soil, preventing red rice establishment. Armenta and Coulombe (1993) achieved good red rice suppression when puddled fields were flooded for 20 days before seeding with pre-germinated seed. Casting rice seed through the water of flooded fields can prevent red rice establishment, and has been one of the reasons for success in temperate areas. Wet seeding and continuous or pinpoint flood is considered a necessity in many red rice-infested areas of the US such as Louisiana. Red rice has virtually disappeared from California where this system is combined with the use of red rice-free seed. To benefit from the anaerobiosis approach in the tropics, submergence-tolerant cultivars (Yamauchi, *et al.*, 1993), good land levelling and water control is required, unfortunately, this is not always the case among tropical rice farmers in Latin America.

Increased rice seeding rates, and the use of pre-germinated seed, have improved the ability of rice to compete with red rice (Sonnier, 1978). However, high seeding rates may result in lodging and higher pest incidence. Pre-germination, gives rice seedlings considerable growth advantage over red rice.

Eliminating red rice seeds in the milling process is difficult. Overmilling to remove the red pericarp increases costs and leads to head rice losses. However, some millers in southern Brazil utilize large numbers of electronic units with photosensors that detect the darker red rice seeds, removing them with an air jet from the bulk seed. The costly investment in such operation reflects the lack of success in preventing and controlling red rice infestations. Hybridization with commercial rice often results in progenies (F1) without coloured pericarp, which later can segregate into pigmented seed. Such seed would not be detectable by colour sensors.

Continued monocrop of irrigated rice will inevitably lead to red rice infestation (Smith, 1992). Rotation with other crops, besides modifying the habitat, allows for the use of herbicides that cannot be employed selectively in rice, such as alachlor and dinitroanilines (Griffin & Harger, 1990). Crop rotations can successfully reduce red rice infestations (Montealegre and Vargas, 1992; Marchezan, 1995), but lower market prices for alternative crops and soil drainage problems, usually discourage farmers from this practice (Galli, 1992).

Red rice usually becomes taller and distinguishable from broadcast-seeded rice in the field at about 30 to 40 days after emergence, only then can it be manually removed. Much of the competition damage to the crop has already occurred. Earlier differentiation in row-seeded rice allows for timely cultivation or hoeing (Smith, 1992). Reinfestations are somewhat prevented in Colombia (Cauca Valley) by hand pulling, or cutting with a machete, red rice panicles before they set seed. However, red rice seed shattering by earlier panicles (Marchezan, 1996), and new ones resulting from asynchronous tillering (Fischer & Ramírez, 1993), limit the usefulness of this practice. Armenta & Coulombe (1993) reduced a red rice infestation by 40% using a manual rotary hoe 23 days after seeding rice.

*Herbicide use*

The use of pre-plant incorporated (PPI) molinate has been an effective and widely known alternative (Smith, 1981 and 1992; Baker, J. *et al.*, 1986; Abud, 1986). Seed protectants can be used with dry-seeded rice to prevent injury by molinate (Smith, 1992). When seed protectants oxabetrinil and flurazole were used with PPI molinate, good and selective control of red rice was obtained (Garcia & Fischer, 1993, unpublished). Kwon (1989) obtained 86-94% red rice control with molinate PPI followed by fenoxaprop or sethoxydim at panicle initiation of rice; fenoxaprop injured rice slightly. Best result were obtained by maintaining the floodwater, or keeping the soil moist by frequent irrigation, for several weeks after seeding (Smith, 1992).

Red rice's morpho-physiological similarity with rice makes its selective removal with herbicides very difficult. The stale seedbed technique is one of the most widely adopted practices among irrigated (70% of the infested area in Colombia) and lowland rainfed rice farmers, whereby red rice is encouraged to germinate by tillage and/or flushes of irrigation during 12 or 15 days. Following, glyphosate, paraquat, or oxyfluorfen can be sprayed when red rice is between the seedling and tillering stage; thereafter, commercial rice is seeded (Montealegre & Vargas, 1992; Armenta & Coulombe, 1993; Abud, 1994).

The use of rope-wick applicators is becoming popular for treating discrete patches of infestation. Wicks soaked with a glyphosate solution "comb" red rice plants when they become taller than rice. However, much of the competition damage has already occurred when the herbicide is applied, but the method is useful to prevent field reinfestations by eliminating plants with immature panicles. This environmentally friendly principle has also been adapted in Cuba for hand rogueing (G.Antigua, 1993, personal communication).

*Germplasm*

Three different opportunities can be considered here: The use of more competitive rice cultivars; submergence tolerant rice, and the development of herbicide-resistant rice germplasm. Rice cultivars differ in their competitiveness with grasses. Late and tall cultivars tend to be more competitive against red rice than modern semidwarfs (Diarra *et al.*, 1985a; Kawano *et al.*, 1974; Smith, 1991). Morphological traits responsible for such competitiveness have been identified (Fischer & Ramírez, 1994 and 1995[1]; Fischer, *et al.* 1995 and 1997), and studies are under way at CIAT to understand the breeding implications for developing competitive rice plant types. This approach should provide a useful component for integrated red rice management. The existence of allelopathic rices genotypes (Lin *et al.*, 1993) and evidences of autoallelopathic effects (Ruschel & de Paula, 1994), suggest opportunities for research in this area.

Following reports by Yamauchi *et al.* (1993), extensive screening was conducted at CIAT to identify submergence-tolerant rice germplasm. Pre-germinated rice seeds were slightly buried in puddled soil, to prevent duck damage, and placed under 7 cm water, at temperature and redox potential similar to those in tropical paddies[2]. Thus, many lines with the ability of emerging under the anoxia of flooding water were identified for use in breeding programs.

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Genes for resistance to certain herbicides, such as glufosinate (Linscombe *et al.* 1994), glyphosate and imidazolinones have been introduced into rice through biotechnological techniques or conventional breeding, respectively. This allows for the selective control of red rice with herbicides that would otherwise kill rice. Germplasm with tolerance to alachlor has been identified for use in breeding programs to introduce herbicide resistance into commercial rice (Smith, 1992; G.Antigua, 1993, personal communication). Dilday *et al.* (1995) identified rice accessions from Colombia, Brazil, India and the US with tolerance to glyphosate and sulfosate. The success of herbicide-resistant rice cultivars depends heavily on: (i) the prevention and management of the eventual transfer of genes for herbicide resistance to red rice or wild rices through random natural crossing (Galli, 1992; Duke *et al.*, 1991; Darmency, 1995; Dyer, 1995); (ii) avoiding repeated use of a specific herbicide + herbicide-resistant cultivar combination, to prevent selection in favour of naturally-occurring herbicide-resistant red rice genotypes. Glufosinate-resistant biotypes have been found in natural red rice populations (Noldin *et al.*,1994). Similarly, repeated use of a given herbicide could develop resistance in weed populations other than red rice (Dyer, 1995).

Outcrossing, though rare, can transfer genes for herbicide resistance to red rice or to other *Oryza* species abundant in Latin America. It has been recommended, that the genetic engineering for herbicide-resistance in crops be accompanied by risk assessment and the introduction of genetic barriers for outcrossing (Duke *et al.*, 1991). Also, a weed management package should be developed to prevent the spread of weed resistance following the use of a herbicide-resistant cultivar. The herbicide for which resistance in a given crop is sought, should have small environmental impact and low potential for developing resistance in weed populations (Darmency, 1995). There are serious problems, against which the risks of introducing herbicide-resistant rice should be weighted. However, gene flow is a relevant issue, and it would seem that the successful implementation of this technique in the future will depend upon the implementation of acceptable genetic barriers to control gene flow or reduce the fitness of hybrid progenies (Gressel, 1999, personal communication).

*Integrated Management*

According to Smith (1992) a thorough red rice control program should combine the use of red rice-free seed, water and equipment, with crop rotation, physical removal, good water control, and herbicides. Integrating weed management is a complex task, where risk and cost-benefit analysis interact with market opportunities, feasibility, and farmers' perceptions; it is a decision process for selecting management alternatives to be combined in an integrated program. Farmers can be assisted in such choices if realistic decision rules are made available to them (Fischer & Ramírez, 1993b). Yield loss functions, derived from crop-weed competition studies, allow predicting yield losses due to red rice interference, and thus assisting field men in cost-benefit analysis regarding weed management integration. If a farmer knows the magnitude of the potential losses that would result from a given level of red rice infestation, he would then be in a better position to decide how much to spend in avoiding such losses.

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# WILD RICE IN SUB-SAHARAN AFRICA: ITS INCIDENCE AND SCOPE FOR IMPROVED MANAGEMENT.

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## SUMMARY

The main wild rice species in Africa South of Sahara are the annual *Oryza barthii* and perennial *O. longistaminata. O. glaberrima* y *O. punctata* are of local importance. The latter is cultivated in some parts of West Africa and only considered as a weed in crop areas of *O. sativa*, where occasionally it causes damage. Conducted research are reviewed and prevailing rice production systems in Ghana, Mali and Tanzania are described.

## RESUMEN

Las principales especies de arroz salvaje en el Africa al Sur del Sahara son las especie anual *Oryza barthii* y la perenne, *O.longistaminata*. *O. glaberrima* y *O. punctata* son de importancia local. Esta última es cultivada en algunas partes de Africa Occidental y solo considerada como maleza en campos de *O. sativa* que ella infesta ocasionalmente. Las investigaciones desarrolladas son reseñadas y se describen los sistemas de producción en Ghana, Mali y Tanzania.

## WILD RICE SPECIES AND THEIR DISTRIBUTION

Annual and perennial wild rice (*Oryza*) species are important and often difficult to control weeds of the irrigated and flood plain ecologies of West and East Africa. They are of similar appearance to cultivated rice in the vegetative stage and compete vigorously with the crop. Infestations are a major constraint to the sustainable intensification of lowland rice production. In Africa, three species of wild rice pose problems to rice cultivation, *Oryza barthii* A. Chev., *O. longistaminata* A. Chev. & Roehr and *O. punctata* Kotschy ex Steudel (Holm *et al*. 1997). The two former species are of particular importance and are widely distributed, from Swaziland to Ethiopia and Senegal, are closely related and often found in the same habitat (Vaughan, 1994). The species have vigorous growth and readily shed grains prior to harvest. The rhizomes and perennial habit of *O. longistaminata* enables the species to survive bush fire, shallow cultivation and prolonged dry seasons. *O. barthii* is an annual weed which can become a major problem particularly in direct seeded rice, and it is easily distributed in contaminated rice seed (Johnson, 1997). The species has a similar distribution to *O. longistaminata* and has been recorded in Burkina Faso, Cote d'Ivoire, Gambia, Guinea, Mali, Liberia, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Tanzania, Uganda, Zambia and Zimbabwe (Clayton, 1970; Fernandes *et al.*, 1971; Hepper, 1972). *O. punctata,* also distinguished from *O. longistaminata* by the absence of rhizomes, is known from Angola, Cote d'Ivoire, Ghana, Kenya, Madagascar, Nigeria, Sudan, Swaziland, Tanzania, Uganda, Zanzibar (Clayton, 1970; Fernandes et al., 1971; Hepper, 1972). Weedy, shattering forms of *O. sativa* "red rice" with a red pericarp or occasionally with black seeds have on rare occasions been introduced with planting seed into Africa, as occurred in Swaziland (Parker and Dean, 1976). The uncertain genesis and identity of wild rices, the extent of gene introgression with crop cultivars and the degree of morphological and genetic variation further complicate the development of management strategies for these weeds.

## RICE PRODUCTION SYSTEMS AND WILD RICE PROBLEMS

Rice has been grown in Africa for the past 3,500 years, and the endemic *Oryza glaberrima* Steudel has now largely been replaced by *Oryza sativa* L. introduced from Asia (Grist, 1965). Changes in the food preferences of West African consumers have resulted in an imbalance between regional rice supplies and demand, which has led to the increased importation of rice and the expenditure of scarce foreign exchange. Demand for rice in West Africa grew at an annual rate of 6% between 1973-92, imports of rice grew at an annual rate of 8.4 %, and in the early 1990s averaged 2.6 million tons. Rice production in West Africa has grown by 8.5% annually between 1983 to 1992, as a result of expanding area and small (1.9% per year) increases in yield. Rice production in West Africa accounts for approximately 60% of production in sub-Saharan Africa (WARDA, 1996).

Lowland production, including mangrove and deep water systems, covers about 60% of the total rice area in West Africa and these systems comprise with differing levels of land development, from no control of water to where rainfall can be retained or irrigation water supplied to flood the rice crop. Irrigated production systems, with one or two crops per year, are found in all agro-ecological zones from the Sahel to the humid forest zone. In most West African countries yields average 4-5 t ha, but individual farmers in the Sahel achieve yields very clsoe to the biological yield potential of up to 10 t/ha in a single season (Dingkuhn & Sow, 1997). Less land development occurs in the rainfed lowland systems, which extend to about 1.1 million hectares. Rainfed lowland fields are located in the savanna floodplains and the Sahel zones, and the bottoms of inland valleys in the savanna and forest environments. The inland valley systems are widely considered to have the greatest potential for area expansion, due to high natural fertility and resilient soil structure.

In smallholder systems, cultivation varies from minimal tillage in extensive systems to repeated deep cultivation remove troublesome perennial weeds such as *O.–longistaminata*. Cultivation to remove such perennial weeds requires careful timing as the soil should be moist enough to allow cultivation, yet the roots and rhizomes must be allowed to dry between cultivations if control is to be effective. The similarity to domestic rice makes the wild rices, including the perennial *O. longistaminata* and the annual *O. barthii*, particularly difficult to control.

In northern Ghana, *O. barthii* and *O. longistaminata* were identified as being problems in farmers' fields at a number of locations. Surveys in the Senegal River valley, of irrigated rice throughout the Sahel, and of rice producing areas of Cote d'Ivoire have identified both species to be a problem (Godderis, 1990; Diallo and Johnson, 1997; Marnotte, 1990). In Mali, populations of *O. longistaminata* have been reported to be more than 150 plants $m^{-2}$ at some on-farm sites in the Niger valley (Dembele *et al*, 1990). This species is also a dominant weed of deep water rice fields on the flood-plains of Sierra Leone causing farmers to abandon extensive areas previously used for rice cultivation (Riches, 1989).

There have been fewer reports of wild rice as a problem in other regions of Africa. In Tanzania, weeds were reported as the main problem in rainfed rice, and annual and perennial wild rices were, the cause of very low yields on large scale farms (Kanyeka, 1994) and a major problem confronting small scale farmers (Matthews et al., 1994). Wild rices are the only known alternative hosts for African Rice Gall Midge (ARGM) and are important hosts for Rice Yellow Mottle Virus (RYMV). RYMV and ARGM are important pests of rice in Tanzania and a number of West African countries including Nigeria, Burkina Faso, Mali, Sierra Leone and Ghana.

**USES OF WILD RICE**

There are reports that seeds of *O. longistaminata* are collected from the soil surface, after shattering and once the annual flood has receded, in Mali and are sometimes used to supplement cultivated rice in the diet - a full day can be needed for one person to gather 2-3 kgs (Nyoka, 1983). Further, floodplains along the major rivers in West Africa, which are frequently infested by *O. longistaminata*, are used for cattle grazing during the dry season.

**CASE STUDIES**

East Africa - Tanzania

In the Eastern Zone, Kilosa District, the annual wild rice *O. punctata* infests rice production areas. This is an area where the flood is not controlled, which is similar to the rainfed systems in the inland valley rice in W. Africa. Some land is tractor ploughed prior to the rain, elsewhere it is prepared by hand hoe; fields are not levelled. Herbicides are not widely used and farmers rely on hand weeding. It is likely that in these areas *O. punctata* is spread on floodwater. *O. longistaminata* is found in deeply flooded areas or on uncultivated land.

In the Southern Highlands, the Kapunga estate comprises 3000ha of irrigable arable land. The estate is now in the 9th year of production and the area under rice has declined to only 570 ha this year because of infestation of much of the estate by *O. longistaminata*. This was present when the scheme was established but built up rapidly under the production system based on flood irrigation of dry, direct seeded rice. The situation has become so severe that most of the estate is now too heavily infested to allow rice production by direct seeding. Field operations in the direct seeded system, which is in the process of being abandoned, are as follows: burn crop and weed residue in September/October (dry season), disc plough, harrow, drill seed rice in November, irrigate and manage weeds with pre/post-emergence herbicides and maintenance of flood. This system, with applications of urea, originally yielded about 4.2 tons per ha but yields are now little more than 1 ton due to the wild rice. Fields have therefore been progressively abandoned.

Attempts were made to bring the wild rice under control with pre-plant applications of glyphosate. Land was dry ploughed and irrigated to stimulate wild rice shoot emergence before applying glyphosate ($15 US l), but doses of 3.6 kg a.i. ha have not resulted in good control. This is apparently due to uneven shoot emergence at the time of herbicide application, and dormancy of some rhizomes. The system which has evolved and which provides more effective control of the wild rice is based on wet seeding. Land is ploughed, irrigated and rotovated 3-4 days later. The fields are left under flood for about 2 weeks to allow the rhizome system of the wild rice to rot. Pre-germinated seed is broadcast by fertiliser spreader, or more evenly by hand, and water is drained to allow crop establishment and then the flood is restored. Herbicides are used as appropriate. This system resulted in good control of wild rice compared to where the old direct seeding system is still being used. But it may require several seasons to suppress established wild rice. Where canals are infested with *O. longistaminata*, the irrigation remains a continual source of reinfestation.

At Mabarali estate, initially there was 3,200 ha under cultivation, however due to increasing problems over the years with both *O. longistaminata* and *O. barthii*, the area under cultivation has declined expected to little more than 800 ha.. As at Kapunga, direct dry seeding was originally used but the wild rices became uncontrollable with this method and now only 100 ha is planted in this way. The canals are overgrown with wild rice and which are thus sources of re-infestation.

Transplanting is now being practised after the land is ploughed, flooded and rotovated. It has been reported that it is possible to control *O. longistaminata* by puddling and transplanting but *O. barthii* remains. It has also been noted that there are differences in the ability of cultivars to compete with *O.barthii* with short stature "Katrin" being overgrown by *O. barthii* while the tall "Kilombero" cultivar can suppress the wild rice.

West Africa, Ghana

Wild rices are a widespread problem in the Northern and Upper East Regions and there are marketing problems as a result of contamination with "red rice". There are reports of up to 20% contamination in rice seed with grain with a red pericarp (thought to be *O.glaberrima*). It was also reported that fields have been abandoned due to the perennial wild rice, *O. longistaminata.*

Approximately 38% of the rice grown in Ghana comes from the Northern region, compared to 24% for the Upper East and 1% for the Upper West regions. In the Northern region the majority of production comes from larger farms of up to 200 ha, mainly on rainfed lowlands. Land preparation and harvest is mechanised with tractors and combine harvesters. Contamination of rice with grain with red pericarp is a major problem. In Tamale market samples of par-boiled, hand milled rice contaminated with (c. 25%) grains with red pericarp sells for about 40% of the market price for uncontaminated rice.

In the Northern Region, rice is rain fed and is dry seeded after the land has been cultivated by tractor following burning of the fallow vegetation. Where these areas are low lying they may be heavily infested with *O. longistaminata.* In the Upper Eastern Region, irrigation schemes at Tono (2500 ha) and Vea (850 ha) have been established to assist small holder producers to intensify their production. Participating farmers are expected to contribute to the costs of supplying the tractor services and irrigation costs. Farmers receive between 0.2-0.6 ha of land. *O. longistaminata* had been a major problem on the project particularly in the early years of the scheme in the mid-1980s. A major effort had been undertaken in 1993 to control the weed based on repeated puddling using twin axle tractors and flooding, and replacing direct seeding of the crop by transplanting. Approximately 400 ha of wild rice infested land was recovered through this initiative and the problem is now largely confined to the drains and some areas of the irrigated areas. Farmers on the project recognise that areas infested with *O. longistaminata* are the more fertile and productive areas for rice production and they tend to favour these. This suggests that farmers viewed the weed as being a surmountable problem. After puddling the land, the rhizomes are removed from the mud by hand and piled along the bunds. After transplanting the rice, hand rouging was undertaken, again placing the *O. longistaminata* rhizomes on the bunds.

Mali

Large rice production areas extending for more than 50,000 ha are irrigated from the Niger river. The majority of the land area has been well levelled and there is generally a high level of crop management. Yields are on average between 3.4 and 4.8 t ha depending on the locations. Wild rices, and particularly *O.longistaminata* have been major problems and have forced farmers to change to transplanting instead of direct seeding. There remain however large areas, for example 900 ha in the Macina area, which have been abandoned due to *O. longistaminata.* Recent efforts to rehabilitate these, based on improved tillage and transplanting are proving successful.

## PAST RESEARCH ON THE MANAGEMENT OF WILD RICE.

Field trials in Mali have demonstrated rice grain losses in the order of 85% in fields heavily infested by *O. longistaminata*. (IER, 1989) while in Senegal populations of *O. barthii* have been found to cause yield loss of up to 97% (Davies, 1984). The build up of populations of both perennial and annual wild rice species can result in land being abandoned. There has however, been relatively little concerted research effort to develop sustainable management techniques, with the context of African rice production systems.

Much of the work on wild rice control that has been reported from West Africa has concerned the use of herbicides. Little attempt appears to have been made however to consider the resource implications for farmers of the adoption of herbicides for this purpose. Dalapon and glyphosate, applied to *O. longistaminata* on fallow land or pre-planting have both been shown to be effective treatments (Boeken, 1972; Aubin, *et al*.,1976; WARDA, 1979, Diallo, 1995). Glyphosate, applied 15 days prior to sowing of rice, also provides effective control of *O. barthii* (Davies, 1984).

There is some evidence of differences in the competitive ability of rice cultivars with wild rice and that long duration cultivars are more competitive than short duration materials (Diarra *et al*. 1985). Farmers in eastern India are said to favour purple leaf cultivars which can be distinguished from seedling wild rices, and hence facilitating hand weeding, although these are lower yielding that other cultivars. Improved cultivars which are adapted to infested situations have been developed by CRRI, Cuttack, in India, but as domestic and wild rices can cross-pollinate, it is possible that wild rice may also develop populations with purple stems and leaves (Malik and Moorthy, 1996).

A traditional control measure for *O. longistaminata*, practised in Mali, has been the rotational "under-water" mowing of plants on fallowed areas (Nyoka, 1983). This is said to provide adequate suppression of wild rice to allow production of a crop in the subsequent season, although the effects are only temporary and the technique is very labour intensive. As the rhizome system of *O. longistaminata* is relatively shallow, only shallow tillage is needed to sever this from adventitious roots which exploit moisture deeper in the profile and allow survival of the plant during the dry season. Repeated dry season cultivation can therefore, lead to the desiccation and death of the rhizome system. Timing, in relation to soil moisture can be critical. Although a single ploughing prior to flooding failed to control the weed in trials conducted by WARDA (1979), "undercutting" with a blade set shallow in the soil, was effective if carried out twice before planting. Tillage has also been shown to influence *O. barthii* populations (Davies, 1984). A stale seed bed technique using rotary cultivation was shown to be particularly effective, leading to reduced levels of infestation and increased rice yield in Senegal.

## CONSIDERATIONS FOR IMPROVED MANAGEMENT OF WEEDY RICES AND FUTURE RESEARCH NEEDS

The majority of farmers in sub-Saharan Africa have few resources and poor access to information and the extension services. The research that has been conducted on the management of weedy rices clearly shows that there are tremendous opportunities to improve control, but that techniques need to be adapted to farmers' circumstances.

Relatively little is known of the **biology** of the wild rices in terms of their life cycles, seedbed dynamics, conditions required for germination and the viability of seeds. Particularly in relation to the perennial species, detailed studies of the growth and physiology may shed light on the most effective points of intervention, particularly with regard to fallow management and dry season cultivation. There have been few systematic studies to determine the variability occurring within and across population at different locations, this would involve **taxonomic work** and studies of **phenotypes** in relation to growth and adaptation to the environment. Particularly in relation to the annual species, there is much to be learnt regarding the influence of crop and weed management on weed ecology and the succession of species over time. There is little information that has been adapted to the African environment on the **optimum herbicide regimes** in terms of timing, stages of growth and rates. Seed supplies are commonly contaminated with weed seeds, including weedy rices, which presents a major constraint to efforts to improved weed management**. Community based seed production systems**, if effectively developed would give farmers access to improved seed supplies and have a significant element of accountability built in to ensure that supplies are uncontaminated. The development of these structures requires participative research to ensure that effective structures can be established.

**Acknowledgement**
The Crop Protection Programme of the UK Department for International Development's Renewable Natural Resources Knowledge Strategy funded participation in the workshop by the senior author. DFID however can accept no responsibility for any information provided or views expressed.

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## RED RICE CONTROL IN RICE PRE- AND POST-PLANTING

A. Ferrero & F. Vidotto

### SUMMARY

Several experiments were carried out in Italy, from 1995-1998 to test red rice control methods in rice pre- and post-planting. Pre-planting experiments, carried out from 1997-1998, compared the efficacy of several antigerminative herbicides, in red rice pre-emergence. The mixture of dimethenamid + pretilachlor (1.25+ 0.64 kg a.i./ha) in flooded soil gave the best results and prevented red rice germination by about 90%. Experiments of red rice control to test post-emergence herbicide treatments were carried out from 1995-1997. It was also performed in combination with the stale seed bed technique in two experiments aimed at: 1) determining the effects of tillage for seed bed preparation and soil moisture on red rice germination; 2) comparing the efficacy of different post-emergence herbicides and mechanical interventions on weed seedlings. The results of experiment 1) showed that minimum tillage and good soil moisture conditions favoured red rice emergence, creating the best conditions for post-emergence control, while ploughing and flooding remarkably affected weed germination. The results of experiment 2) pointed out that the harrowing or shallow ploughing were significantly less effective than chemical treatment with dalapon to control red rice seedlings. This experiment also showed that cycloxydim (0.95 kg a.i./ha) and clethodim (0.28 kg a.i./ha) were as effective as dalapon, and showed the possibility of replacing this herbicide at much lower dosages.

Red rice control in post-planting treatments was studied in 1996-1998 in three experiments. The first one was to determine the acquisition of germinability and shattering ability after flowering of red rice seeds; the second was to assess the efficacy of panicle cutting of the weed while the third, to assess the efficacy of the localised application of glyphosate and cycloxydim on the weed panicle. The results of the experiment 1) showed that the weed seeds started to shatter and germinate 9 days from the flowering of red rice panicles. Experiments 2) and 3) pointed out that the double treatment with cutting equipment and the application of glyphosate (7.2 % a.i. concentration) and cycloxydim (4% a.i. concentration) affected the viability of red rice seeds by more than 90%.

### RESUMEN

Varios experimentos fueron llevados a cabo en Italia, durante el período de 1995-1998 a fin de ensayar métodos para el control del arroz rojo con tratamientos de pre- y pos- plantación.

Los experimentos de pre-plantación se desarrollaron entre 1997 y 1998, en los que se comparó la eficacia de varios herbicidas antigerminativos en fase pre-emergente del arroz rojo. La mezcla de dimethenamida + pretilachlor ( 1.25+ 0.64 kg i.a../ha) en suelo inundado dio los mejores resultados y evitó la germinación del arroz rojo en un 90%. Los experimentos de control en pos-emergencia del arroz rojo se llevaron a cabo en 1995-1997, en combinación con 2 experimentos para evaluar la técnica de control de pre-plantación, cuyo objetivo fuet: 1) determinar los efectos de la preparación del terreno y la humedad del suelo en la germinación del arroz rojo; 2) comparar la eficacia de diferentes herbicidas de pos-emergencia y de intervenciones mecánicas sobre las plántulas de la maleza. Los resultados del experimento 1) mostraron que un mínimo de laboreo del suelo y buenas condiciones de humedad en el suelo favorecen la emergencia del arroz rojo, creando las mejores

condiciones para un control de pos-emergencia, mientras que la aradura y la inundación afectan marcadamente la germinación de la maleza. Los resultados del experimento2) puntualizan que la labranza superificial y el pase de grada fueron significativamente menos efectivos que el tratamiento químico con dalapon para el control de las plántulas de arroz rojo. Este experimento también mostró que cycloxydim (0.95 kg i. a./ha) y clethodim (0.28 kg i. a./ha) fueron tan efectivos como dalapon, y mostraron la posibilidad de reemplazar a este herbicida con dosis de aplicación más bajas.

El control del arroz rojo en pos- plantación se estudió en 1996-1998 en 3 experimentos para: 1) determinar la adquisición de capacidad germinativa y de desgrane después de las semillas de arroz rojo; 2) evaluar la eficacia del corte de la panícula de la maleza; 3) evaluar la eficacia de la aplicación localizada de glifosato y cycloxydim sobre la panícula de la maleza. Los resultados del experimento 1) mostraron que las semillas de la maleza comienzan a desgranarse y germinar 9 días después de la floración de las panículas de la maleza. Los experimentos 2) y 3) puntualizaron que el doble tratamiento con corte mecánico y la aplicación de glifosato (7.2 % i.a. de concentración) y cycloxydim (4% i.a. de concentración) afectaron la viabilidad de las semillas de arroz rojo en más de un 90%.

**INTRODUCTION**

Red rice (*Oryza sativa* L. var. *sylvatica*) is a weedy byotipe of the cultivated rice (*Oryza sativa* L.), spread in many of the world growing areas (Parker & Dean,1976; Ferrero & Finassi, 1995). Known in Italy since the last century, and for some time considered as a pathologic strain of the crop (Jacometti, 1912) this weed shows a wide variability of anatomical, biological and physiological features (Kwon et al., 1992; Craigmiles, 1978). At seedling stage, red rice plants are difficult to distinguish from the crop (Hoaghland & Paul, 1978), while after the tillering the identification of the weed is possible thanks to many gross morphological differences in comparison with the rice varieties: more numerous, longer and more slender tillers, leaves which are often hispid on both surfaces, tall plants, pigmentation of several plant parts (in particular of the pericarp), easy seed dispersal after their formation in the panicle (Diarra *et al.,* 1985; Coppo & Sarasso, 1990; Kwon *et al.,* 1992). The break off of the seeds onto the soil before crop harvesting allows the weed to disseminate and feed the soil seedbank (Smith, 1981; Diarra *et al.,* 185a; Diarra *et al.,* 1985b). The spread of red rice became significant mainly after the shift from rice transplanting to direct seeding, and started to be very severe, particularly in European Countries over the last 15 years after the cultivation of weak, semidwarf indica-type rice varieties (Tarditi & Vercesi, 1993). At present, the spread is mainly related to the planting of commercial rice seeds containing grains of the weed.

The weed affects rice yield because of its high competitive capacity (Diarra et al., 1985a; Kwon et al., 1991a, 1991b; Pantone & Baker, 1991; Finassi et al., 1996). The red layer of the weed grains harvested with the crop have to be removed with an extra milling but this operation results in broken grains and grade reduction (Smith, 1981; Diarra et al, 1985a, 1985b).

The close similarity between red rice and the commercial varieties has prevented the application of herbicides that are able to selectively control the weed. The main weed control strategies that are applied by rice growers are those of the planting of clean seeds, chemical or mechanical control both in pre- and post-emergence of red rice in crop pre-planting (e.g. with the stale seed bed technique) or in crop post-planting (e.g. by cutting the panicle) and rotation (Parker and Dean, 1976; Tarditi and Vercesi, 1993; Català, 1995; Ferrero and Vidotto, 1998; Vidotto et al., 1998). In most cases, two or more of these strategies are combined. In some conditions, the weed pressure is so high that the only way to reduce red rice populations is to adopt rotation, although, this practice shows some constraints in particular environmental conditions such as in the presence of saline and hydromorphic soils (Sagarra, 1987; Català, 1995).

This paper describes the results of several studies carried out to evaluate the effectiveness of mechanical and chemical means to control red rice in pre- and post-planting of the crop.

**CONTROL IN PRE-PLANTING OF CROP**

Red rice pre-emergence

Red rice pre-emergence intervention normally represents the best management system of the weed, as it does not require any delay in rice planting or choice of early or short varieties, and relies mainly on the use of antigerminative herbicides. Pretilachlor is, at present, the only herbicide authorised in Italy, for this kind of application. The efficacy of the product varies considerably according to the soil characteristics and weather conditions and does not exceed, on average, 50% of the germinable seeds. The experiments carried out in Italy were mainly aimed at finding herbicides with a better activity than Pretilachlor. A two-year research, which started in 1997, compared the activity of Dimethenamide, a product already used in maize weed control and other experimental herbicides, and considered to be effective against red rice (Table 1). Treatments were carried out on soils flooded with 5-7 cm of water. Inlet and outlet floodgates were kept closed for 5 days after the treatments.

The mixture of Pretilachlor + Dimethenamid showed good and constant results (83-93% efficacy) while the effects of Dimethenamid alone varied more. Pretilachlor alone maintained the efficacy that is normally found in farm applications. Dithiopyr and Fluthiamide showed an efficacy of 53 and 41%, respectively. Visible early injuries to the crop were observed in Dithiopyr treatments. Phytotoxicity was no longer visible at the stem elongation stage of the crop.

In 1998, the greatest reduction of emergence at rice seeding time was recorded in plots treated with Pretilachlor + Dimethenamid (about 83% of efficacy in comparison to the untreated plots), while the other treatments showed levels of control that were always lower than 70%. Temporary phytotoxic effects on the crop were observed in the plots treated with Pretilachlor + Dimethenamid.

Red rice post-emergence

Red rice control in post-emergence of the weed is mainly performed in combination with the stale seed bed technique. This practice, commonly known in Italy as “false seeding”, is applicable only if weather conditions allow the weed to reach the 2-3 leaf stage in the first ten days of May, in order to be in a position to plant an early and still profitable variety.

Cultural practices are normally those of early seed bed preparation, followed by field irrigation to stimulate red rice germination, and weed control treatment. Destruction of red rice seedlings can be performed by the application of non residual systemic herbicides, 2 days before rice planting, or the use of blade or disk harrows. After control treatment the soil is regularly flooded and planted, in 2-3 days, with early varieties (e.g. Loto, Selenio, etc.). The most used herbicide in Italian conditions for this kind of application is Dalapon at 10-13 kg a.i ha-1.

Table 1. Red rice control in weed pre-emergence. Efficacy of herbicides applied in the 1997-1998 experiment

| Treament | Active ingredient | Dosage f.p.a | Dosage a.i.b | % red rice control |
|---|---|---|---|---|
| | | l ha-1 or kg ha-1 | kg ha-1 | |
| **1997** | | | | |
| Untreated | - | - | - | 0 |
| Rifit® | Pretilachlor | 3.0 | 1.5 | 85 |
| Frontier® | Dimethenamid | 1.2 | 0.96 | 93 |
| Rifit®+ Frontier® | Pretilachlor+ Dimethenamid | 2.5-0.8 | 1.25+0.64 | 90 |
| Dimension® | Dithiopyr | 2.0 | 0.24 | 53 |
| **1998** | | | | |
| Untreated | - | - | - | 0 |
| Rifit® | Pretilachlor | 3.0 | 1.5 | 52 |
| Frontier® | Dimethenamid | 1.2 | 0.96 | 25 |
| Rifit®+ Frontier® | Pretilachlor+ Dimethenamid | 2.5-0.8 | 1.25+0.64 | 83 |
| FOE 5043 | Fluthiamide | 0.7 | - | 46[FV1] |

af.p.: formulated product
ba.i.: active ingredient

The success of the stale seed bed practice is strictly related to the number of seedlings which are able to emerge from the seed bank prior to the treatment. It is very important for this reason to apply appropriate tillage operations and maintain soil humidity which can favour seed germination. The experiments carried out in these last years pointed out that, on average, the emergences recorded in harrowed and ploughed plots were about 7 and 2.5%, respectively of the number of seeds counted in the 0-10 cm layer (Figure 1).

The studies concerning the influence of water on red rice germination, showed that seeds placed in the upper soil layer (0-1 cm) germinated for 50% when the soil was continuously kept moist, and 18% when the soil was submerged under 2-3 cm of water. Both in moist and flooded soil there was an emergence reduction according to the increased depth of the seeds. Germination at 4-5 cm depth was only 8% in the moist soil and nil in the flooded soil.

The results of these studies pointed out that most favourable conditions for red rice emergence with the false seeding practice can be obtained adopting minimum tillage for seed bed preparation and maintaining the soil wet till control operations are performed.

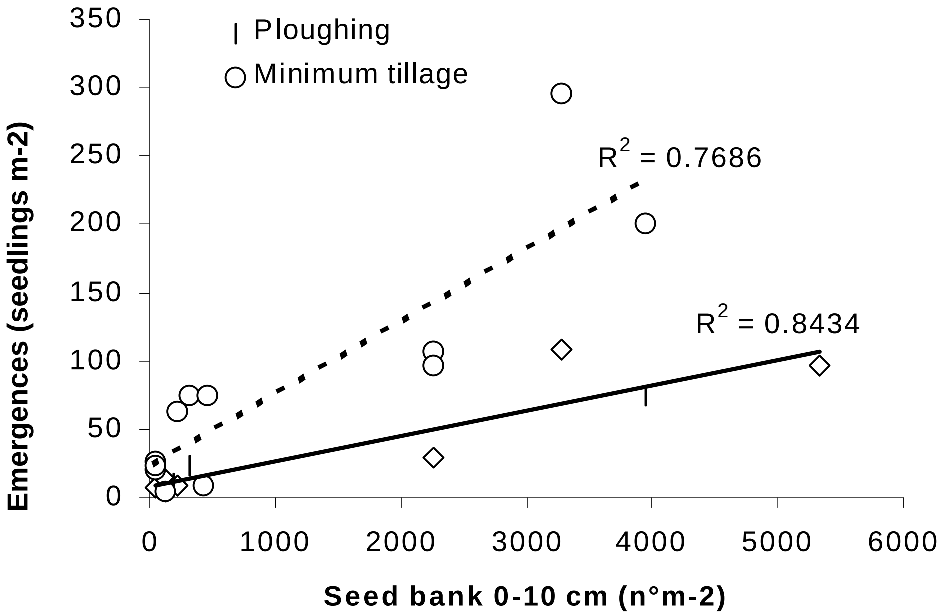



Figure 1. Red rice emergences from seed bank in relation to the soil tillage for seed bed preparation.

Several trials were conducted to assess the efficacy of mechanical means and herbicides, applicable at rates lower than that of dalapon, against red rice.

In an experiment carried out from 1995-1996, dalapon, applied at 12 kg a.i. ha-1; was compared to harrowing and shallow ploughing treatment. Harrowing was carried out with a machine with curved knives, as working elements. Shallow ploughing operations were performed using a mouldboard plough with seven elements adjusted to operate only at a depth of 6-8 cm. Red rice control was performed both years at the 2-3 leaf stage of the weed.
The efficacy of different treatments was assessed considering the red rice density, weed seed bank evolution, rice yield and the number of red rice grains in the harvested paddy.

The buried seeds were randomly sampled, in each plot, taking at least 6 soil 10 cm deep cores. The cores were split into three portions, corresponding to 0-1, 1-5 and 5-10 cm depths. The seeds were separated from the soil by using a device, constructed on purpose for seedbank determination, based on the use of water at high pressure to separate weed seeds from soil particles (Ferrero and Vidotto, 1997).

In the first year, dalapon treatment resulted in the best control of red rice seedlings (98%). Harrowing and shallow ploughing showed an effectiveness of 73 and 69%, respectively (Table 2). In 1996, dalapon was less effective than in the previous year (92%), and showed no significant differences from the mechanical treatments (91 and 86%, for harrowing and ploughing, respectively). This behaviour could be due to the anticipation of the herbicide treatment which did not permit successful control of the red rice, and allowed some seedlings to escape the herbicide action.

In 1995, the rice yield appeared to be clearly related to the degree of red rice control recorded in each plot. The highest yield (6.4 t ha-1) was obtained from the plots treated with dalapon. Shallow ploughing, harrowing and no-treatment resulted in a yield reduction of 14, 25 and 47%, respectively, in comparison to the chemical treatment. An analysis of the paddy, harvested in the different plots, showed a red rice seed content of 3.2% (w/w) for the shallow ploughing, 3% for harrowing, 1.45% for dalapon and 16.7% in the untreated plots.

The yields obtained in 1996 in the treated plots ranged from between 5.9 and 6.2 t ha-1, but as with the efficacy results, did not show any significant differences for the different treatments.

Table 2. Efficacy of mechanical and chemical means for red rice control with the stale seed bed technique.

| Treatment | 1995 | | 1996 | |
|---|---|---|---|---|
| | density reduction (%) | yield (t ha-1) | density reduction (%) | yield (t ha-1) |
| Harrowing | 73 | 4.8 | 91 | 6.2 |
| Shallow ploughing | 69 | 5.5 | 86 | 5.9 |
| Dalapon | 98 | 6.4 | 92 | 6.2 |
| Untreated | - | 3.4 | - | 3.2 |
| LSD ($P$ = 0.05) | 18.47 | 0.87 | | 2.13 |

Table 3. Influence on the seed bank evolution of red rice due to the application of mechanical and chemical means for red rice control with the stale seed bed techinque.

| Treatment | Red rice seed bank (seeds m-2) | | | |
|---|---|---|---|---|
| | 0-1 cm depth | 1-5 cm depth | 5-10 cm depth | Total |
| *Beginning of experiment* | 734 | 1723 | 47 | 2504 |
| *End of experiment* | | | | |
| Harrowing | 1551 | 165 | 33 | 1749 |
| Shallow ploughing | 198 | 132 | 33 | 363 |
| Dalapon | 2574 | 1518 | 33 | 4125 |
| Untreated | 7557 | 16500 | 396 | 24453 |

The total number of red rice seeds in the 0-10 cm depth layer, assessed at the beginning of the experiment, was, on average, 2504 m-2 in all the plots (Table 3).

These seeds had the following distributions in the soil: 29.3% at 0-1 cm depth, 68.8% at 1-5 cm, 1.9% at 5-10 cm.

After 2 years, the seed bank varied considerably according to the treatments. In the ploughed plots, the number of seeds decreased to 14% (363 seeds m-2) of the initial value, and was distributed with 54.5% at 0-1 cm depth, 36.4% at 1-5 cm, and 9.1% at 5-10 cm. The harrowing caused a slight reduction of the seed bank (to 1749 seeds m-2; 0-10 cm depth) with a major localisation (88.7%) in the 0-1 cm layer. Despite the greater effectiveness, the dalapon treatment showed a seed bank increase of about 1.6-fold, with the following distribution: 62.4% at the 0-1 cm depth, 36.8% at 1-5 cm and 0.8% at 5-10 cm.

In the untreated plots, the number of red rice seeds in the soil increased to 24453 m-2. The distribution was 30.9%, 67.5% and 1.6% at 0-1, 1-5 and 5-10 cm depth, respectively.

The unexpected seed bank reduction in the plots subjected to shallow ploughing was probably related to a delay of development and ripening of the red rice plants which emerged after the treatment. For this reason most red rice seeds did not shatter and were harvested with the paddy.

Another experiment carried out for 3 years starting from 1995 was aimed at comparing some graminicides already used in other crops and considered to be effective at low rate against red rice (Table 4) to dalapon.

The herbicides that were less effective in 1995 were abandoned in the following years. The products which showed a partial effectiveness in 1995 were tested at higher rates together with some new herbicides. Red rice control was performed for the three years at the 2-3 leaf stage of the weed. After flooding, the rice was immediately seeded with soaked Lido variety seeds at 190 kg ha-1 in 1995 and 1996 and the Loto variety at 220 kg ha-1 in 1997.

Counting of the number of red rice plants in the different plots at 70 days after treatment (DAT) pointed out that cycloxydim and dalapon resulted to be the best with over 95% efficacy. The results obtained with the other treatments were not considered to be sufficient, as they gave an effectiveness percentage that was lower than 74.6%.The only visible effect determined by the treatment with glyphosate, clethodim and quizalofop-ethyl isomer D on red rice was a temporary slowdown of the weed development which did not prevent it from maturing and shattering. The natural death rate of red rice seedlings, assessed in the non-treated plots at 70 DAT, was about 24%. Phytotoxicity symptoms on the crop were not observed in any of the tests.

In 1996, the red rice emergence was higher than in the previous year, with an average density of 188.9 ± 33 (S.E.) plants m-2. In this trial, dalapon, cycloxydim and clethodim + mineral oil at both dosages gave the best results in the visual assessment and in the counting of the plants that escaped treatment. The assessments performed 60 DAT showed an efficacy ranging from 98.6 to 100% for these herbicides. The worst result was obtained with glyphosate trimesium, which showed a residual infestation that was not significantly different from the untreated plots. At 60 DAT, a natural reduction of about 47% of the plant number was observed in the untreated plots. As in the 1995 trial, the selectivity towards the crop was good in all the plots.

In 1997, the density of red rice seedlings before the treatment was noticeably lower than in the preceding years, with a mean of 3.6 ± 0.44 (S.E.) plants m-2. In this trial, the three compared treatments showed no significant differences, in terms of herbicide effectiveness, and the infestation density assessed before treatment was reduced in all the test by over 95%. Despite the low density of the initial infestation, a natural density reduction of over 50% was observed in the untreated plots at 60 DAT.

Table 4. Efficacy of herbicides applied for red rice control with the stale seed bed technique.

| Treament | Active ingredient | Dosage f.p.a | Dosage a.i.b | Density reductionc |
|---|---|---|---|---|
| | | l ha-1 or kg ha-1 | kg ha-1 | (%) |
| **1995** | | | | |
| Untreated | - | - | - | 24.4 |
| Targa® Gold | Quizalofop - ethyl isomer D | 1.5 | 0.07 | 67.5 |
| Stratos® | Cycloxydim | 3.0 | 0.60 | 96.8 |
| Poladan® | Dalapon | 15.0 | 12.75 | 100.0 |
| Sulfosate® | Glyphosate – trimesium | 4.0 | 0.64 | 55.0 |
| Roundup® Bioflow | Glyphosate – isopropylammonium | 2.0 | 0.72 | 73.6 |
| Gallant® | Haloxyfop-ethoxyethyl | 1.2 | 0.15 | 58.2 |
| Select® | Clethodim | 0.6 | 0.14 | 74.6 |
| | LSD (*P= 0.05)* | | | 19.25 |
| **1996** | | | | |
| Untreated | - | - | - | 46.6 |
| Targa® Gold | Quizalofop - ethyl isomer D | 3.0 | 0.16 | 91.6 |
| Stratos® | Cycloxydim | 4.5 | 0.95 | 100.0 |
| Poladan® | Dalapon | 15.0 | 12.75 | 99.2 |
| Select® + mineral oil | Clethodim + mineral oil | 0.8 + 0.15 | 0.19+0.15 | 98.6 |
| Select® + mineral oil | Clethodim + mineral oil | 1.2 + 0.15 | 0.28+0.15 | 99.6 |
| Ronstar® + Roundup® Bioflow | Oxadiazon + Glyphosate – isopropylammonium | 1.2 + 3.5 | 0.30+1.26 | 75.4 |
| Sulfosate® | Glyphosate – trimesium | 6.0 | 0.96 | 51.6 |
| | LSD (*P= 0.05)* | | | 6.36 |
| **1997** | | | | |
| Untreated | - | - | - | 53.4 |
| Select® | Clethodim | 1.2 | 0.28 | 98.6 |
| Stratos® | Cycloxydim | 4.5 | 0.95 | 97.7 |
| Poladan® | Dalapon | 15.0 | 12.75 | 95.4 |
| | LSD (*P= 0.05)* | | | 1.34 |

af.p.: formulated product
ba.i.: active ingredient
cdensity reduction: as % of red rice plant density recorded in untreated plots

**CONTROL IN RICE POST-PLANTING**

Prior to testing the efficacy of possible control techniques in rice post-planting, several experiments were carried out in 1996 and 1997 to assess the acquisition of shattering ability and germinability after flowering in order to establish the appropriate time to control the weed in post-emergence by means of panicle cutting or systemic herbicides, applied with wiping bar equipment.

It was apparent from these studies that red rice seeds started to become viable at 9 days from the beginning of flowering with a germinability of about 20% (Fig. 2B). This value increased quickly and had already reached about 85% at 12 days after flowering (DAF).

The shattered grains showed a lower germinability till 24 DAF in comparison to that of the non-shattered ones. From this time on, the germinative capacity of the two groups of seeds was different. In particular, the germinability of the shattered seeds was very low during the first 15 DAF, with a maximum value of about 5%.

This behaviour can most likely be explained by the incomplete development of the first shattered grains, which broke off mainly because of environmental causes (wind).

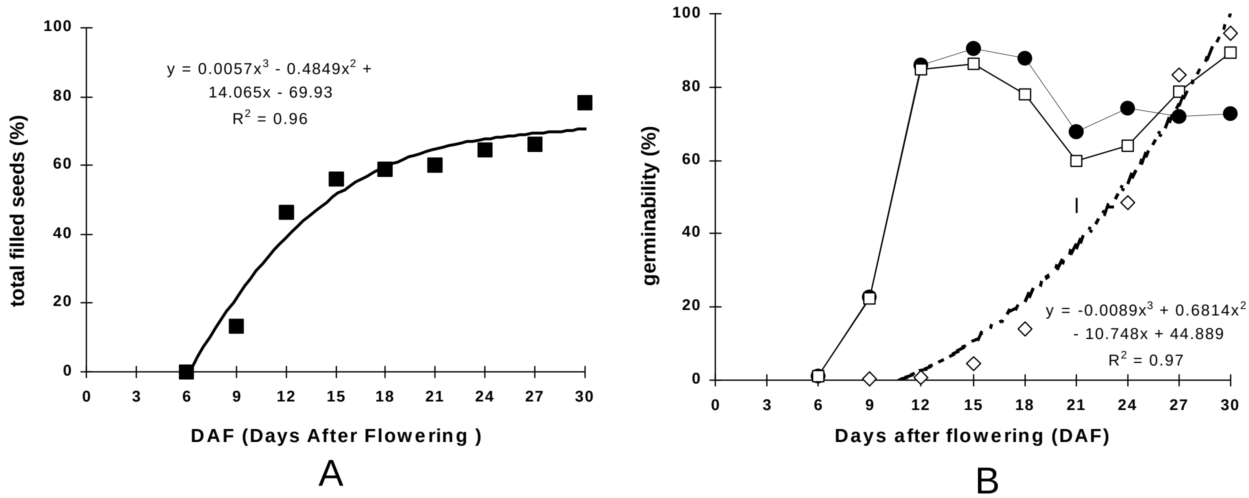
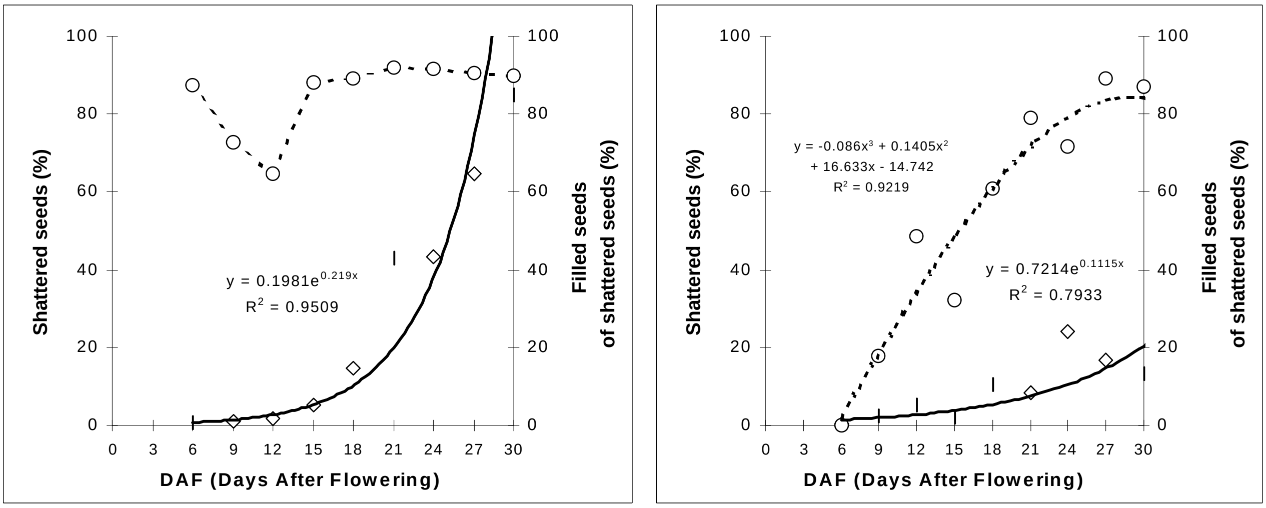



Figure 2. Filled seeds percentage of total seeds (A); total germinability evolution of the shattered (◇) and non-shattered (●) seeds and total mean germinability of filled seeds (□) (B) in the 1996-97 experiments. Symbols represent mean observed data over the two years; lines represent fitted functions.

The shattering that occurred after 15 DAF concerned more filled and physiologically mature grains. Shattering started to be visible from 9 DAF to 12 DAF in 1997 (Fig. 3), and increased gradually until complete development of the panicle (30 DAF). At that stage, shattering concerned about 65% in 1996 and 15% in 1997 of the total grains.

The knowledge of this behaviour allows one to establish the appropriate time to control the weed in post-emergence by means of panicle cutting or systemic herbicide application with wiping bar equipment which prevents grain dropping or germination. The application of both control systems relies on the cultivation of short height varieties in order to allow the control of the taller weed culms.




1996 1997

Figure 3. Shattering ability of red rice seeds in 1996 and 1997. Shattered seed percentage of total seeds (—) and filled seed percentage of shattered seeds (---).

The experiment carried out in 1997-1998 to control red rice with cutting equipment in rice post-planting pointed out that a double pass of a cutting equipment fitted with roll crushers resulted in a reduction of 94% of the panicles, in comparison to the untreated plots (Table 5). The first pass was performed prior to the 10 days from flowering initiation and the second one 20 days after, in order to control panicle re-growths. The cut panicles which escaped the passage through the crashing roller showed a germinability of 19%. A single cutting intervention controlled the panicles in the field by 89%, but the panicles which escaped the roller crashing still had a residual germinability of about 52%.

Table 5. Influence of panicle cutting on red rice control

| Treatments | % of cut panicles (referring to pre-treatment number) | Germinability of red rice seeds (as % of total seeds) | | |
|---|---|---|---|---|
| | | cut but not passed through c. roller | passed through c. roller | not cut |
| 1 cutting | 89 | 51.7 | 19 | 89.3 |
| 2 cuttings | 94 | 9.3 | 0.3 | 85.7 |

In synthesis, assuming an infestation of 30 panicles m-2 (corresponding to about 2000 seeds), the use of a crushing roller would allow a reduction of about 70% and 94% of the initial number of germinable seeds, with a single or double pass, respectively. The machine used for cutting interventions consists of a 5 m bar derived from the cutting device of a combine harvester, mounted onto the front of a tractor. The cutting bar is positioned over a couple of contra-rotating rollers for weed seed crashing.

Red rice control by means of systemic herbicides in rice post-emergence is based on the use of moistening bar equipment mounted on a self-moving machine. The machine is equipped with a 6 m long bar covered with a spongy carpet, which is maintained saturated with the herbicide solution through natural drops from a tank positioned above. The results of a research carried out from 1997-

1998, to compare different moistening materials and systemic herbicide rates, showed that this equipment only affected the germinability of the red rice seeds and did not significantly influence the number and the height of red rice plants(Table 6). The efficacy varied according to the moistening materials which were used to cover the bar and the type and rate of the herbicides applied.

The use of spongy materials combined with the application of glyphosate at 35% concentration gave a germinability reduction of about 99%. The same rate of glyphosate applied with a velchrom carpet showed a lower reduction (82%). Cycloxydim had an incomplete efficacy (69%) when applied at 5% with sponge, but showed a high and constant efficacy at all rates, when applied with velchrom. In this experiment, 33.5% of the panicles in the experimental field escaped the treatments as their height was equal or lower than that of the crop. Such a high percentage would likely favour the selection of short size biotypes which cannot be controlled either with cutting or moistening bar equipment.

Table 6. Post-emergence red rice control with moistening bar. Efficacy of glyphosate and Cycloxydim applied at different rates with sponge and velchrom moistening material.

| Treatments | | Dosage f.p.a | Dosage a.i.b | Germinability reductionc |
|---|---|---|---|---|
| Moistening material | Herbicide | % | % | % |
| Sponge | Glyphosate | 20 | 7.2 | 72 |
| Sponge | Glyphosate | 35 | 12.6 | 99 |
| Sponge | Cycloxydim | 5 | 1 | 69 |
| Sponge | Cycloxydim | 10 | 2 | 94 |
| Sponge | Cycloxydim | 20 | 4 | 96 |
| Velchrom | Glyphosate | 20 | 7.2 | 93 |
| Velchrom | Glyphosate | 35 | 12.6 | 82 |
| Velchrom | Cycloxydim | 5 | 1 | 92 |
| Velchrom | Cycloxydim | 10 | 2 | 94 |
| Velchrom | Cycloxydim | 20 | 4 | 97 |

af.p.: formulated product
ba.i.: active ingredient cGerminability reduction: as % of pre-treatment values

**CONCLUSIONS**

The results of the studies here discussed have shown that different techniques can be applied in crop pre- and post-planting to control red rice. The efficacy of these techniques resulted to be noticeably influenced by agronomical practices applied during crop management.

In crop pre-planting the mixture of dimethenamid + pretilachlor in flooded soil showed good and constant results in the prevention of red rice germination.

The results of the control in weed post-emergence when applying the stale seed bed technique were greatly influenced by the soil tillage adopted for seed bed preparation and soil moisture during weed germination. Minimum tillage and good soil moisture conditions favoured red rice emergence, creating the best conditions for post-emergence control, while ploughing and flooding remarkably affected weed germination. Seed bed preparation with ploughing can be considered helpful as an agronomical control measure where direct weed control means are not planned.

Mechanical control was significantly less effective than chemical treatment with Dalapon. Mechanical means resulted in a new flush of weed emergences after interventions due to the germination stimulation of the seeds bought to the soil surface by the implements. The results of the experiments also showed that when using the stale seed bed technique, cyclohexanediones such as cycloxydim and clethodim were as effective as Dalapon, and showed the possibility of replacing this herbicide at much lower dosages.

Red rice control in crop post-planting can be successfully performed both by panicle cutting and the localized application of systemic herbicides. The application of both control systems has to be carried out within 9 days from the flowering of red rice panicles as from that time onwards the weed seeds start to be able to shatter and germinate. A double pass with the cutting equipment fitted with roll crusher reduced by more than 90% the potential increase of the seed bank due to the shattering of the weed seeds. Similar results were obtained with the application of glyphosate or cycloxydim to the weed panicles using a moistening bar covered with sponge or velchrom.

The interventions with cutting or wiping bar should be considered a complementary means of red rice control, possibly combined with other more effective measures in crop pre-planting. Cutting or moistening systems, in fact, can be applied to red rice plants at flowering stage when all the competitive effects towards cultivated rice have already occured.

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# EFICACIA DE HERBICIDAS DE POST-EMERGENCIA CONTRA EL ARROZ ROJO EN PORTUGAL

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**SUMMARY**

Red rice is one of the most important weed in rice producing areas of Portugal. This production is obtained in three regions of the country mainly closed to three rivers (Mondego, Tajo, and Sado). Although various methods are usually implemented for red rice control, such as production of clean rice seeds, crop rotation and water management, chemical control plays an important role in the elimination of red rice.

Results of two-year herbicide trials for the control of red rice, conducted in Valle de Mondego, are herewith described. The most effective treatments were cycloxydim (200 g a.i./ha) applied pre-planting after red rice emergence followed by fluazifop-p-butil (250 g a.i./ha) applied post-emergence (3-4 leaf stage of red rice) combined with drainage before the application and flooding three days after.

Glyphosate (720 g a.i./ha) seems to destroy red rice, but in fact the weed regrows some days after the application.

**RESUMEN**

El arroz rojo es una de las malezas más importantes en el arroz en Portugal. Esta producción se obtiene en tres regiones del país, ubicadas en tres ríos (Mondego, Tajo y Sado). A pesar de que se practican varios métodos para el control del arroz rojo, tales como producción de semilla limpia, rotación de cultivos y manejo del agua. El control químico juega un papel importante en la eliminación del arroz rojo.

Los resultados de pruebas de dos años para el control del arroz rojo, llevadas a cabo en Valle de Mondego, son aquí descritos. Los tratamientos más efectivos fueron cicloxidim (200 g a.i./ha) aplicado en pre- siembra y después de la emergencia del arroz rojo seguido de fulazifop-p-butil (250 g a.i./ha) aplicado en pos- emergencia (estadio de 3-4 hojas del arroz rojo) combinado con drenaje previo a la aplicación y riego tres días después.

Glifosato (720 g a.i./ha) parecía destruir las plantas de arroz rojo, pero de hecho la maleza reverdecía días después de la aplicación.

## INTRODUCCION

El cultivo del arroz ocupa en Portugal una superficie de 32 000 ha, cuya producción ha aumentado sustancialmente debido a la introducción de las variedades Ariete e Thaibonnet, que son altamente productivas, y también debido al desarrollo tecnológico operado en los últimos años, particularmente una mejor nivelación de los terrenos mediante laser.

Las regiones arroceras en Portugal se ubican en tres rios, a saber: Mondego, Tajo, y Sado.

El arroz rojo (*Oryza sativa* L.) es una de las más importantes malezas en los arrozales del país. Esta maleza es altamente competitiva con el arroz cultivable y reduce ocasionalmente las producciones en cerca de un 50% o más. El control del arroz rojo es bastante difícil debido a la similitud de las características morfológicas y fisiológicas con el arroz cultivable.

Actualmente el combate del arroz rojo pasa por varias etapas, tales como:

- **Purificación de las semillas de arroz.** Uno de los motivos de la proliferación del arroz rojo, es por el uso de lotes de arroz comercial almacenado de un año para otro. Para impedir esa utilización se acordó por la Unión Europea que los lotes de semillas solamente serían certificados de tener un máximo de 3 granos de arroz rojo en un total de 500 gramos de arroz comercial. Este límite, por ende, no es suficiente para impedir la contaminación en los arrozales de arroz salvaje, pues debiera ser de 0 grano de arroz rojo.

- **Rotación de siembra.** La rotación del arroz con otro cultivo en campos infestados con arroz rojo, es muy importante en la reducción del nivel de infestación del arroz.

- **Control del cultivo.** Es importante eliminar las plantas de arroz rojo, antes que éstas florezcan, lo que se puede lograr quemando los tallos, estimulando la germinación del arroz y destruyendo después mecánica ó químicamente, entre otros.

Para combatir esta plaga, la Unión Europea financió un Proyecto con la participación de Portugal, Italia, España, Francia, y Grecia durante el período de 1997 al 1999. El objetivo de este proyecto fue el de estudiar con más detalles la biología y el control integrado del arroz rojo.

## MATERIALES Y METODOS

Los campos de experimentación para las técnicas de control de arroz salvaje fueron los del Valle de Mondego (Quinta do Seminário). Estos experimentos se ejecutaron a partir de la segunda semana del mes de mayo de 1997 y 1998. Las áreas de cada parcela fueron de 500 metros cuadrados con cuatro replicas. Las observaciones fueron realizadas en a los 30, 70, 90 y 120 días después de la aplicación del herbicida. La eficiencia del herbicida fue determinada según la fórmula de Abbot . La variedad sembrada fue "Ariete" y la densidad de siembra fue de 180 kg $ha^{-1}$ y 200 kg $ha^{-1}$ respectivamente en 1997 y 1998.

La preparación del suelo se hizo dando dos pases de cultivador y dos pases de fresadora ("rotavator"). Se aplicaron tres niveles de nitrógeno, el primero antes de la siembra, el segundo en el comienzo de la formación de la plántula y el tercero al inicio del crecimiento de los tallos.

Los herbicidas utilizados en el combate del arroz rojo están descritos en la Tabla 1.

**Tabla 1 -** Dosis de Herbicidas utilizados y condiciones de aplicación

| Herbicida | Dosis g sa $ha^{-1}$ | Condiciones de aplicación |
|---|---|---|
| Glufosinate ammonium | 450 | Aplicado antes de la siembra del arroz. |
| Cycloxydim | 200 | Fué inundado el cantero con poca agua (4 cm) |
| Glyphosate | 720 | para provocar la emergencia del arroz rojo. |
| Fluazifop-P-butyl | 250 | Cuando éste se encontraba con 2-3 hojas, fue |
| Sethoxydim | 186 | retirada el agua, y aplicado el herbicida. |
| | | Pasados los 3 días fue restablecida la circulación |
| | | normal de agua y se procedió a la siembra. |

Se utilizó molinate + bensulfuron-metil (Viktor) para el control de gramíneas (*Echinocloa crus-galli* y *E. oryzoides*; *Glyceria declinata, G. fluitans; Leersia orizoides*; *Panicum repens*; *Paspalum paspalodes*) y propanil + bentazone para el control de las de hoja ancha y ciperaceas (*Cyperus*; *Alisma lanceolata* y *plantago-aquatica.*).

## RESULTADOS Y DISCUSION

De las observaciones realizadas a lo largo de dos años, pudimos constatar que la infestación del arroz rojo en el arrozal fue del orden de un 65%. Aunque 1997 fue un buen año para los productores de arroz, se observó una caída de la producción de arroz, del orden del 30%, en las parcelas donde se aplicaron los herbicidas.

En 1998, debido a la distribución no uniforme del arroz rojo en el terreno experimental, se dividió la zona de cultivo en dos bloques A y B. Así, en el Bloque A, donde la infestación del arroz rojo era menor, se aplicaron dos nuevos herbicidas, s*ethoxydim* y f*luazifop-P-butyl*, mientras que en B donde la infestación fue superior, mayor, se mantuvieron los mismos herbicidas del año anterior y se introdujo un nuevo herbicida que fue el g*lyphosate*.

Comparando las producciones obtenidas, Tabla 6 y 7 con las producciones de los respectivos testigos, se puede afirmar que en el Bloque A hubo un pequeño aumento de producción que varió entre 6,6% y 12,3%, mientras que en el Bloque B esta diferencia fue más significativa, ya que la infestación del arroz rojo fue del orden del 58%, por lo que el aumento de la producción de arroz osciló entre 16,1% y 29,3%.

Se puede concluir que en dependencia de los niveles de infestación del arroz rojo, las respuestas a la acción de los herbicidas serán también diferentes. Cycloxydim se comportó en ambos años como el más eficiente de los herbicidas utilizados.

Glyphosate da la sensación que destruye todo el arroz rojo, sin embargo, al pasar los días el arroz rojo quemado reverdece.

Para el Bloque A los tratamientos con fluazifop-p-butil fueron los más efectivos, mientras que para el Bloque B lo fue cycloxydim.

**Tabla 2** – Eficacia sobre las malezas ( %) - ensayo 1997

| Observaciones | % Eficiencia Cycloxydim | % Eficiencia Glufosinate ammonium | Testigo % de recubrimiento |
|---|---|---|---|
| 30 DPA* | 90.0 | 75.0 | 35.0 |
| 70 DPA | 95.0 | 75.0 | 50.0 |
| 90 DPA | 97.5 | 70.0 | 65.0 |
| 120 DPA | 97.5 | 70.0 | 65.0 |

* DPA- Dias Posteriores a la Aplicación

**Tabla 3** – Eficacia ( %) ensayo 1998

| Observaciones | % Eficiencia Fluazifop-P-butyl | % Eficiencia Sethoxydim | Testigo A Arroz Rojo (%) |
|---|---|---|---|
| 30 DPA | 75.3 | 68.2 | 10.6 |
| 70 DPA | 81.0 | 75.2 | 13.1 |
| 90 DPA | 81.7 | 76.5 | 14.4 |
| 120 DPA | 81.7 | 76.5 | 14.4 |

DPA – Dias Posteriores a la Aplicación

**Tabla 4** – Eficacia ( %) ensayo 1998

| Observaciones | % Eficiencia Glufosinate ammonium | % Eficiencia Cycloxydim | % Eficacia Glyphosate | Testigo B Arroz Rojo (%) |
|---|---|---|---|---|
| 30 DPA | 78.3 | 86.2 | 74.3 | 31.7 |
| 70 DPA | 72.2 | 81.9 | 59.7 | 45.0 |
| 90 DPA | 60.2 | 78.5 | 51.6 | 58.1 |
| 120 DPA | 60.2 | 78.5 | 51.6 | 58.1 |

**Tabla 5** – Producción de arroz. Ensayo 1997

| Tratamientos | Producción (kg ha$^{-1}$) |
|---|---|
| Glufosinate ammonium | 8416 |
| Cycloxydim | 8939 |
| Testigo B | 6082 |

**Tabla 6** – Producción de arroz. Ensayo 1998

| Tratamientos | Producción (kg ha$^{-1}$) |
|---|---|
| Sethoxydim | 6740 |
| Fluazifop-P-butyl | 7158 |
| Testigo A | 6275 |

**Tabla 7** – Producción de arroz. Ensayo 1998

| Tratamientos | Producción (kg $ha^{-1}$) |
|---|---|
| Glufosinate ammonium | 5750 |
| Cycloxydim | 6458 |
| Glyphosate | 5445 |
| Testigo B | 4566 |

# STRATEGIES AND EFFECTS OF CROPPING PRACTICES ON THE LEVELS OF RED RICE INFESTATION IN THE CAMARGUE (FRANCE).

Jean-Claude Mouret

**SUMMARY**

In France rice area is about 20 000 ha, all cultivated exclusively in Rhône delta, Southeast part of the country. Rice is an intensive crop, which is direct-seeded and flooded all season from April to October. Weeds are the main constraint to rice production and among the major weed species, red rice is able to cause a 50% reduction of crop yields, particularly in areas of monocropping.

Our study shows the results of the survey, which objective was to identify various strategies practised by farmers to control red rice. We also tried to assess the effectiveness of these strategies.

In 263 plots assessed, we found that one third of them were normally treated with herbicide pre-planting treatment, 7% were hand-weeded, 5% weeded pre-planting mechanically and 15% were commonly rotated with upland crops. In the rest third rice growers informed that they do not do anything in particular to control red rice. Only 19 of assessed plots showed no red rice presence and 56 plots were heavily infested with a stand of red rice above 50% at crop flowering and harvest. A positive effect of red rice control was also found in areas rotated with upland crops and in areas with high rice seed densities. The cultivar Ariete shows a high competitiveness with red rice. However, the cultivars Thaïbonnet, Loto and Koral are low competitors and this favours high red rice proliferation.

**RESUMEN**

En Francia, el cultivo del arroz se desarrolla en 20 000 ha, las que se hallan casi exclusivamente en el delta del río Rhône en el sudeste del pais. Se trata de un cultivo muy intensivo con siembra directa y sumergida durante todo el periodo de cultivo, es decir desde fines de abril hasta octubre. Las malezas constituyen el factor principal que limita la producción, entre ellas, el arroz rojo capaz de provocar una disminución del 50% de los rendimientos, particularmente en áreas de monocultivo del arroz.

Nuestro estudio presenta los resultados de una encuesta agronómica, cuyo objetivo fue el de identificar las distintas estrategias llevadas a cabo por los arroceros para controlar el arroz rojo. También se intentó medir la eficacia de estas estrategias.

En las 263 parcelas sometidas a análisis, comprobamos que un tercio son tratadas químicamente antes de la siembra, un 7% se escardan a mano, un 5% se desyerban mecánicamente antes de la siembra y un 15% se someten a control mediante rotación con cultivos de secano. En el tercio restante, los arroceros informaron que ellos no hacen nada de particular para controlar el arroz rojo. Solo 19 de las parcelas analizadas no presentaban ninguna planta de arroz rojo y 56 parcelas estaban muy infestadas (superior a un 50% de infestación al momento de la floración y la cosecha). Se comprobó un efecto positivo de la rotación sobre el nivel de infestación de arroz rojo y también un efecto positivo de la densidad de siembra de arroz utilizada. La variedad Ariete presenta un efecto competitivo alto sobre el desarrollo del arroz rojo. Sin embargo, las variedades Thaïbonnet, Loto y Koral presentan poco poder competitivo, lo cual favorece la proliferación del arroz rojo.

## INTRODUCTION

In the Camargue, about 20.000 hectares are cultivated with rice, either in monoculture or in crop rotation systems. This region is situated at the northern limit of the ecological area of rice production. Intensive cultivation is practised with direct seeding and permanent irrigation. The rice is sowed at the end of the month of April and harvested in September. In monoculture systems, red rice has constituted, for the last ten years, a major limiting factor for the paddy yield. In order to control this constraint, rice farmers who manage farms of high hectarage (around 160 hectares), have implemented different strategies and practices which we have identified and analysed.

**METHODOLOGY**

The programme was conducted in 3 phases:

Phase 1: a survey of rice farmers' red rice control strategies. This survey was based on open questions to identify each farmer's perception of red rice infestation. In particular:

- to attain the specific conditions of infestation or non infestation on each farm surveyed,
- to establish a dynamic of the evolution of the infestation on the farm,
- to map out the different levels of infestation,
- to complete the red rice control strategy survey with the specific adaptation used by the farmers.

Beyond the specific red rice control strategy, a complete rice cropping itinerary has been established and related to the whole farm cropping system.

Phase 2: a field assessment of soil and climatic condition, rice density and red rice infestation. This assessment was conducted by using a specific appraisal approach where all data are related to each other : the specific soil and climatic conditions, the weed and rice density as well as, the rice cropping itinerary.

Phase 3: an analysis of the two previous phases by construction of a typology of red rice control strategies and assessment of their degree of efficiency.

**RESULTS**

**1. Red rice control strategies**

On the 28 farms surveyed, 10 farmers didn't develop any modification on their cropping itinerary to control red rice. 15 farmers used a chemical control of pre-emerged red rice, on the whole farm for two of them, or only on part of the rice field.

A final comment is that 5 out of 28 farmers carried out manual weeding, usually as a complementary method of control.

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**False Seeding** is a cultivation technique used to stimulate the emergence of undesired rice varieties before sowing the variety to be cultivated: thus, **pre-emerged red rice**.

« **Red Rice »** is used throughout the text as a global generic term for all rice varieties considered as weeds in a given situation in the rice fields of Camargue.

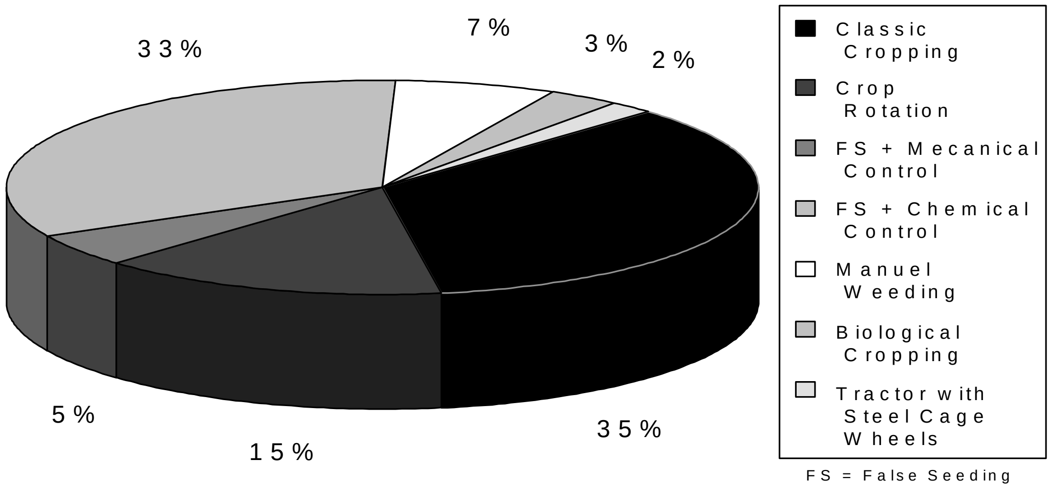


**FIGURE 1 : the different strategies of red rice control**

Figure 1 shows that 35% of the area surveyed didn't receive any specific control of red rice. Chemical control of pre-emerged red rice was used on 33% of the area surveyed. Mechanical control of pre-emerged red rice was observed on 5% of the area. The winter flooding technique followed by tractor work (the tractor is fitted with wide steel wheels) concerned 2,5% of the total surface. The introduction of crop rotation as a way to control red rice was seen on 16% of the area. Biological rice cropping (3,5%) which doesn't use any synthesis product can be assimilated to the crop rotation technique as rotation is the only way to control weeds in this situation. Manual weeding, considered by farmers as an additional technique of red rice control, was carried out on 200 ha; in other words, 7% of the surface surveyed.

## 2. DESCRIPTION OF THE MAIN RED RICE CONTROL STRATEGIES USED.

### 2.1. The chemical control of pre-emerged red rice.

For this operation an early flooding of the rice field, about three weeks before sowing, is needed. The aim is to create good germination conditions for the red rice and then to destroy it with chemicals.

According to the recommendation of the CFR (French Rice Centre), the flooding should be done in two steps. The first step is to cover the field with 3 to 5 cm of water for a week to start red rice germination. The second step is to raise the water up to 10/15 cm for at least two weeks to weaken the roots of the first shoots. Spraying takes place after drainage of the rice field. The chemical doses vary between 0,7 l to 1,2 l/ha for Oxadiazon and 10 to 12 kg/ha for Dalapon. The CFR also recommends rinsing the field two to three days after the treatment to avoid any risk of toxicity to the crop.

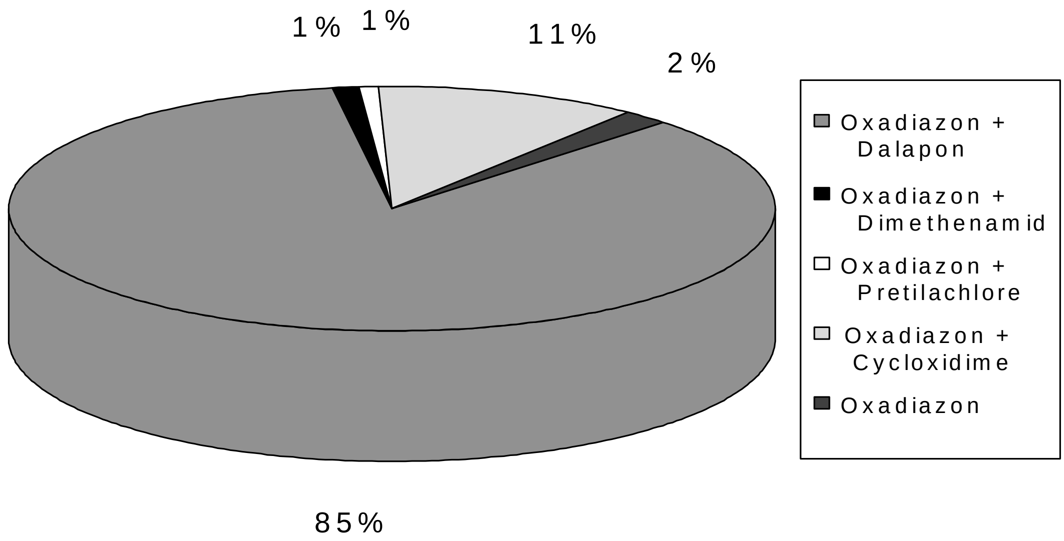


**FIGURE 2 : the different chemical control methods used on pre-emerged red rice**

In Figure 2, we can see that the mix Oxadiazon + Dalapon represents 85% of the chemical control methods. Other mixes like Oxadiazon + Cycloxidime (11%), Oxadiazon + Dime-thenamid (1%), Oxadiazon + Pretilachlore (1%) or Oxadiazon as a single active ingredient (2%), have been observed as well.

<u>2.2. The mechanical control of pre-emerged red rice.</u>
Here, three different techniques can be described.

- The first technique tries to create the best condition for the emergence of red rice without flooding the field. This can be obtained by a good seed bed preparation and a settling of the soil, to bring the moisture up, a couple of weeks before sowing. Then, a mechanical destruction of the weeds can take place. To do an efficient job, the recommended implement is of the horizontal rotary type (e.g. rotary hoe). This implement needs to work deep enough to destroy the germinated plants buried underneath the surface.

- The second technique is mechanical destruction after flooding. The aim is to provoke weed germination, not by using the natural humidity of the soil as in the precedent case, but by a short irrigation of the field. The moisture needs to get down to 15 centimetres. After drainage, the soil dries out and a mechanical destruction is applied. To realise this technique properly, it is important to dig some furrows across the field to allow for quick movement in of the water, or out, in case of heavy rain.

- The third technique is mechanical destruction in the water. The field is kept flooded for three week before sowing. The implement used for the destruction of the red rice in this case is the rotary harrow. This job is carried out with the water at a very low level, when the soil is muddy.

2.3. <u>Crop rotation</u>

In this case, the objective is to break the monocultural system of rice cropping which favours the proliferation of red rice. Knowing the dormancy effect, the farmers stop cropping rice for two or three years.
Hard wheat is the most common crop used in rotation with rice and the most adapted for both economical and ecological reasons. Hard wheat, sown during the autumn and harvested by mid July, allows the mechanical control of pre-emerged red rice through the summer.
The particular conditions in the Camargue (hydromorphy and salinity) and also certain economical constraints don't authorise the systematic use of crop rotation to control red rice. The biological cropping itinerary, which does not use any synthesis product, is obliged to use rotation with the possiblity of mechanical control of pre-emerged weeds.

2.3. Manual weeding.

The manual weeding of red rice usually takes place when fields are lightly infested. This technique is often used as a complement of and when another strategy (e.g. control of pre-emerged red rice) has given poor results.

## 3. EFFECTS OF CROPPING PRACTICES ON THE LEVELS OF RED RICE INFESTATION.

Figure 3 presents the distribution of the 263 rice fields in relation to the level of infestation observed, where:
Only 19 fields (7%) were not infested with red rice (class 1).
Almost half of the fields (47%) were spread over class 2 and 3. These two classes represent low to very low levels of infestation, which means less than one red rice plant per $m^2$.
On the other hand, classes 6, 7 and 8 which correspond to the most infested fields, only grouped 9% of the total number.
Under the assessment conditions, we did not seen any field entirely infested with red rice (100% weed cover).

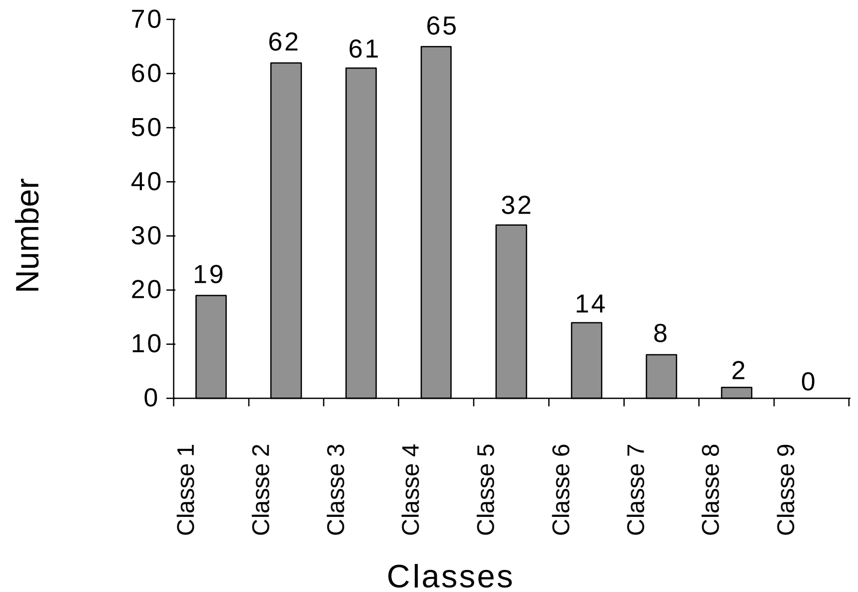


**Figure 3 : graph of the distribution of the fields assessed in relation to their level of red rice infestation.**

In order to simplify the analysis of the effects of the differents strategies on red rice infestation, we created three classes of red rice cover which are : RECRO 1 for the field with very little infestation, RECRO 2 for the field with an average infestation, RECRO 3 for the field with high infestation.
The results of the statistical analysis are presented by cross tablulation to show the frequency of each infestation class in relation to the strategy employed. The effects of other cropping practices : ground preparation, sowing technique, sowing rate and variety used, are also analysed on the same principal.

Table R1 shows three classes of infestation in relation to four main strategies employed by farmers:

* With the classical way of cropping, in other words, when no specific strategy is employed, over half of the fields are situated in the higher level of infestation category and only 23% of them are lightly infested.
* With the strategies of chemical or mechanical control of pre-emerged red rice, the number is spread over the three classes. This means that, in a third of the situations, the strategy employed gave no results.
* When crop rotation is employed, the proportion is inverted. As the table shows, 42% of the number of fields included in a crop rotation have light infestation of red rice.

Regarding the ground preparation, Table R2 shows that only 35% of the rice fields were ploughed. The rest of the fields were worked with chisel ploughs or disks. But no real effects of the two methods of ground preparation are discernible as the numbers are evenly spread between the three levels of infestation.

| **Level of infestation** | | **RECRO 1** | **RECRO 2** | **RECRO 3** | **Total** |
|---|---|---|---|---|---|
| **Strategies** | | | | | |
| classic | N | 14 | 15 | 32 | 61 |
| rotation | N | 29 | 22 | 20 | 71 |
| mechanical control | N | 7 | 7 | 7 | 21 |
| chemical control | N | 36 | 34 | 38 | 108 |
| Total | N | 86 | 78 | 97 | 261 |

RECRO 1 = light infestation, RECRO 2 = average infestation, RECRO 3 = heavy infestation

**Table R1 : Effect of red rice control strategies : Strategies x level of infestation.**
(total number : 263, individuals missing: 2)

In Table R3, two ways of sowing rice are identified : under water, the most common situation, and on dry ground before flooding. Even if this last sowing technique is less represented, we can see that it corresponds to a high percentage (70%) of light infestation. A finer analysis of the consequences of this way of sowing could be useful to confirm, or not, this result.

| Level of infestation | | RECRO 1 | RECRO 2 | RECRO 3 | Total |
|---|---|---|---|---|---|
| Ground preparation | | | | | |
| ploughing | N | 28 | 27 | 37 | 92 |
| no ploughing | N | 59 | 52 | 60 | 171 |
| Total | N | 87 | 79 | 97 | 263 |

**Table R2 : Effect of ground preparation : Ground preparation x level of infestation.**
(total number : 263, individuals missing: 2)

Table R4 compares the effect of three sowing rates on the levels of infestation. This table shows the number of strongly infested fields is nearly twice as high with a light sowing rate than with a high sowing rate. The tendency is inverted when looking at the relation between sowing rates and the class of light infestation of red rice. This is an interesting result which can explain a competitive effect, at seedling time, between domestic rice and red rice. Another hypothesis is that farmers usually rise the sowing rates in fields where the soil conditions (hydromorphy, salinity) penalise the germination of seeds including red rice seeds. This idea could also be checked by conducting a specific experiment.

Finally, Table R5 shows a clear effect of rice varieties on the level of infestation of red rice. The fields cropped with the variety Ariete suffered strong levels of infestation in only 27% of cases. This percentage went up to 50% when using other varieties (54% for the variety Thaï bonnet). On the other hand, 75% of the fields lightly infested were sown with the variety Ariete.

**Table R3 : Effect of sowing techniques : sowing types x level of infestation**
(total number : 263, individuals missing: 2)

| Level of infestation | | RECRO 1 | RECRO 2 | RECRO 3 | Total |
|---|---|---|---|---|---|
| sowing technique | | | | | |
| In water | N | 74 | 77 | 93 | 244 |
| On dry ground | N | 12 | 1 | 4 | 17 |
| Total | N | 86 | 78 | 97 | 261 |

**Table R4 : Effect of sowing rates : sowing rate x level of infestation.**
(total number : 263, individuals missing: 2)

| Level of infestation | | RECRO 1 | RECRO 2 | RECRO 3 | Total |
|---|---|---|---|---|---|
| Sowing rate | | | | | |
| < 220 kg/ha 1 | N | 23 | 28 | 46 | 97 |
| 220 to 240 kg/ha | N | 25 | 24 | 29 | 78 |
| > 240 kg/ha | N | 38 | 26 | 22 | 86 |
| Total | N | 86 | 78 | 97 | 261 |

**Table R5 : Effect of rice varieties: variety x level of infestation.**

(total number : 263, individuals missing: 2)

| Level of infestation / Varieties | | RECRO 1 | RECRO 2 | RECRO 3 | Total |
|---|---|---|---|---|---|
| Ariete | N | 63 | 27 | 34 | 124 |
| Loto | N | 2 | 15 | 13 | 30 |
| Thaïbonnet | N | 4 | 12 | 19 | 35 |
| Koral | N | 6 | 14 | 21 | 41 |
| *Others* | N | 11 | 10 | 10 | 31 |
| Total | N | 86 | 78 | 97 | 261 |

## CONCLUSION

This programme conducted on a large scale (28 farms, 263 fields) shows the diversity of farmers' approaches in relation to red rice control strategies. In one third of the situations, the farmers surveyed don't change their weeding practices for a specific control of red rice. Another third of the farmers use the chemical control of pre-emerged red rice, mainly with the mix Oxadiazon/Dalapon, before sowing. The crop rotation, rice/hard wheat, was introduced in 16% of the fields surveyed. This strategy was also observed in the case of biological cropping (3%). The mechanical control of pre-emerged red rice was employed on 3% of the farms surveyed. Manual weeding usually took places as a complement of another strategy.

The assessment analysis shows that only 7% of the fields surveyed didn't have red rice infestation whereas 20% had strong infestation. None of the strategies identified is predominant in terms of red rice control efficiency. Nevertheless, crop rotation is often related with low infestation whereas the classic cropping system is often related to high infestation. The variety Ariete confirmed a sign of competitiveness, higher than the others varieties present in our sample. Finally, we have shown a positive relation between the sowing rate and the level of red rice infestation (the highest rates, over 240kg/ha, seem to help the control of red rice). This relationship needs to be confirmed by a more detailed analysis and possibly by conducting further experiments.

# HERBICIDE RESISTANT RICE (*ORYZA SATIVA* L.) – A THREAT OR A SOLUTION

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## SUMMARY

Herbicide resistant crops (HRCs) are already commercially available, particularly of soybean, canola, cotton and maize. Incorporation of resistance to non-selective herbicides into crops provides more flexibility to farmers to control otherwise hard-to-kill weeds and enables them to replace traditionally used herbicides with others more environmentally benign. Major agrochemical companies and research centres are making efforts to develop and commercialise rice cultivars resistant to glyphosate, glufosinate-ammonium, and imidazolinones. These transgenic or conventionally bred varieties would allow selective control of red rice (*Oryza sativa*) and other weedy *Oryza* species in rice. There is concern, however, about the possible negative impact of the introduction of these new varieties, particularly in relation to the possible transfer of resistance genes from rice crop to red rice and other compatible weedy *Oryza* species. It is not anticipated that transfer of herbicide resistance will confer fitness advantages to red rice and weedy *Oryza* species making them more invasive or aggressive in the absence of herbicide use or in the non-agricultural environment. Red rice control, however, would become more difficult if the herbicide effectiveness is lost. It is also possible that volunteer herbicide-resistant rice would become a more serious problem, as it would not be controlled with products such as glyphosate or glufosinate-ammonium. Finally, farmers' dependence on these new herbicides for weed management could increase the number of herbicide resistant weeds that are already an aggravating problem in rice production.

## RESUMEN

Varios cultivos resistentes a herbicidas están disponibles en el mercado, especialmente soya, canola, algodón y maíz. La incorporación de resistencia a herbicidas no selectivos en estos cultivos proporciona mayor flexibilidad a los agricultores en el manejo de malezas de difícil control y permite el reemplazo de algunos herbicidas de uso tradicional por otros considerados más benignos para el ambiente. Varias compañías de agroquímicos y centros de investigación realizan esfuerzos para desarrollar y comercializar variedades de arroz resistentes a herbicidas, sobre todo a glifosato, glufosinato de amonio e imidazolinonas. Estas variedadesmodificadas o seleccionadas permitirían el combate selectivo de arroz rojo (*Oryza sativa*) y otras especies nocivas de *Oryza* en arroz. Sin embargo, preocupan los posibles efectos negativos de la introducción de estas nuevas variedades, especialmente por el riesgo de que los genes de resistencia se transfieran del arroz comercial al arroz rojo y a especies compatibles de *Oryza*. No se anticipa que la adquisición de resistencia a herbicidas proporcione ventajas de adaptación al arroz rojo y a las otras especies de *Oryza* como para que se tornen más nocivas en ausencia del herbicida o en ambientes no agrícolas. Sin embargo, su control sí podría dificultarse al perderse a mediano plazo la eficacia de los herbicidas totales en uso. Además, es posible que se agraven los problemas de control químico de arroz voluntario, el cual no podría eliminarse con productos como glifosato o glufosinato de amonio. Finalmente, la dependencia de estos nuevos herbicidas para el manejo de malezas en arroz, podría agravar el serio problema ya existente de malezas resistentes a herbicidas en el cultivo.

## INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop in the world creating the basic ingredient in the diet of half the worlds population. Increasing population in Asia is predicted to raise rice demand with 30% over the next 25 years. This prediction considers the fact that economic growth in Asia might change the preferred diet from rice to wheat based products (IRRI, 1994).

Weeds are a constant constraint to rice production and cause yield losses in all rice production systems and in all seasons (Zoschke, 1990). Severity of weed problems and species composition varies from one field to another because each site has a unique combination of physical and environmental conditions (Savary *et al*., 1996). Labor for transplanting and hand weeding is increasingly scarce and forcing farmers to switch to direct seeding thereby loosing the early season advantage of the flooded condition to suppress initial weed growth, especially of grasses.

Rapid industrialization and urbanization compete with agriculture for limited resources, especially water. Additionally, much of the irrigation infrastructure is poorly maintained, which further reduces water availability for rice production. Measures to conserve water in rice production such as intermittent flooding and shallow water depths are generally less efficient with respect to weed control. With labor and water shortages there are few weed control alternatives other than increased use of herbicides.

Generally, herbicides are more effective, easy to use and less expensive than hand labor. These desirable features of herbicides have hindered the development of alternative control strategies. The shift to direct seeding which has been accompanied with widespread, often exclusive, use of herbicides for weed control in rice has the adverse consequence of promoting a shift from relatively easily controlled broad-leaved weeds to more tolerant grass weeds, especially “weedy rice” including “red rice” (Moody, 1992). In addition, continuous use of herbicides may lead to evolution of herbicide-resistant weeds. Resistant biotypes are not rare, normally do not lack vigor, and some are not easily controlled with other herbicides. Some weed populations have resistance to several herbicide groups. Currently more than 200 cases of resistance to at least 16 major herbicide groups have been documented in almost 150 weed species worldwide and the area infested with herbicide resistant weeds is increasing ( Heap 1999). Adverse effects of increased herbicide use on health and on the environment are also of major concern.

Over the last decade there has been a keen interest among the agro-chemical industry to develop herbicide resistant crops. Justification for such development is the potential improvement in weed control and environmental benefits brought about by being able to use more efficient and environmentally benign herbicides that would replace old-generation chemicals. Behind the scene, however, it is a fact that developing herbicides with new modes of action is becoming increasingly hard and expensive making it profitable to develop new niches for existing products.

The success of herbicide resistant rice depends on the cost of commercial seeds which in many rice producing areas compete with seed saving strategies. The possible benefits in terms of increased yield and lower production cost will have to be obvious to the farmer.

In this paper we will discuss opportunities and risks related to the introduction of herbicide resistant rice in the major rice producing areas of the world. In this regard we considered it pertinent to describe fundamental aspects of the biology of weedy and wild rice and the tools to assess the consequences associated with the introduction of herbicide resistant rice.

**"RED RICE" OR "WEEDY RICE"**

Weedy rice and/or red rice is an increasing problem in all rice growing areas in the world. Weedy rice and red rice are the same species as cultivated rice (*Oryza sativa* L.) but undesirable, early-shattering off-types with dormancy mechanism. Weedy rice can be morphologically very similar to, and naturally cross with, cultivated rice. Whether it is referred to as weedy rice or red rice is mostly related to geographical location *e.g*. in the US it is called red rice, in Asia it is called weedy rice and in South America it is usually called red or "contaminating" rice. In US, weedy rice problems occur in continuous rice fields. In Asia, however, continuous rice growing has been practiced for thousands of years without occurrence of weedy rice problems, thus continuous rice is hardly the sole explanation for why weedy rice is an increasing problem.

Many weedy rice populations in the US have a red pericarp (thereby the name) and are therefore relatively easy to distinguish from cultivated rice. In the US, red rice has been known as a weed since 1846 and was probably introduced from India (Craigmiles, 1978). Red rice was described as having red pericarp, pubescent light-green leaves and pubescent seeds (Diarra et al. 1985). Recent studies have added information on morphological traits, thus red rice has generally more tillers and panicles per plant and produces less seed of comparable size per panicle than cultivated rice. Red rice grows taller than the cultivated varieties it associates with and shatters seeds that are predominantly (about 80%) dormant (Noldin et al. 1999). Red rice biotypes from Venezuela varied in growth habit, tillering capacity, color of the pericarp and seed shattering that ranged from 17% to 83%. (Ortiz-Domínguez 1999).

Langevin et al. (1990) studied the hybridization of red and cultivated rice. Hybrids generally, but not always, diverted morphologically from the parents. As for red rice, the hybrids are generally taller, more tillering, have longer and wider flag leaf than both red rice and cultivated rice. The authors suggested that this was a result of hybrid vigor in first generation hybrids. The ability to hybridize with cultivated rice is a major concern when herbicide-resistant rice cultivars are to be widely released. This would have major dyer consequences as herbicide resistant "weedy" rice would flourish.

Oka (1991) characterized weedy rice as intermediate between wild and domesticated forms occurring in direct-seeded rice fields, irrigation ditches, and dikes but they cannot survive in natural habitats. Weedy rice retains wild-plant characters such as seed shedding and dormancy, red pericarp and awns. Similarity between weedy rice and cultivated rice in the vegetative stage makes it difficult to remove them by hand. Weedy rice tolerate adverse conditions and have a higher outcrossing rate than domestic cultivars. They usually mature uniformly about a week before the domesticate cultivars they associate with. However, weedy rice in Asia have a large variation in phenotype and white pericarp is more common than the red pericarp. Suh et al. (1997) classified 152 accessions of weedy rice originating from ten countries in four groups based on morphological and physiological characteristics and isozyme and DNA markers. The first group (Group I) was composed of 54 accessions from temperate countries (mostly from Japan, Bhutan, US, Nepal and Brazil) and was identified as "*indica*-type, similar to cultivars." A few of the accessions in this group, however, exhibited characteristics associated with *japonica*, indicating the possibility of gene flow between *indica* and *japonica*. Group II (24 accessions from more tropical climates including

India, Bangladesh and Thailand) was designated as *indica*-type, similar to wild rice. It is proposed that this group originated from hybridization between wild and cultivated rice. Group III, *japonica*-type similar to cultivars, included 63 accessions originating from Korea and Bhutan which were assumed to be old rice cultivars that reverted to a weedy from. The remaining eleven accessions from China and Korea comprised Group IV (*japonica* - similar to wild rice) which is likely to have evolved from gene flow between *japonica* cultivars and wild rice from China. Similarly, Oka (1991) suggested two categories of weedy rice: those occurring together with wild rice (most frequent in India and Thailand) and those distributed in regions where no wild rice is found.

## CULTIVATED RICE AND OTHER *ORYZA* SPECIES

*Oryza sativa* and *O. glaberrima* are the cultivated species of rice. The first one, known as Asian rice, is produced worldwide; the second species (African rice) is produced in areas of West Africa. The cultivated *O. sativa* are divided in two main varietal groups, *indica* and *japonica*; the later is further divided in tropical (= *javanica*) and temperate (= typical japonicas) Japonicas (Khush 1997). Additionally, there are more than twenty wild species in the genus *Oryza*, eight of them are tetraploids; the rest as well as the cultivated species are diploid (Brar and Khush 1997, Khush 1997). Eight different genomes have been identified in the genus *Oryza*. Genomes are assigned based on morphological, physiological and biochemical differences, including crossing relationships, chromosome number, chromosome pairing behavior of $F_1$ hybrids from crosses between species with known and unknown genomic constitution and, more recently, by evaluation of divergence at the molecular level through total genomic DNA hybridization (Aggarwal et al. 1997). Table 1 lists species in the genus *Oryza* with their corresponding genome. According to their genetic relationships, species are grouped in four complexes (Sativa, Officinalis, Ridleyi and Meyeriana), except *O. brachyantha*, which does not belong to any of these complexes (Aggarwal et al. 1999).

The cultivated rice *(O. sativa*) and its closely related wild species *O. perennis*, *O. nivara* and *O. longistaminata* share the AA genome. These wild species can be easily crossed with *O. sativa* and desirable genes from them can be transferred to cultivated rice by conventional crossing and back crossing procedures. However, wild species with genomes other than AA are difficult to cross with *O. sativa* (Brar and Khush 1997). *O. glumaepatula*, the only Sativa complex species from America and conventionally considered a subtype of *O. rufipogon*, has been determined to be closer related to *O. barthii* than to the Asian forms (*O. sativa*, *O. nivara*, and *O. rufipogon*) according to recent genetic analyses. *O. glumaepatula* may have evolved either independently or from African ancestors over a long period of time (Aggarwal et al. 1999). BBCC tetraploids belonging to the Officinalis complex are considered of recent origin; species of the Officinalis and Sativa complexes are likely to have differentiated separately as distinct groups and undergone parallel evolution (Aggarwal et al. 1999). The Ridleyi and Meyeriana complexes probably evolved as a single lineage and are related to each other.

There is still discrepancy about the designation of some species. For a long time, the A-genome species *O. meridionalis*, *O. glumaepatula*, *O. rufipogon* and *O. nivara* were considered to be different forms of *O. perennis*. *O. perennis* was renamed *O. rufipogon* and some of the Australian germplasm was reclassified as a new species, *O. meridionalis*. The designation of *O. meridionalis* as a separate species was recently supported by RAPD analysis (Martin et al. 1997). *O. schlechteri* Pilger is a rare, stoloniferous plant known to occur in a very limited number of locations in Papua

New Guinea and in Irian Jaya, Indonesia (Naredo and Vaughan 1992) with unknown genome whose taxonomic position is unclear.

Detailed consideration to the taxonomic status of the endemic Central and South American *O. glumaepatula* was recently given in a series of morphological and genetic studies (Juliano et al. 1998, Naredo et al. 1998, Lu et al. 1998). In the initial characterization, most accessions were clearly distinct from *O. rufipogon* and *O. nivara* but some accessions, especially from Brazil, were atypical and seemed to form a separate group. Further studies evaluated by hybridization the relationship between confirmed accessions of *O. glumaepatula* and *O. nivara*, *O. rufipogon*, *O. meridionalis* (from Australia), as well as the atypical *O. glumaepatula* diploid accessions (Naredo et al. 1998). The ability of *O. glumaepatula* to cross with these species was highly variable; comparatively low seed set was observed in crosses with *O. meridionalis* than with the other New World diploids (*O. nivara* and *O. rufipogon*) but, in general, hybrids of *O. glumaepatula* were highly sterile. Atypical accessions were probably introduced to South America as weedy types along with cultivated rice. A weedy rice accession from Cuba was assumed to have hybrid origin.

Most studies related to gene flow among species of the genus *Oryza* have been conducted with cultivar breeding in mind, and very limited information is available on the gene exchange from cultivated rice to weedy and wild rice. Wild *O. rufipogon* rice are crossable with *O. sativa*, sometimes producing swarms in the field and sterile hybrids. *O. breviligulata* (= *O. barthii*) is the wild progenitor of *O. glaberrima*. Fertile hybrids between the two taxa are possible and do occur naturally in the field (Oka 1991). Naredo et al. (1997) and Lu et al. (1997) evaluated the ability to cross, fertility of $F_1$ hybrids, and the chromosome pairing at metaphase I in hybrids of *O. meridionalis* with Asian AA-genome species (*O. nivara*, *O. rufipogon*, the weedy type *O. sativa* f. *spontanea* Rosch., and the cultivated *O. sativa*). Limited interspecific hybridization between *O. meridionalis* and the Asian species was achieved, except for the combination with *O. sativ*a which did not produce any hybrids.

Majumder et al. (1997) documented, based on morphological and cytological comparisons, the evolution of intermediate types as a result of genetic introgression from traditional *O. sativa* varieties (Thaothabi and Moirangphoe) to the wild species *O. rufipogon* in Manipur, India. Because of sudden ecological changes in the area and human interference by growing cultivated rice, hybrids proliferated almost bringing to extinction the founder *O. rufipogon* population. A similar case of extinction of a wild *O. rufipogon* population in the central plain of Thailand was recently reported by Akimoto et al. (1999). As cultivated rice is predominantly selfing, most gene flow occurred from the cultivated plants to the wild species, which has a greater outcrossing rate (Akimoto et al. 1999). This emphasizes the relevance of risk evaluation for movement of herbicide resistance genes from the crop to wild and weedy rice.

**HERBICIDE-RESISTANT RICE**

Generally, in the discussion about herbicide resistant crops there has been two benefits drawn to the attention of the public. First, more efficient cropping systems with more efficient weed control measures could result in less land producing the required food in the world. This would preserve marginal land from exploitation resulting in conservation of ecosystems and habitats and thereby genetic resources. The increased efficacy in cropping systems will lead to the second benefit: reduction in the fossil fuel input into agricultural production (Mannion, 1995). For rice, however, these proposed benefits are challenged by the increasing needs of a growing population which might make it necessary to use all available land for food production.

Major research efforts are being directed towards the development of herbicide-resistant field crops (Dekker and Duke 1995). The primary focus of this research is to incorporate genes that enable the host crop to be resistant to broad spectrum herbicides such as glyphosate and glufosinate. Both herbicides are considered environmentally benign in comparison to other chemicals already in use in such crops. Herbicide-resistant rice cultivars, including glufosinate-resistant (Datta et al. 1992), sulfonylurea-resistant rice (Li et al. 1992), immidazolinones and finally glyphosate resistant rice have already been developed and field tested (Table 2). The reason for the keen interest in developing herbicide resistant rice is to attain control of “red rice” (Americas) or “weedy rice” (Asia), as red and weedy rice cannot be controlled selectively in drill seeded rice (Gealy and Dilday, 1997).

There are obvious benefits to be gained by introducing herbicide resistant rice. It will provide the farmer with new efficient chemical options for weed control. Glyphosate and glufosinate targets both monocot and dicot weeds, which most likely will enable less use of herbicides in terms of amount and number of applications. These herbicides can be used in post-emergence at rates adjusted to the present weed infestation and spraying can be performed within a wider time frame due to their high efficacy. This makes the farmer less vulnerable to unfavorable weather conditions. Thus herbicide resistant rice could result in adequate control of hard-to-kill weeds such as weedy rice. Also weed populations already resistant to currently used herbicides could be controlled with these broad-spectrum herbicides.

Weed control with the herbicide to which a crop has been bred or transformed for resistance must be developed in relation to time of application, dose, crop phytotoxicity and integration with other herbicides or agronomic practices. Much of the research in this regard has been conducted with glufosinate-resistant rice.

Sequential applications of glufosinate (0.42 kg $ha^{-1}$) in early pre-emergence and at flooding provided almost complete control of red rice and other grasses, including *Echinochloa crus-galli* in glufosinate-resistant rice in Arkansas, USA, without crop injury to two transformed cultivars (Bengal or Cypress). However, one of the cultivars (Gulfmont) was severely affected by glufosinate (Wheeler et al. 1998). Environmental conditions influence the efficacy of glufosinate in glufosinate-resistant rice. Flooding reduced the efficacy of the herbicide under field conditions and more detailed studies under greenhouse conditions determined that glufosinate efficacy was reduced when red rice was submerged between 25% and 50% of its height. Plant height and dry weight of red rice plants increased as flood water depth increased regardless of glufosinate rate (Sankula et al. 1997a). Interestingly, in this study Gulfmont transgenic rice was not affected by glufosinate while “Koshihikari” lines were injured as much as 53%. Inconsistent grass control with glufosinate has also been observed in post-emergence applications to resistant soybean and corn (Ritter et al. 1998). The use of a pre-emergence grass herbicide in combination with one post-emergence glufosinate application gave a more consistent and season long control.

Glufosinate damage to transgenic rice is growth-stage dependent. Glufosinate (2.2 kg $ha^{-1}$) damage was greater when applied to young rice seedlings (one- to two-leaf growth stage) than to older seedlings (three- to four-leaf growth stage) under field conditions (Sankula et al. 1997b). When applied at the booth stage, crop injury from glufosinate was visually estimated from 3% to 14% but still resulted in a 16% yield penalty. Similar results were also reported by Griffin et al. (1999). According to Sankula et al. (1997b) the best control of red rice was obtained when it was applied at the three- to four-leaf stage; injury to red rice was up to 11 times higher than the injury caused to the transgenic cultivar. Glufosinate toxicity to transgenic rice also increased when it was applied in combination with either triclopyr or acifluorfen; the mixture with the former resulted in a yield reduction of up to 76% compared to glufosinate alone. Best red-rice control was obtained with a mixture of propanil (3.4 kg $ha^{-1}$) plus glufosinate (0.6 kg $ha^{-1}$) yet yield reductions varied between 17% and 28% compared to the weed-free control depending on the year (Sankula et al. 1997c). In glufosinate resistant corn, Berzsenyi et al (1998) concluded that adequate weed management requires multiple sprays with glufosinate in combination with herbicides with residual activity or mechanical.

In a greenhouse study, Zhang et al. (1999) showed that the survival rate of red rice treated with glufosinate, in several glufosinate-resistant rice lines, was less than 1% with seed production of the surviving red rice being reduced by 99%. However, Gealy & Dilday (1997) found differential susceptibility to glufosinate among red rice lines. A screening of 59 red rice samples from the rice growing area of Texas did not determine substantial differences in sensitivity to glufosinate although some accessions exhibited limited tolerance to the herbicide during the first days after application (Hessler et al. 1998).

Initial studies on weed control in imidazolinone resistant rice (IMI rice) were conducted with imazethapyr, a herbicide proven effective against red rice and other rice weeds when applied as a soil or foliar treatment. Season-long control (> 95%) of red rice was obtained with 70 g $ha^{-1}$ in post-emergence. Control obtained with pre-plant or pre-emergence applications was further improved if imazethapyr was sequentially applied in post-emergence with only minor (< 5%) crop injury (Hackworth et al. 1998). Imazethapyr also controlled *Brachiaria platyphylla* and *E. crus-galli* but did not provide adequate control of *Eclipta prostrata* and *Sesbania exaltata* (Dillon et al. 1998). Imidazolinone herbicides, especially imazethapyr, effectively controlled red rice in rice; when red rice densities were high (> 925 plants $m^{-2}$); best control was obtained with sequential applications of the herbicide (Sanders et al. 1998). These type of applications of imidazolinones, which are also used in the rotational crop (soybeans), may subject weed populations to excessive selection pressure with a group of chemicals that has proven resistant-prone. The situation would be aggravated if other herbicides with the same mode of action (sulfonylureas or pyrimidyl-oxybenzoates) were used to eliminate other grasses, broadleaf weeds, and sedges. First release of commercial varieties of IMI rice is anticipated for 2001 (Hackworth et al. 1998).

There is limited information about the development of glyphosate-resistant rice. Dilday *et al.* (1995) reported the evaluation of about 14000 rice accessions for glyphosate and sulfosate tolerance. Eight accessions were identified as tolerant to both herbicides, five of them originated from Colombia and one each from Brazil, India and the US. Accessions had brown to light-brown bran and long or medium grains. However, Monsanto is already testing transgenic glyphosate resistant rice accessions in field experiments[3]. No published results are yet available. Experience from other glyphosate-resistant crops indicate that, as being done with glufosinate- and imidazolinone-resistant rice, development research must be conducted before suitable application

[3] Http://www.isb.vt.edu/cfdocs/fieldtests3.cfm

techniques can be recommended to farmers. For example in glyphosate-resistant soybeans, red rice was controlled by glyphosate applied at several growth stages (two-leaf, four-leaf, and two- to three-tillers). However, seedhead production was substantially reduced only when glyphosate was applied at the latest growth stage because new seedlings emerged soon after the application at the two- and four-leaf stage (Askew *et al*. 1998).

Undoubtedly, the introduction of herbicide resistant rice will provide farmers with additional tools for controlling red rice and other weeds that either escape or are resistant to currently available herbicides. However, the long term benefits of herbicide resistant rice will depend on the judicious use of the broad spectrum herbicides, particularly when they would be also used in rotation crops or when products of equal modes of action are already being applied to rice fields. These conditions would be conducive to the evolution of herbicide resistant weeds although two of the herbicides being considered, glufosinate and glyphosate, are known to be “low risk” for resistance evolution. However, field-evolved glyphosate resistance has been already documented in a grass weed, *Lolium rigidum* (Powles et al. 1998). The most important concern, nevertheless, is the risk of red rice becoming resistant to these herbicides. Moreover, they required to be combined with residual herbicides, some of the benefits of herbicide-resistant rice become undermined.

**ASSESSING THE RISKS WITH HERBICIDE RESISTANT RICE**

Critical voices of herbicide resistant crops in general, are often raised. This is also true for herbicide resistant rice. Some of the criticisms are based on political and social statements, such as “herbicide resistant crops put the farmers in the pocket of the agrochemical industry”, which only briefly will be touched upon here in relation to the common practice among rice farmers of saving seeds from season to season. In the developing world, farmers keep seeds from season to season. This has been the traditional way to preserve their cultivars (land-races) which often have desirable characteristics. With modern cultivars this is practised as a money saving measure. Additionally, in some instances adaptation for local environment could have taken place also for modern cultivars, which makes the locally grown seeds better suited for the local environment. With herbicide resistant rice this practice might have to stop. Other glyphosate resistant crops have been accompanied with a “technology use agreement” (Monsanto) in which the farmer promise not to keep, sell or give away seeds for replanting purposes. If such an agreement falls in place for glyphosate resistant rice, farmers saving seeds might impose legal problems. Another way of protecting their profit is used by AgrEvo as they produce hybrid seeds and thereby the harvested seeds will be segregating. A third possibility is still in the pipeline and it is called “terminator gene”. This gene is supposedly to be inserted together with the herbicide resistant gene and will prevent the offspring from germinating. This technology would therefore totally stop the tradition of saving seeds for the next season. What will happen is still to be seen, but it is a possibility that herbicide resistant rice will become too expensive for rice farmers in the developing world.

This paper, however, will concentrate on biological constraints and risks likely to be associated with the introduction of herbicide resistant rice.
Whether herbicide resistant rice will create a problem depends on several conditions which all have to be included in a risk analysis addressing the following general questions which will be discussed in more detail below:

1. Will herbicide resistance among weeds increase as a result of increased selection pressure?

2. Can the resistance gene spread from the crop to weedy species/biotypes?
3. Will the resistant crop leave problematic volunteers in the field?
4. Will conventional tillage and weed control measures of that particular cropping system control potential resistant weeds (risk management)?
5. Within what time frame is weed resistance problems likely to occur?
6. How will herbicide use patterns be affected?
7. What options are the farmers left with in case of problems with resistant weeds?

**WILL HERBICIDE RESISTANCE AMONG WEEDS INCREASE AS A RESULT OF INCREASED SELECTION PRESSURE?**

Repeated use of herbicides with the same mode of action creates the risk of selecting a herbicide resistant weed population. Fifteen weed species associated with rice have evolved resistance to herbicides, including the most widely used compounds such as propanil and some of the most recently introduced families such as the sulfonylureas (Table 3).

Propanil has been used in rice for more than 40 years being widely recognised for its efficacy against species of *Echinochloa*, other grasses and several broadleaf weeds. However, resistant populations of junglerice (*Echinochloa colona*) were reported in Costa Rica in 1991 (Garro et al. 1991) and later in Colombia (Fischer et al. 1993) and in the rest of Central America (Garita et al. 1995). More recently, propanil-resistant junglerice populations were also found in Mexico (Villa-Casarez 1998). Resistance to propanil also has been documented in barnyardgrass in Greece (Giannopolitis and Vassiliou 1989), USA (Smith et al. 1992) and Sri Lanka (Marambe et al. 1997). Furthermore, junglerice also evolved resistance to fenoxaprop-*p*-ethyl in Costa Rica (Caseley et al. 1995) and Colombia (Valverde, unpublished); there are populations resistant to either propanil or fenoxaprop or both. Fenoxaprop-resistant junglerice is also resistant to cyhalofop-butyl, fluazifop-*p*-butyl, quizalofop, cycloxidim and sethoxydim (Caseley et al. 1995, 1997). Additionally, there are barnyardgrass populations resistant to butachlor and thiobencarb covering an estimated area of 2 million hectares in China (Huang and Gressel 1997). Watergrass (*E. phyllopogon*) populations resistant to fenoxaprop, thiobencarb, molinate y bispyribac were recently found in California (Fischer et al. 1999). Resistance to sulfonylureas and 2,4-D has evolved in aquatic or amphibious species associated with rice (Table 3).

Resistance to inhibitors of the enzyme acetolactate synthase (especially, sulfonylureas and imidazolinones) has been discussed widely in the literature because its rapid evolution and economical implications.. According to Croughan et al (1996) it was required to screen 300 million rice plants of different rice accessions to find two mutants resistant to imidazolinone herbicides. This indicates that the mutation frequency for sulfonylurea herbicide resistance in *O. sativa* could be estimated between $10^{-8}$ and $10^{-9}$. Mutation frequency for these groups of herbicides is normally estimated in about $10^{-6}$ (Chaleff and Day, 1984) yet this group of herbicides is responsible for most of the increase in resistance cases world-wide (Heap, 1999). This might indicate, however, that sulfonylurea resistance in weedy rice would require more time to evolve than in other weed species provided that selection pressure and other factors are equivalent.

If herbicide resistant rice is used exclusively, it becomes important to rotate the crop in such a way that herbicide treatments change from season to season. In areas where rice is grown in rotation with other crops herbicide rotation should be deployed to prevent development of herbicide resistant weeds.

**CAN THE RESISTANCE GENE SPREAD FROM THE CROP TO WEEDY SPECIES/BIOTYPES?**

Assessment to quantify the risk of development of herbicide resistant weedy rice has only been sparse so far and much more knowledge is needed to prevent resistance problems for the farmers of the developing world. Especially, since regulation of transgenic crops often is insufficient or lacking. Hybridisation potential varies among rice cultivars. In a study of hybridisation between cultivated rice and red rice Langevin et al. (1990) found hybridisation percentages ranging from 1% in the cultivar Lemont to 52% in Nortai. This again indicates that herbicide resistant weedy rice is likely to develop.

More can be learned from case studies of other herbicide resistant crops with similar features. For example, studies by Kerlan et al. (1992) indicated that the risk of gene dispersal resulting from outcrossing of transgenic glufosinate-resistant rapeseed with weedy *Brassica* spp. was limited, but Mikkelsen et al. (1996) demonstrated that when transgenic rapeseed was grown with a weedy relative, transgenic weed-like plants occurred after only two generations of hybridisation and backcrossing. These findings with rapeseed suggest that herbicide resistant rice and weedy rice may have the potential to hybridise and thereby conferring herbicide resistance to “weedy” rice within few generations therefore, the benefits of the herbicide resistance gene may only be short lived.

Multiple resistance in weedy rice *e.g*. biotypes with resistance to both glyphosate and glufosinate could become a problem if cultivars with the two resistance genes are grown in adjacent fields or if the cultivars succeed each other in the field and volunteer rice plants escape spraying.

An important question is whether or not the $F_1$-hybrids already posses the trait of seed dormancy or if dormancy is only present in second generation hybrids ($F_2$) or backcrosses ($BC_1$). If dormancy is not present in the $F_1$ a proper management strategy which enables the $F_1$ to germinate readily after the rice harvest may be sufficient to avoid build up of resistant weedy rice in the soil seed bank. However, Langevin (1990) found that rice X red rice hybrids did express dormancy.

In oilseed rape-*Brassica rapa* hybrids it has been documented that there is a significant fitness penalty in the $F_2/BC_1$ generations, which may explain why the two species can be retained as separate species despite potential high hybridisation frequencies (Hauser *et al*., 1998). Okuno (1999) found hybrid weakness in the $F_2$’s and later generations of two *O. sativa* cultivars. The two cultivars however where *japonica* and *indica* respectively and this could be the reason for lacking fitness in $F_2$’s . Other researchers have found that hybridisation of red rice and cultivated rice resulted in hybrids with a later flowering date (Langevin, 1990). Depending on which cultivar is grown in the next season the $F_1$ hybrids might flower too late to ever become a problem.

Continuos rice production is common in many regions, but alternating with another crop may prevent build up of resistant weedy rice, in the same way as for other herbicide resistant weeds.

The above aspects need to be addressed case by case for the local rice production system and weedy rice population in order to predict the likelihood of build up of resistant weedy rice. A first step in such research would be to address the weedy rice problem by examining where and why populations and infestations are increasing.

**WILL THE RESISTANT CROP LEAVE PROBLEMATIC VOLUNTEERS IN THE FIELD?**

Volunteers are crop plants from a previous crop that have germinated from seeds or vegetation. In general, volunteers are already a problem in current agriculture either acting as a weed in other succeeding crops with lower competitive ability or the volunteers can be a problem in crop of the same species because they contaminate the crop. Practical experience has shown that rice can be a problematic volunteer in *e.g.* succeeding vegetable crops. Introduction of glyphosate resistant rice varieties is likely to exclude the farmer from using glyphosate pre-sowing to control rice volunteers and the farmer will have to use either another grass herbicide (*e.g.* paraquat) or use mechanical control, which could not be feasible because of weather conditions. Volunteer rice in succeeding rice crop will only become a problem in production of certified seeds.

**WILL CONVENTIONAL TILLAGE AND WEED CONTROL MEASURES OF THAT PARTICULAR CROPPING SYSTEM CONTROL POTENTIAL RESISTANT WEEDS (RISK MANAGEMENT)?**

Farmers are already using post harvest spraying with a non-selective herbicide to control weedy rice seedlings. Some are using harrowing to further initiate germination weedy rice. Depending on the degree of dormancy in the hybrids this strategy may help to prevent resistance from becoming a problem in the weedy rice species. At this stage, however, it is hard to predict if current management strategies directed towards weedy rice will be sufficient.

**WITHIN WHAT TIME FRAME IS WEED RESISTANCE PROBLEMS LIKELY TO OCCUR?**

Our present knowledge about the consequences of growing herbicide resistant rice on a large scale is limited because it is based primarily on small scale releases and on expected similarities with current agricultural practices. These questions associated with occurrence of resistance in weedy rice can best be addressed experimentally by multi-year experiments, but these experiments are

costly, they may require approval of field releases and experience from practical growing of herbicide resistant rice may become apparent before the experimental results are ready.

As an alternative, a simulation model could integrate knowledge about herbicide-tolerant crops with known agricultural practices in order to predict the consequences of introducing different herbicide resistant rice cultivars in a particular rice production system. The model could indicate approximately when populations of volunteers or resistant hybrids with weedy rice will become a severe agronomic or environmental problem. This approach was used to test herbicide use and occurrence of resistance in weeds and volunteers in different scenarios with herbicide resistant oilseed rape (Madsen *et al*., 1999).

Experiences from the gene flow of other traits from cultivated rice to weedy rice can give an idea on how fast herbicide resistance will spread from rice to weedy rice. In the Philippines male-sterility was spread from breeding lines to weedy rice after 2 seasons of rice in the same field (Courtois, pers. comm). Again this indicates that resistance development in weedy rice could become a problem within a short time frame.

**HOW WILL HERBICIDE USE PATTERNS BE AFFECTED?**

Dose-response curves have previously been used to compare weed control with glyphosate to currently used in sugarbeet (Madsen & Jensen, 1995). Data obtained from herbicide sprayings on different common weeds (bioassay or field trials) can be evaluated with a logistic dose-response model (Streibig *et al.*, 1993) which allows for a comparison of rates to obtain a certain efficacy level. This approach will provide an indication of rate needed for a sufficient weed control based on weed infestation and local climatic conditions. Long term effects on herbicide use could be evaluated using the above mentioned simulation approach, however, it should be emphasised that such a model will need validation under suitable experimental conditions before any reliable predictions can be made about long-term consequences of growing herbicide resistant rice.

**AVAILABLE ALTERNATIVES TO HERBICIDE RESISTANT RICE**

There are several herbicides available for controlling weeds in rice, including weedy grasses. However, because weedy and red rice is the same species as cultivated rice and other weedy species also belong to the genus *Oryza*, all herbicides that are selective to cultivated rice are also ineffective to control these species. For example, the remarkable selectivity of propanil to rice is due to the activity of an aryl acylamidase (AAI) that hydrolyzes the herbicide to 3,4-dichloroaniline (DCA) and propionic acid in rice plants (Frear and Still 1968; Still and Kuzirian 1967; Yih et al. 1968). Selectivity of propanil to rice is achieved because most weeds have no AAI or, if present, the enzyme has a much lower activity compared to that of rice (Hoagland and Graf 1972). However, AAI is found in several wild species of the genus *Oryza* whose response to propanil is related to the activity of the enzyme; the species with low or absent AAI activity being easily controlled by the herbicide (Chen and Matsunaka 1990). Interestingly, greater AAI activity was found in A-genome species than in the most genetically distant species belonging to the Ridleyi and Meyeriana complexes. *O. brachyantha* (FF) and *O. australiensis* (EE) had no AAI activity. All species of the B, C, and D genomes exhibited AAI activity. In the case of *O. alta* and *O. latifolia* (both CCDD) AAI activity was related to foliar morphology: accessions with wide leaves had higher enzymatic activity than those with narrow leaves.

In the rice crop, red and weedy rice control, with herbicides, relies on non-selective products that can be used only if the crop does not come in contact with them or by extremely accurate timing when there is marginal selectivity. For example, glyphosate is used in several rice farms in Central and South America to eliminate red and weedy rice plants that usually outgrow those of the crop. The herbicide is applied only to the leaves and emerging panicles of undesirable plants with a rope wick or by hand with a sponge moistened with a concentrated solution. Kwon et al. (1991) controlled red rice in water- and drill-seeded rice by 79% and 49%, respectively, by pre-plant incorporation of molinate. Control was improved to 94% and 86% in the two cultures when fenoxaprop was applied in late post-emergence (panicle initiation of commercial rice). Sethoxydim at panicle initiation as well as the growth regulators maleic hydrazide (applied 7 days after heading) or amidochlor (applied at >90% heading) also improved red rice control. The authors did not indicate the growth stages of red rice, at the time of application of the herbicides or growth regulators, but injury to rice must be prevented by timing applications when red rice is in susceptible stages but commercial rice is in tolerant stages. If this timing is wrongly applied late applications can prevent grain filling in the crop. Synchronous maturity between the commercial variety (CR-1113) and red rice did not allow selective red rice control in separate trials with mefluidide and maleic hydrazide in Costa Rica (Valverde unpublished).

Fischer (1996) reviewed available tactics for integrated red rice management in Latin America, a subcontinent with diverse rice ecosystems and socioeconomic conditions, which would ultimately determine the feasibility of a range of control options under different conditions. Therefore, should the weed management principles discussed by Fischer (1996) be relevant for similar production systems elsewhere. Among alternatives to control red rice, emphasis should be placed on the use of weed-free, certified seed. Most tropical countries allow some weedy or red rice contamination in certified rice seed. Additionally farmers frequently save or share their own seed aggravating the dispersal of red and weedy rice (Fischer 1996).

Pre-plant herbicides are also widely used for weedy rice control. In Latin America is common to delay rice planting to allow control of red rice with glyphosate or oxyfluorfen or both. Stale seedbed preparation is widely adopted in Colombia (Fischer 1996). Newly introduced herbicides such as oxadiargyl are now being used applied on standing water to eliminate red rice. Time that should be allowed for dissipation of residual activity by this type of herbicides varies with soil and local conditions. Sometimes, the effect of herbicides can be supplemented or substituted by shallow harrowing. In Italy, comparable red rice control was obtained with mechanical and chemical (dalapon) control (Ferrero *et al*. 1999). In Spain, puddling significantly reduced red rice panicle density (Catalá 1995).

Agricultural practices can have a severe impact in red and weedy rice infestations. Foloni (1995) describes an interesting example from Brazil. In the major irrigated-rice production areas (states of Rio Grande do Sul, Santa Cataria, Paraná, and São Paulo) red rice had not been a problem until the late 60s and early 70s when an IR-type rice variety was introduced. The variety had a longer life cycle than the traditional ones (Lebonet and Blua bela) allowing red rice to shatter its seed before commercial rice harvesting. Over the years populations increased to an average infestation of 95% of the 800000 ha planted in Rio Grande do Sul, one-third of which are heavily infested.

In Brazil, approximately 300 000 ha of rice are planted under the minimum and no-till system. After the soil is prepared (minimum tillage) or before planting (no-till) glyphosate is used to eliminate weedy rice already 25-30-cm tall, whose germination had been promoted by irrigation. As the soil is not inverted, excellent control is achieved before planting the rice crop (Foloni 1995).

Other agronomic practices may increase or take advantage of the competitiveness of the crop against the weeds. But unfortunately, red and weedy rice is usually more competitive than the crop (Fischer and Ramirez 1993). Increasing seeding rate of cultivated rice from 50 kg $ha^{-1}$ up to 150 kg $ha^{-1}$ had only a minor effect on red rice seed production in field tests in Arkansas (Estorninos et al. 1998).

Crop rotation also plays an important role in controlling weeds closely associated with one of the crops, such as red rice in rice. In the United States, red rice is usually controlled in rotation crops, especially soybean and sorghum. Growers typically rotate out of rice and into soybeans for one growing season to limit red rice infestations in the subsequent rice crop (Askew et al. 1998). In the rice crop, control depends on a combination of pre-emergence chemicals and cultural practices but control is frequently ineffective (Sanders et al. 1998).

When herbicide resistant red and weedy rice develop these other herbicides and cultivation practices will have to be used. There is no reason to believe that herbicide resistant weedy rice will have a fitness penalty and thereby disappear by itself. Once it is there, other control options must be in place to reduce the impact of red and weedy rice.

**CONCLUSION**

Herbicide resistant rice gives us an opportunity to control weedy and red rice in rice. Also grass weeds can be better controlled than with the available management strategies. This option, however, could become short-lived as a result of development of herbicide resistant weedy or red rice populations. Conventional control measures will, in such case, still be working in most cases, and therefore, is herbicide resistant rice not a threat *per see*. More knowledge on weedy and red rice biology is needed to get a thorough understanding of the impact of implementing herbicide resistant rice. This is especially true for Asia and South and Latin America, where very limited work have been done on weedy rice biology.

Herbicide resistant rice could become very expensive technology to use because of the need to buy seeds every year. This might prevent the success of herbicide resistant rice in the developing world.

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Table 2. Herbicide resistant genetically modified rice field tested in 1996-1999 (http:77www.nbiap.vt.edu/cfdocs/globalfieldtests.cfm).

| Herbicide | Company | Gene | Country | Number of field trials |
|---|---|---|---|---|
| Glyphosinate | AgrEvo | BAR | Argentina[1] | 1 |
| | AgrEvo | BAR | Italy | 1 |
| | AgrEvo | BAR | Japan | 2 |
| | Louisiana State Uni. | 1. Phosphinothricin acetyl transferase<br>2. B-glucuronidase<br>3. Hygromycin phosphotransferase | USA | 18 |
| | AgrEvo | 1. Phosphinothricin acetyl transferase<br>2. Hygromycin phosphotransferase | USA | 7 |
| | AgrEvo | Phosphinothricin acetyl transferase | USA | 35 |
| | USDA-ARS | 1. Phosphinothricin acetyl transferase<br>2. B-glucuronidase | USA | 1 |
| Imidazolinone | American Cyanamid | Acetohydroxyacid synthase variant | USA | 5 |
| Glyphosate | Monsanto | EPSPS | USA | 13 |
| | Monsanto | CBI | USA | 32 |

1. Only up until 1998

**Table 3. Weeds associated with rice that have evolved resistance to herbicides[1].**

| | Species | Botanical family | Life cycle | Herbicide to which resistance evolved | Country | References |
|---|---|---|---|---|---|---|
| 1 | *Alisma plantago-aquatica* | Alismataceae | Perennial | Bensulfuron | Portugal | Calha et al., 1997 |
| 2 | *Cyperus difformis* | Cyperaceae | Annual | Bensulfuron | Australia | Graham et al. 1994 |
| | | | | | USA | Pappas-Fader et al 1993 |
| 3 | *Damasonium minus* | Alismataceae | | Bensulfuron | Australia | |
| 4 | *Echinochloa colona* | Poaceae | Annual | Propanil | Central America | Garita et al. 1995 |
| | | | | | Colombia, Mexico | Fischer et al. 1993 |
| | | | | Fenoxaprop | Costa Rica | Villa-Casarez 1998. |
| | | | | | | Caseley et al. 1995 |
| 5 | *Echinochloa crus-galli* | Poaceae | Annual | Propanil | Greece, USA, Sri Lanka | **Giannopolitis and Vassiliou 1989** **Smith et al. 1992, Marambe et al. 1997** |
| | | | | Butachlor, Thiobencarb | China | Huang and Gressel 1997 |
| 6 | *Echinochloa phyllopogon* | Poaceae | Annual | Fenoxaprop, Molinate, Thiobencarb, Byspiribac | USA | Fischer et al 1999 |
| 7 | *Fimbristylis miliacea* | Cyperaceae | Annual | 2,4-D | Malaysia | Watanabe et al. 1997 |
| 8 | *Limnocharis flava* | Butomaceae | Perennial | 2,4-D | Indonesia | Heap 1999 |
| 9 | *Limnophila sessiliflora* | Scrophulariaceae | Perennial | Sulfonylureas | Japan | Itoh and Wang 1997 |
| 10 | *Lindernia dubia, L. dubia var. major* | Scrophulariaceae | Annual | Sulfonylureas | Japan | Itoh and Wang 1997 |
| 11 | *Lindernia micrantha* | Scrophulariaceae | Annual | Sulfonylureas | Japan | Itoh and Wang 1997 |
| 12 | *Lindernia pyxidaria* | Scrophulariaceae | Annual | Sulfonylureas | Japan | Itoh and Wang 1997 |
| 13 | *Monochoria korsakoii* | Pontederiaceae | Annual | Sulfonylureas | Japan | Wang et al. 1997 |
| 14 | *Sagittaria montevidensis* | Alismataceae | Perennial | Bensulfuron | Australia | Graham et al. 1994 |
| | | | | | USA | Pappas-Fader et al 1993 |
| 15 | *Sphenoclea zeylandica* | Sphenocleaceae | Annual | 2,4-D | Malaysia | Itoh 1994 |
| | | | | | Philippines | Sy and Mercado 1983, Mingo et al. 1986 |

**Table 1. Species of the genus *Oryza* with their respective genome and distribution, grouped according to genomic complexes[1].**

| Species | Genome | Distribution |
|---|---|---|
| <u>*Oryza sativa* complex</u> | | |
| *O. sativa L.* | AA | Worldwide, cultivated |
| *O. nivara Sharma et Shasty* | AA | Tropical and subtropical Asia |
| *O. rufipogon* Griff. (=*O. perennis* Moench) | AA | Tropical and subtropical Asia, tropical Australia. |
| *O. glaberrima Steud.* | AA | West Africa, cultivated |
| *O. barthii* A. Chev (=*O. breviligulata* A. Chev. et Roehr) | AA | Africa |
| O. glumaepatula *Steud.* | AA | Central and South America |
| *O. longistaminata* A. Chev. Et Roehr. | AA | Africa |
| ***Oryza officinalis* complex** | | |
| *O. punctata* Kotschy ex. Steud. (2n = 24) | BB | Africa |
| *O. punctata* Kotschy ex. Steud. *(2n = 48)* | BBCC | Africa |
| *O. minuta* J. S. Pesl. ex. C. B. Presl. | BBCC | Philippines and Papua New Guinea |
| *O. malamphuzhaensis* | BBCC | India |
| *O. officinalis* Wall ex. Watt | CC | Tropical and subtropical Asia, tropical Australia |
| *O. rhizomatis* Vaughan | CC | Sri Lanka |
| O. eichingeri *A. Peter* | CC | South Asia and East Africa |
| *O. alta* Swallen | CCDD | Central and South America |
| *O. grandiglumis* (Doell) Prod. | CCDD | Central and South America |
| *O. latifolia* Desv. | CCDD | Central and South America |
| *O. australiensis* Domin. | EE | Tropical Australia |
| Oryza meyeriana *complex* | | |
| *O. granulata* Nees et Arn. ex. Watt | GG | South and Southeast Asia |
| *O. meyeriana* (Zoll. et Mor. ex Steud.) Baill. | GG | Southeast Asia |
| *O. indandamanica* | GG | India |
| ***Oryza ridleyi* complex** | | |
| *O. ridleyi* Hook. f. | HHJJ | South Asia |
| *O. longiglumis* Jansen | HHJJ | Irian Java, Indonesia, Papua New Guinea |
| *Unclassified* | | |
| *O. brachyantha* A. Chev. et Roehr. | FF | Africa |

[1]Compiled from information presented by Aggarwal et al (1999, 1997), Khush (1997), and Oka (1991). Superscripts were not used in designating genomes following the recommendation of Lu et al. (1998).

# CONCLUSIONS AND RECOMMENDATIONS
# CONCLUSIONES Y RECOMENDACIONES

1. There is an evident increase in red rice incidence in many rice producing countries, due to the increase of direct-seeded areas.

2. The Global workshop suggests using the term weedy/ red rice instead of red rice because there are several biotypes with white pigmentation which interfere with rice cropping.

3. Most of the countries attending the global workshop have data on different biotypes of weedy/red rice and their characterization. It is extremely important that all countries affected by this pest make efforts to characterize existing biotypes and their behaviour in field conditions, data that will later serve to improve measures for the control of this weed.

4. There are others countries where the magnitude of the problem posed by weedy/red rice has not been estimated and/or studied, e.g. Senegal and other countries in West Africa. However, in these countries studies have been carried out regarding the negative incidence of some endemic wild *Oryza* species, such as *O. barthii, O. longistaminata* and *O. punctata*.

5. There is no simple method for the control of weedy/red rice. Only through integrated control approach reduction of weedy/ red rice infestation can this be effectively achieved.

6. The main sources of weedy/red rice infestation are rice seeds contaminated with weed seeds and weedy/red rice seed bank in soil. Therefore any control measure should be aimed at reduction of infestations from these sources.

7. In some countries the presence of some weedy/red rice seeds is tolerated in rice seeds. However, experience on the control of this weed from other countries that use advanced technologies shows that not even one single weedy/red rice seed should be tolerated in rice seeds.

8. National institutions and those in charge of seed production should make every effort to produce rice seeds free of weedy/red rice seeds. It is also important to create awareness at the rice farmer level about the incidence of weedy/red rice and the importance of its control in order to improve yields and yield quality and to increase incomes.

9. The reproduction of basic and foundation seed should be carried out in areas that are totally free of weedy/red rice infestation. Certified rice seeds should be free of weedy/red rice seeds.

10. Control measures against weedy/red rice in the field are diverse and their implementation will depend on the specific site conditions. However, any control measure should be aimed at reduction of weedy/red rice seed bank in soil in the medium or long term.

11. To date the most efficient control measures have been those based on the combination of wet soil preparation to bring about the emergence of weedy/red rice seeds, followed by the application of herbicide over the weed stand and before rice seeding, e.g. glyphosate, and water management before and after seeding.
12. Under upland and irrigation conditions, it is advisable to implement, whenever possible minimum tillage or zero tillage combined with the use of non-selective herbicides. This practice is cheap and sustainable by rice farmers.

13. For better development of weedy/red rice control it is important to determine the socio-economic factors affecting the adoption of some optimal control measures.

14. Within the context of integrated management it is necessary to conduct regular studies of the behaviour of available rice cultivars in terms of their ability to compete with weedy/red rice, life-cycle and tolerance to submersion during flooding.

15. The use of post-emergence herbicides in the process of land preparation needs improvement. It is necessary to find other chemical alternatives in order to avoid repeated use of the same chemical. This also applies to post-harvest application in rice areas.

16. The socio-economic feasibility of crop rotation in areas with high infestations of weedy/red rice should be studied in order to improve the methods for controlling the weed and also preserving soil fertility.

17. It is also advisable to make a more in-depth study of the effect of water management and fertiliser application on weedy/red rice infestations in different soil conditions.

18. Generally all research on this topic should aim at sustainable reduction of weedy/red rice seed bank in soil through integrated control procedures.

19. A web page on weedy/red rice is considered a good option for good exchange of experiences on this area of pest management. The workshop suggested locating this web page at the University of Turin, Italy, under the leadership of Dr Aldo Ferrero, possibly financed by the European Union project on weedy rice. This web page could have as its main objective the publication of a database of the institutions, personnel and available results on weedy/red rice control.

20. The need to develop more activities related to farmer's education on weedy/red rice control is evident. To this end, it was suggested that technical assistance could be given by FAO to implement a regional project (e.g. in Latin America). It is obviously important that relevant authorities from the countries give priority to the solution of this problem in rice and officially request assistance from FAO.

21. Due to the magnitude of the weedy/red rice problem in several countries and its increased incidence, it was suggested that working groups on this subject be set up within the framework of existing weed societies, such as IWSS, EWRS, SWMH and others. Such working groups should stimulate research in order to find new control solutions.

1. Existe un incremento sustancial de la incidencia del arroz rojo en los países productores de arroz, lo cual está dado por el incremento de las áreas de siembra directa en muchos países.

2. El taller global sugiere llamar arroz maleza/rojo en lugar de solo arroz rojo, ya que existen biotipos de pigmentación blanca que interfieren con la producción del arroz cultivable.

3. Una mayoría de los países que asistieron al taller global poseen datos sobre la diversidad de biotipos de los arroces malezas/rojos y su caracterización. Es importante que los países afectados por este problema realicen esfuerzos en función de caracterizar los biotipos existentes y su comportamiento en el campo, datos que servirán posteriormente para mejorar las medidas de control de esta plaga.

4. Existen otros países, donde aun no se ha cuantificado la magnitud del problema de arroz maleza/rojo, por ejemplo Senegal y otros de Africa Occidental. No obstante, en estos países se han hecho estudios y se disponen de datos sobre la incidencia negativa de especies salvajes endémicas de *Oryza*, como es el caso de *O. barthii, O. longistaminata* y *O. punctata*.
5. No existe una medida sencilla de control del arroz maleza/rojo. Solo a través de procedimientos integrales de control, se podrá reducir efectivamente la población de arroz maleza/rojo.
6. Dos son las fuentes de infestación del arroz maleza/rojo: las semillas de arroz cultivable contaminadas de arroz maleza/rojo y el banco de semillas de ésta última en el suelo. Por lo que las medidas de control deben ir dirigidas a atacar estas fuentes de infestación.

7. En algunos países se acepta alguna presencia de semillas de arroz maleza/rojo en las semillas del arroz cultivable. Sin embargo, la experiencia de otros países más avanzados en el control de esta plaga, es que no se debe admitir ni una semilla de arroz maleza/rojo en las semillas de arroz cultivable.

8. Las instituciones nacionales y aquellas encargadas de la producción de semillas deben hacer un esfuerzo por producir semillas libres de granos de arroz maleza/rojo. También es necesario crear una conciencia al respecto en el ámbito del productor de arroz, para que así mejore sus rendimientos, la calidad de los mismos, así como sus ingresos.

9. La reproducción de semilla básica y de fundación de arroz debe realizarse en lotes libres de infestación de arroz maleza/rojo. La semilla certificada debe estar totalmente libre de arroz rojo.
10. Las prácticas de control de arroz maleza/rojo en campo son variadas y dependen de las condiciones específicas de cada lugar. No obstante, toda medida debe ir dirigida a reducir el banco de semillas de arroz maleza/rojo en los campos a mediano o largo plazo.

11. Hasta ahora las mejores medidas han resultado ser la combinación de la preparación húmeda del suelo para provocar la emergencia temprana de plántulas de arroz maleza/rojo, seguido del uso de herbicidas en pre-siembra, por ejemplo, glifosato, y el manejo del agua antes y después de la siembra.
12. Para las condiciones de secano y bajo riego, se debe utilizar la labranza reducida o la cero labranza con el uso de herbicidas no selectivos, como una alternativa sostenible y de bajo costo.
13. Para un mejor desarrollo del manejo de arroz maleza/rojo es importante determinar los factores socio-económicos que afectan la adopción de medidas óptimas de control.
14. Dentro del contexto del manejo integrado es necesario realizar estudios regularmente sobre el comportamiento de las distintas variedades de arroz en lo relativo a su habilidad competitiva, ciclo de vida y tolerancia de sumersión durante la inundación del campo.

15. Susceptible de mejorar es aun la práctica de uso de herbicidas pos-emergentes en el proceso de preparación del terreno. Se deben buscar otras alternativas químicas que eviten el uso de un mismo herbicida repetidamente. Lo aquí apuntado es igualmente valido para los tratamientos herbicidas de pos-cosecha.

16. La factibilidad socio-económica de la rotación de cultivos en áreas con fuertes infestaciones de arroz maleza/rojo debe ser estudiada como vía que ayude a mejorar los métodos de control y a preservar la fertilidad del suelo.

17. Se debe profundizar aun más en los estudios de manejo del agua y los fertilizantes, y su influencia sobre las infestaciones de arroz maleza/rojo en los distintos suelos.

18. En general toda investigación debe dirigirse a lograr una reducción sostenible de la infestación de arroz maleza/rojo en el banco de semillas mediante procedimientos de manejo integrado.

19. La creación de una página web sobre arroz rojo/maleza se considera como una buena opción para profundizar en el intercambio de experiencias en el manejo de esta plaga. El taller sugirió la posibilidad de disponer de esta página web en la Universidad de Turin bajo la dirección del Dr. Aldo Turin y con posibles fondos de la Unión Europea. Esta página web puede tener como objetivo principal el publicar una base de datos sobre instituciones, personal y resultados disponibles en materia de control de arroz rojo/maleza.

20. Se ha evidenciado la necesidad de desarrollar más actividades de capacitación al agricultor en materia de control de arroz rojo. A tales efectos se sugirió la posibilidad que la FAO preste asistencia técnica en este aspecto a través de la implementación de un proyecto regional. Para lograr tales objetivos es primordial que las autoridades de la agricultura de los países entiendan como una prioridad la búsqueda de una solución a este problema y soliciten oficialmente a la FAO la asistencia en cuestión.
21. Por la magnitud deI problema de arroz rojo en muchos países del mundo y por ser su incidencia creciente, se sugirió la posibilidad de crear grupos de trabajo en sociedades científicas dedicadas al manejo de malezas, como IWSS, EWRS, SWMH y otras. Tales grupos de trabajos estimularían la investigación en el tópico y la búsqueda de nuevas soluciones.

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