PEST FACT SHEET

Oryza rufipogon Griff.

Oryza rufipogon is a vigorous, strongly competitive plant, which is difficult to eradicate. Infestations of this wild rice reduce yield and lower the grade of cultivated rice. Although its presence does not change the taste or nutritional value of commercial rice, consumers regard it's presence as foreign particles in the otherwise white rice. A severe problem in cultivated rice, *O. rufipogon* is so similar to the crop vegetatively that it cannot be identified and removed before it flowers, by which time it will have been competing with the crop for many weeks. It subsequently sheds most of its seed before harvest and contributes little or nothing to the overall grain yield. A significant amount of taxonomic confusion surrounds this species which is not known to occur in Canada or Mexico and, according to some authors is only found in a single US state - Florida. *Oryza rufipogon* is unlikely to be associated with cereal grains other than rice.

Preferred Scientific Name *Oryza rufipogon* Griff.

Other Scientific Names *Oryza aquatica* Rosh.
Oryza cubensis Eckman ex Gotoh & Okura
Oryza fatua J. Koenig ex Trin., nom. nudum
Oryza formosana Masamune et Suzuki
Oryza glumaepatula Steud.
Oryza paraguayensis Wedd. ex E. Fourn.
Oryza sativa subsp. *rufipogon* (Griff.) de Wet
Oryza sativa var. *abuensis* G. Watt
Oryza sativa var. *bengalensis* G. Watt
Oryza sativa var. *coarctata* G. Watt
Oryza sativa var. *fatua* Prain
Oryza sativa var. *paraguayensis* Parodi
Oryza sativa var. *rubribarbis* Desv.
Oryza sativa var. *rufipogon* (Griff.) G. Watt
Oryza sativa var. *savannae* Körn.
Oryza sativa var. *sundensis* Körn.

Common Names English - brownbeard rice, common wild rice, wild rice, perennial wild red rice, red-bearded rice, red rice, wild red rice
Australia - arrozrana, jingirra, wild rice
Brazil - arroz-preto, arroz-vermelho
Indonesia - padi burung, padi hantu
India - birhni, karga,reesa
Laos - khao nok, khao pa
Malaysia - padi hantu, padi yang
Thailand - khao phee

Notes on Taxonomy and Nomenclature

The genus *Oryza* is classified under the tribe Oryzeae, subfamily Oryzoideae. This genus has two cultivated species (*O. sativa* L. and *O. glaberrima* Steud.) and more than 20 wild species distributed throughout the tropics and subtropics. The genus *Oryza* probably originated about 130 million years ago in Gondwanaland and species were distributed amongst different continents when Gondwanaland split up. Perennial and annual ancestors of *O. sativa* are *O. rufipogon* and *O. nivara* (Khush, 1997).

There are wild, weedy and domesticated races of most crop plants. The wild races can survive without man, the weedy ones survive because of man and the domesticated races demand care and cultivation for survival (Harlan 1976). According to a review of *Oryza* species by Takeoka (1962), *O. rufipogon* is considered to be a progenitor of *O. sativa*, and together with *O. longistaminata* and *O. sativa* forms the *O. sativa* complex. Takeoka used the name *O. barthii* for O. longistaminata, but that name now refers to the annual wild rice species of West Africa. Takeoka (1962, 1963) made a comprehensive study of the group, resolving much of the confusion that had previously existed. Analysing awn length, lifespan and root type, characters that had previously been used, he characterized the *O. sativa* complex, and found that they were also divided geographically. In a recent review of the genus, Khush (1997) suggests that the name O. *nivara* should be retained for the annual forms of the wild (shattering) rice in Asia.

The degree of shattering observed in wild and weedy rice is much higher than that exhibited by shattering (shedding) genes in cultivated rice. There are a number of loci controlling seed shedding with major and minor effects. When major genes are involved, shedding is dominant over non-shedding. The occurrence of shedding segregants from crosses between non-shedding parents suggests complementary action between loci (Tang and Morishima 1988).

The grains of wild rice ripen earlier and less regularly than those of cultivated rice and are extremely prone to shattering. The stem of wild rice is comparatively more brittle and round in cross section than that of cultivated rice; the surface of the leaf sheath of wild rice is softer and spongier than that of cultivated rice; leaves are generally narrower, deep green and occur at short intervals on the stem and wild rice plants generally have a spreading habit and flower earlier than cultivated rice plants (Angiras and Singh 1985).

Before Takeoka's work, the Asiatic individuals were known as *O. fatua* (*O. sativa* var. *fatua*, *O. sativa* forma *spontanea*) or *O. rufipogon*. American plants were listed as *O. perennis*. African individuals were referred to as *O. longistaminata* or *O. perennis*. However Takeoka redefined the complex and indicated that the Asiatic plants should be included in one species as indicated by Bor (1960) and the correct specific name for them is *O. rufipogon*. As the American plants had no clear distinction from the Asiatic plants in terms of awn length and rhizomes, he also called them *O. rufipogon*. However, African plants were separated from *O. rufipogon* as a different species, called *O. longistaminata*, on account of their different underground systems.

A key for separating the complex makes use of spikelet characters. *O. sativa* has persistent spikelets, *O. rufipogon* has deciduous spikelets and *O. longistaminata* is perennial with creeping and branched rhizomes (Bor 1960, Takeoka 1963). Second (1985), using isoenzyme analysis, described an *O. rufipogon* complex with geographical forms separated from South Asia, China, Papua New Guinea, Australia and the Americas.

O. rufipogon and *O. sativa* intercross and have a high rate of natural crossing. There are considered to be numerous intergradations between the two species (Chang *et al.* 1982). Sometimes hybrid swarms are produced and the hybrids show no sterility. In contrast to wild plants, domesticated rice cultivars are characterized by a low rate of seed shedding at maturity, a low degree of seed dormancy, synchronous heading, self-pollination and high grain yield (Oka 1991). Hybridization and backcrossing between perennial wild rice and cultivated rice has created a highly variable range of weedy perennial wild rice types, including annual types, resulting in much taxonomic confusion.

Rao *et al.* (1997) found interspecific hybrids between cultivated rice and *O. rufipogon* and *O. nivara* in six populations in roadside ditches, isolated ponds, canals and rice fields in Laos. It is suggested that gene flow occurred from the cultivated to the wild species. Hybrids resembled the cultivated forms for most morphological characters until flowering, where they developed conspicuous panicle and grain characters, which resembled the wild species, and red or purple bristles of intermediary length. In China, high genetic diversity occurred in *O. rufipogon* populations from Guigang in Guangxi growing adjacent to cultivated rice fields, and it is suggested that this was due to the flow of genes from these neighbouring cultivated rices (Cai *et al.* 1996).

Khush (1997) reviewed the genus and defined *O. rufipogon* in the narrowest sense as a perennial, restricted to Asia from Pakistan to China and Indonesia, and tropical Australia. He uses the name *O. nivara* for the wild annual species, also of Asia, intermediate between *O. rufipogon* and *O. sativa*. All three species have the same AA genome and are not readily distinguished other than by their annual / perennial character and deciduous/non-deciduous spikelets. Following Khush's usage, many of the records and illustrations of *O. rufipogon* in the literature should be more correctly attributed to *O. sativa* (or *O. nivara*).

On the basis of RFLP analysis of nuclear DNA, Sun *et al.* (1997) suggested that common wild rice from China could be classified into three types: primitive types, indica-like types and japonica-like types. The genetic diversity found among Chinese wild rice accessions was related to their geographical distribution.

Juliano *et al.* (1998) compared the morphological variation of 26 diploid *O. glumaepatula* accessions from South America and Cuba, held in the International Rice Genebank at IRRI, with that of *O. rufipogon* and *O. nivara* from Asia. Sixteen spikelet and grain, eight leaf and culm, and four panicle characters were analysed using principal component analysis and hierarchical agglomerative cluster analysis. Most of the accessions from South America were quite distinct from O. rufipogon, with which they have often been grouped as a single species in some taxonomic treatments. Their study supports a distinct taxonomic status of a group of diploid wild rices from South America as *O. glumaepatula*. Naredo *et al.* (1988) confirmed *O. glumaepatula* as an independent species.

The great morphological variation in the genus *Oryza* causes taxonomic difficulties. Due to widespread misuse of the name *O. rufipogon* and the difficulty of distinction between closely related taxa, this Fact Sheet interprets the name in the broadest sense to include the many forms of annual 'red rice', 'black rice' and 'wild rice', as well as the strictly perennial *O. rufipogon* of South-East Asia.

Habitat

A tufted wild rice, *O. rufipogon* grows in shallow water, irrigated fields, pools, ditches and sites with stagnant or slow, running water. It occurs at altitudes from 0 to 1000 m and is suited to sites that support populations of cultivated rice.

Distribution List

Asia

Afghanistan - present, no further details (Holm *et al.* 1979)
Bangladesh - restricted distribution (Holm *et al.* 1979, Moody 1989, EPPO 2002)
Cambodia - present, no further details (Moody 1989)
China
- Fujian (Pang 1992)
- Guangdong (Pang 1992)
- Guangxi (Pang 1992)
- Hong Kong (Holm *et al.* 1979)
- Hunan (Pang 1992)
- Jiangxi (Pang 1992)
- Taiwan (Chang, 1975)
- Yunnan (Pang 1992)

India
- Andhra Pradesh (Chang 1975)
- Assam (Chang 1975)

Bihar (Chang 1975)
Karnataka (Chang 1975)
Madhya Pradesh (Chang 1975)
Orissa (Chang 1975)
Tamil Nadu (Chang 1975)
Uttar Pradesh (Chang 1975)
West Bengal (Chang 1975)
Indonesia (Chang 1975)
Irian Jaya (Chang 1975)
Java (Chang 1975)
Kalimantan (Chang 1975)
Sulawesi (Chang, 1975)
Iran (Holm *et al.* 1979)
Iraq (Holm *et al.* 1979)
Korea, DPR (Holm *et al.* 1979)
Korea, Republic of (Holm *et al.* 1979)
Laos (Moody 1989)
Malaysia (Moody 1989)
Peninsular Malaysia (Chang 1975)
Myanmar (Chang 1975, Moody 1989)
Nepal (Moody 1989)
Pakistan (Moody 1989)
Philippines (Chang 1975, Moody 1989)
Sri Lanka (Chang 1975)
Thailand (Chang 1975)
Vietnam (Moody 1989)

Africa

Egypt (Holm *et al.* 1979)
Senegal (Holm *et al.* 1979)
Swaziland (Parker & Dean 1976)
Tanzania (Chen 2001)

North America

USA
Florida (Westbrooks & Eplee 1988)
Hawaii (Holm *et al.* 1979)
Louisiana (Smith 1981)
North Carolina (Smith 1981)
South Carolina (Smith 1981)
Texas (Smith 1981)

Central America

Costa Rica (Holm *et al.* 1979)
Honduras (Holm *et al.* 1979)
Jamaica (Holm *et al.* 1979)

South America

Brazil (Abud 1981)
Espirito Santo (Lorenzi 1982)
Goias (Lorenzi 1982)
Minas Gerais (Lorenzi 1982)
Matto Grosso do Sul (Lorenzi 1982)
Matto Grosso (Lorenzi 1982)

Parana (Lorenzi 1982)
Rio de Janeiro (Lorenzi 1982)
Rio Grande do Sul (Lorenzi 1982)
Santa Catarina (Lorenzi 1982)
Sao Paulo (Lorenzi 1982)
Colombia (Takeoka 1963)
Ecuador (Takeoka 1963)
Guyana (Takeoka 1963)
Peru (Holm *et al.* 1979)
Venezuela (Takeoka 1963)

Oceania

Australia
Australian Northern Territory (Calder *et al.* 1999)
Queensland (Neldner *et al.* 1997)
Papua New Guinea (Takeoka 1963)

Distribution Notes

A native of Asia, *O. rufipogon* is widely distributed in the tropics and subtropics except Africa (Takeoka 1963). According to Hall (1990), the only known population of *O. rufipogon* in the USA occurs in the Florida Everglades. This weedy form of rice differs from weedy forms of *O. sativa* in having a pronounced rhizome and being perennial. The red rices that occur in "Louisiana, Arkansas and California", USA, are annual forms of *O. sativa*. No known populations of perennial wild rice have ever been found in California. Previous populations of perennial wild rice hybrids in the Sacramento Valley have been eradicated (California Department of Food and Agriculture 2001).

No records have been located for this weed in Canada or Mexico.

Biology and Ecology

O. rufipogon is a close relative of cultivated rice, *O. sativa*, and shares many of the characteristics of the crop. It is tolerant of flooding and acid soils (Mandal and Gupta 1997). Vital differences from the crop are the tendency for the seeds to shatter as soon as they are mature and their often prolonged dormancy. Like the crop, the seeds are unable to germinate in saturated soil. Chen (2001) reported that the number of wild rice seeds in a soil sample 1m² x 15 cm deep ranged from 10 to 30,000. After harvest and before disk harrowing, 84.4% seeds remained in the 0 - 3 cm surface layer of soil. Disk cultivation helped move the seeds downward to the 3 - 15 cm soil layer resulting in serious infestations and control difficulties.

O. rufipogon seeds are typically dormant at maturity. Dormancy is partly due to the presence of inhibitors in the seed coat. The seed may remain dormant and viable for up to 3 years or more under field conditions, depending on the biotype and environment. Many seeds decay during long periods of flooded conditions. Germination typically occurs between 15 and 40°C. Seeds often germinate slightly sooner and at lower temperatures than commercial rice seeds. Some biotypes emerge from soil depths of up to 12 cm (California Department of Food and Agriculture 2001). Chen (2001) reported that in a pot experiment, 98% of *O. rufipogon* seeds germinated within the 0 - 4 cm soil layer and only 0.8% seeds germinated in the 4 - 15 cm soil layer. A field investigation further proved that seeds of *O. rufipogon* germinated almost exclusively in the 0 - 4 cm layer, with very few seeds germinating below a depth of 4 cm.

Chen (2001) reported that the growth duration of *O. rufipogon* lasted about 130 days, 30 - 40 days shorter than rice cultivar IR8. The period from the start of inflorescence to seed maturation lasted only 14 - 15 days and the starch transport stage lasted only 10 days. In a pot experiment, a single *O. rufipogon* plant produced 86 tillers, 38 panicles and over 1000 seeds. *O. rufipogon* has similar ecological requirements to the crop and hence tends to benefit from most of the conditions created by farmers for their rice crops.

Wild rice reproduces by seed and vegetatively from rhizomes. Seeds fall near the parent plant but may disperse across greater distances as rice seed contaminants and with human activities, water and soil movement, and possibly by birds (California Department of Food and Agriculture 2001). Although *O. rufipogon* is carefully controlled in rice fields, it reproduces heavily in irrigation canals, shedding its seeds in irrigation water thus, re-infesting commercial fields (Rojas and Aguero 1996).

Economic Impact

O. rufipogon is a vigorous, strongly competitive plant, which is difficult to eradicate (Lazarides 1980). Infestations of wild rice reduce yield and lower the grade of cultivated rice. It is a noxious weed in the southern USA (Smith 1981, Westbrooks and Eplee 1988) and is considered a serious problem in Brazil, particularly where dwarf rice is grown (Abud 1981). Yield reductions of 50 - 60% due to the presence of wild rice have been reported in Pakistan (Tiwari and Nema 1967) and Tanzania (Chen 2001). It has also caused severe problems in direct-seeding rice areas in South-East Asia (Hyakutake *et al.* 1990).

Wild rice can be a severe problem in cultivated rice because it is so similar to the crop vegetatively that it cannot be identified and removed before it flowers, by which time it will have been competing with the crop for many weeks. It subsequently sheds most of its seed before harvest and contributes little or nothing to the overall grain yield. Grains of wild deepwater rice shed within 20 days of pollination. Such wild forms, unless thoroughly rogued out, may seriously contaminate the field and deprive the farmer of a reasonable yield (Zaman 1981). Sometimes wild rice seedlings are more vigorous than commercial rice seedlings but they are usually difficult to distinguish.

Although red rice does not change the taste or nutritional value of commercial rice, consumers regard it's presence as foreign particles in the white rice (Klosterboer 1979). Red rice affects the appearance and market value of milled rice because of its red kernels. Additional milling is required to remove the red pericarp, increasing breakage of cultivated white rice and reducing total milling yield. In addition to milling losses, the farmer also suffers a loss in cultivated rice yield by competition from and preharvest shattering of weedy rice, the extent of loss depending upon the level of weedy rice infestation in the field. A further important characteristic is the dormancy of the seeds, which ensure that it survives repeated tillage.

The relatively weak stems may also result in lodging of both the weed and crop (Ampong-Nyarko and De Datta 1991).

According to Moody (1989), *O. rufipogon* occurs in different rice cropping systems in South and South-East Asia including: dry seeded and deep water rice in Bangladesh; dry seeded, wet seeded, seedling nursery, transplanted and upland rice in India; transplanted rice in Malaysia and the Philippines; wet seeded rice in Sri Lanka; deep water, transplanted and wet seeded rice in Thailand; and dry seeded and transplanted rice in Vietnam.

Morphology

O. rufipogon in the strictest sense is an erect, perennial tufted grass, 150 - 400 cm tall, with culms spongy below, the lower parts floating and rooting at the nodes, the upper parts sub-erect, culm nodes glabrous and hollow. In the broadest sense, as used for the purposes of this Fact Sheet, *O. rufipogon* sensu lato also includes a range of <u>annual</u> types intermediate between *O. rufipogon* sensu stricto and *O.sativa.* Studies on the germplasm of 202 lines of wild rice show that there is an annual type in China. The characteristics investigated include 13 morphological characters, ratooning ability from node cuttings, mode of reproduction and the germination of seed harvested in the current year or stored for 2 - 3 years (Pang and Wang 1996).

Leaf blades are linear, involute in bud (also when dry), acute, flat, somewhat glaucous, scabrid on margins and main nerves, 15 - 18 cm x 10 - 25 mm. Leaf sheaths are loose, cylindrical, glabrous with distinct auricles at the junction with the blade. Auricles are 1 - 7 mm long, narrow, curved, glabrous or lined with long hairs to 2 mm long. Roots are fibrous, often with rhizomes. The inflorescence is terminal and paniculate (axes usually wavy, the spikelets adpressed) well exserted, up to 20 cm long, initially concealed in the spathe-like sheath of the upper leaf, ultimately nodding; the main axis is long and slender, laterally compressed, flexuous; branches angular, rough on the angles.

O. rufipogon has many bisexual spikelets, always awned, easily shed, articulate on top of the stalk, which is more or less distinctly 2-lobed, 7 - 9 x 2 - 2.5 mm; each on a pedicel up to 2 mm long, one flowered; lower glume lanceolate, upper glume similar to lower but narrower, 2.4 mm long, lemma 7 mm long, boat-shaped, oblong, rounded, 3-nerved, with a rough awn, up to 7 cm long, often reddish, jointed on the lemma, but half as broad with similar texture, 3-nerved, bristly, roughish outside the midline, with two short basal processes (mucro) and an apical awn, 6 mm long. Lemma and palea are green to yellowish, often dark red at apex, covered with stiff transparent hairs (Clayton *et al.* 1974, Soerjani *et al.* 1987, Watson and Dallwitz 1992, California Department of Food and Agriculture 2001).

Similarities to other species/conditions

Takeoka (1962) showed that *O. sativa*, *O. rufipogon* and *O. longistaminata* were all very closely related, and noted that *O. sativa* has persistent spikelets whereas the spikelets in *O. rufipogon* are deciduous, and that *O. longistaminata* is perennial with creeping and branched rhizomes. *O. rufipogon* and *O. longistaminata* are also geographically separated; *O. rufipogon* in Asia and *O. longistaminata* in Africa.

Control

Generally, the more a weed ecologically resembles a crop plant, the more serious it can be as a pest. Perhaps the worst weeds of rice are wild species of rice that shed their seeds before the crop is ripe and have seeds with dormancy (Cook 1990). *O. rufipogon* infestations are difficult and expensive to control. There is no single technique that will eliminate the problem. Hand weeding is a possibility, mainly in developing nations, but with hand weeding, workers are faced with the dilemma of distinguishing between weeds and the crop. The closer the weed resembles the crop, the more likely it is to be overlooked during weeding. Chemical control of *O. rufipogon* in rice is difficult because of the close genetic relationship between the weed and the crop.

Effective control of *O. rufipogon* and other weedy rice species in rice depends upon a rigorous weed management program. Integrated weed control systems, involving the use of certified seed (or good quality weed-free seed), good land preparation, the use of stale seed beds to encourage weed germination before seeding, careful crop and water management, herbicides and crop rotation are needed. In crop rotation, rice may be rotated with other crops in alternate seasons and an appropriate herbicide can be used to destroy weedy rice seedlings in these crops. Such programs are recommended for rice in Asia and the Americas (Grist 1986, Smith and Hill 1990, Ampong-Nyarko and De Datta 1991, Moody 1994).

To avoid introducing the weed, the use of weed-free crop seed, the removal of red rice seed from irrigation water i.e. control of red rice growth in irrigation ditches, and the use of clean cultivation equipment are recommended. Wrigley (1969) commented on the difficulty of separating seeds of *O. rufipogon* from rice seeds by winnowing. Weeds and off-types of rice that synchronously flower and mature with the cultivated variety should be hand rogued to reduce crop seed contamination.

Crop rotation is a very effective method of controlling difficult weeds in rice. Rice should be rotated with other grain or legume crops such as sorghum or soybean. During the years in which the alternate crop is grown, cultivation and herbicide treatments should be used to control red rice thoroughly, and provide a clean bed in which to sow rice in the third or fourth year of the rotation. When the alternate crop is grown, pre-plant soil incorporating herbicides such as alachlor or metolachlor, either alone or tank mixed with trifluralin, pendimethalin, metribuzin or imazaquin, may be used. Post-emergence treatments include the use of fluazifop, quizalofop or sethoxydim, or directed sprays of paraquat to control red rice missed by pre-plant treatments.

Transplanting rice has multiple benefits; germination of the weed should be considerably reduced, and those that do germinate can still be removed by weeding. Even if the weeds are not removed they will be much less competitive and produce less seed than they would in a direct-sown crop. Trebuil *et al.* (1983) reported that rice is transplanted when the sown field has a high incidence of wild rice. It has become increasingly difficult to combat wild rice over the years as its morphological characteristic become closer to those of cultivated varieties because of strong selection pressure due to long and careful weeding and possible natural hybridization with cultivated varieties.

The following practices are also effective: plant spacing, where crop competition can be used to reduce weed growth; high seedling rate of cultivated rice to reduce tillering of wild rice; and burning straw after harvest to kill wild rice seeds. *O. rufipogon* seeds that are buried will not germinate in flooded or water-saturated soil, but under these conditions the plants will propagate by stem cuttings or stem bases.
Continuous flooding reduces perennial wild red rice seed survival and attracts ducks that feed on the grains. Seeds do not survive ingestion by waterfowl (California Department of Food and Agriculture 2001).

In Khulna, Bangladesh, an early flowering deepwater rice cultivar Ashina is cultivated when the rice field becomes badly infested with Jhora-dan. Since Ashina flowers 2 - 3 weeks earlier than Johra-dan, weeding of Johra-dan can be easily done after harvesting Ashina (Morishima *et al.* 1991).

Salimath (1921) recommended rotating different rice cultivars with different coloured stems. He recommended growing the white-stemmed cultivar Mugad for 2 years and weeding out all the red-stemmed plants and then in the succeeding 2 years growing the red-stemmed cv. Antarsali and weeding out all the white-stemmed plants. Roy (1921) recommended the use of purple-leaved cultivars, and land preparation (stale seedbed and puddling) for the control of red rice. For effective control of wild rice, Thakur (1969) recommended the growing of BR 11 or BR 12, which are purple cultivars. Srivastava *et al.* (1987) recommend the use of certified seed, regular removal pre- and post-flowering and cultivation of purple-leaved cultivars continuously for 2 or 3 years for the control of wild rice. The rice seedlings are, therefore, easy to distinguish from the green wild rice seedlings.

O. rufipogon is not a weed problem in California, USA, because of a seed certification program. Certified rice seed is used by practically all the farmers in the state and *O. rufipogon* is not permitted in certified seed. In the 10 years before 1932, 28% of California rice seed samples had *O. rufipogon* present at an average of 95 seeds/kg, the highest count being 1060/kg (Bellue 1932).

Mechanical Control

It is recommended that rice is sown in rows so that wild rice can be recognized by its presence between the rows and can be removed by hand or cultivation. Early ploughing of land after harvest to encourage the germination of *O. rufipogon* and control of these emergent weeds by grazing cattle, cultivation with spike tooth harrow or herbicide application are effective. Early ploughing after harvest followed by flooding in the first 3 weeks also aids in the control of the weed. Early season cultivation and harrowing stimulate germination of *O. rufipogon* and may allow the mechanical destruction of several flushes of wild rice growth before rice or rotational crops are planted.

Chemical Control

In the rice crop, infestations are reduced by applying molinate pre-plant incorporated (Smith and Khodayari 1985), water seeding the rice, and maintaining the flood water, or keeping the soil moist by frequent irrigation, for several weeks after seeding. According to Hyakutake *et al.* (1990), *O. rufipogon* from Thailand, Malaysia, Sri Lanka and Brazil was tolerant to thiobencarb, while that from India, Myanmar and Guyana was susceptible. All were susceptible to simetryn regardless of origin.

Thiobencarb can also be surface applied, pre-planting, just before bringing on the flood (Smith and Khodayari 1985). Although thiobencarb has been recommended for use on *O. rufipogon* in rice, it is recommended that the crop seed be treated with a protectant or antidote, such as NA (1,8-naphthalic anhydride), as a safeguard (Wirjarhardja and Susilo 1979, Smith and Hill 1990). Chemicals are more commonly used pre-sowing to destroy the rice weed before the susceptible crop is present, for example, chemicals such as alachlor or metolachlor either alone or tank mixed with trifluralin, pendimethalin, metribuzin or imazaquin are pre-sowing treatments recommended by Smith and Hill (1990). Chen (2001) also obtained effective control of *O. rufipogon* by applying atrazine or atrazine + metolachlor in maize or grain sorghum grown in rotation with rice.

The method of weed control chosen will depend upon the cropping system and the benefit to cost ratio. Recommendations for control of *O. rufipogon* in the developing world are detailed in Moody (1994) and those for the Americas are reviewed by Smith and Hill (1990). Chen (2001) used the following steps to obtain 96% control of *O. rufipogon*:

1. A seedbed was finely prepared by disking and tine harrowing about 1 month before sowing.
2. This was irrigated two to three times to keep the surface soil moist for 25 - 30 days to stimulate germination of wild rice seeds.
3. When the wild rice seedlings reached the 3 - 4 leaf stage (95% of seeds in the 0-4 cm soil layer had germinated), a mixture of paraquat and oxadiazon was applied.
4. Rice seeds were direct seeded to a depth of 1 - 2 cm by drilling under zero-tillage to avoid turning up of wild rice seeds from the deeper soil layers.
5. The field was irrigated after sowing to promote germination of rice seeds.
6. The field was flooded from the 3.5 leaf stage of rice to check emergence of wild rice and other weeds.

A new approach to chemical control of wild and red rice is the use of herbicide-tolerant crop cultivars, which can be safely treated with otherwise non-selective herbicides such as glufosinate (Sankula *et al.* 1997). There is, however, concern that the tolerance genes will be transferred by out-crossing to wild rice, thus eventually reducing the effectiveness of the treatment. For example, Langevin *et al.* (1990) reported morphological convergence between cultivated and weedy *O.sativa*, with hybrids demonstrated to be more vigorous than pure weeds. A genetic barrier to outcrossing should be introduced into the herbicide-resistant crop to prevent the transferring of herbicide resistance to the weed species.

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[1] Although many references were reviewed for this Pest Fact Sheet, the primary basis for it's construction has been modeled upon a "full datasheet" as provided by CABI (2002) and referenced below.

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