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# Technical Recommendations for Irrigated Rice in Mato Grosso do Sul

*José Alexandre Freitas Barrigossi*
Technical Editor

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**Embrapa Arroz e Feijão**
Rod. GO 462, Km 12
CP 179
75375-000 Santo Antônio de Goiás, GO
55-62-35.33.21.00
55-62-35.33.21.94
sac@cnpaf.embrapa.br
www.cnpaf.embrapa.br



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# Autores

**Alberto Baêta dos Santos**
Engenheiro Agrônomo, D.Sc.
Embrapa Arroz e Feijão
Rod. GO 462, Km 12
75375-000 Santo Antônio de Goiás - GO
baeta@cnpaf.embrapa.br

**André Andres**
Engenheiro Agrônomo M.Sc.
Embrapa Clima Temperado
andre@cpact.embrapa.br

**Anne Sitarama Prabhu**
Engenheiro Agrônomo D.Sc.
Embrapa Arroz e Feijão
prabhu@cnpaf.embrapa.br

**Balbina Maria de Araújo Soriano**
Meteorologista D.Sc.
Embrapa Pantanal
balbina@cpap.embrapa.br

**Carlos Magri Ferreira**
Engenheiro Agrônomo D.Sc.
Embrapa Arroz e Feijão
magri@cnpaf.embrapa.br

**Cláudio Lazzarotto**
Engenheiro Agrônomo M.Sc.
Embrapa Agropecuária Oeste
Claudio@cpao.embrapa.br

**Daniel de Brito Fragoso**
Engenheiro Agrônomo D.Sc.
UnitinsAgro
dbfragoso@gmail.com

**Darci Dias Azambuja**
Engenheiro Agrônomo - Especialista
Sementes San Francisco
az.azam@hotmail.com

**Eduardo da Costa Eifert**
Engenheiro Agrônomo D.Sc.
Embrapa Arroz e Feijão
eifert@cnpaf..embrapa.br

**Elaine Cristina Cardoso Fidalgo**
Engenheira Agrônoma D.Sc.
Embrapa Solos
efidalgo@cnps.embrapa.br

**Humberto Gonçalves dos Santos**
Engenheiro Agrônomo D. Sc.
Embrapa Solos
humberto@cnps.embrapa.br

**Jaime Roberto Fonseca**
Engenheiro Agrônomo D.Sc.
Embrapa Arroz e Feijão
jfonseca@cnpaf.embrapa.br

**José Alexandre Freitas Barrigossi**
Engenheiro Agrônomo Ph.D.
Embrapa Arroz e Feijão
alex@cnpaf.embrapa.br

**José Francisco da Silva Martins**
Engenheiro Agrônomo D.Sc.
Embrapa Clima Temperado
martins@cpact.embrapa.br

**José Geraldo da Silva**
Engenheiro Agrônomo D.Sc.
Embrapa Arroz e Feijão
jgeraldo@cnpaf.embrapa.br

**Mariana Cruzick de Souza Magaldi**
Engenheira Agrônoma
Embrapa Arroz e Feijão
mcruzick@cnpaf.embrapa.br

**Mário Luiz Diamante Áglio**
Geógrafo, M.Sc.
Embrapa Solos
mario@cnps.embrapa.br

**Marta Cristina Corsi de Filippi**
Engenheira Agrônoma D.Sc.
Embrapa Arroz e Feijão
cristina@cnpaf.embrapa.br

**Nand Kumar Fageria**
Engenheiro Agrônomo Ph.D.
Embrapa Arroz e Feijão
fageria@cnpaf.embrapa.br

**Orlando Peixoto de Morais**
Engenheiro Agrônomo D.Sc.
Embrapa Arroz e Feijão
peixoto@cnpaf.embrapa.br

**Osmira Fátima da Silva**
Economista
Embrapa Arroz e Feijão
osmira@cnpaf.embrapa.br

**Sidenei Tambosi**
Engenheiro Agrônomo
Consultor Técnico
tambosi@sosrbnet.com.br

**Silvando Carlos da Silva**
Engenheiro Agrícola M.Sc.
Embrapa Arroz e Feijão
silvando@cnpaf.embrapa.br

**Valácia Lemes da Silva Lobo**
Engenheira Agrônoma D.Sc.
Embrapa Arroz e Feijão
valacia@cnpaf.embrapa.br

**Veridiano dos Anjos Cutrim**
Engenheiro Agrônomo D.Sc.
Embrapa Arroz e Feijão
cutrim@cnpaf.embrapa.br

# Presentation

Changes in the composition of cultivated areas are determined by several factors. Undoubtedly, financial profitability and access to the marketplace are important factors in the process. In Mato Grosso do Sul, more than 95% of rice production comes from crops on irrigated lowlands. Their yield is relatively high, 5,681 kg $ha^{-1}$, but still about a ton below the national average, which is strongly influenced by the performance of Rio Grande do Sul, where productivity has already exceeded seven tons per hectare. The search for high yields through good agricultural practices is the best strategy when natural resources, especially soil, water and light are used.

Profitability improvement for irrigated rice in Mato Grosso depends largely on production systems which are appropriate to local conditions and on additional efforts throughout the chain of production.

The need to increase rice production in the State of Mato Grosso do Sul, in a sustainable and competitive way, integrating and invigorating the entire chain of production was the reason Embrapa's research team wrote this paper. It discusses several technologies specifically aimed at increasing the competitiveness of the irrigated rice crop production in Mato Grosso do Sul.

*Pedro Luiz Oliveira de Almeida Machado*
Head, Embrapa Rice and Beans

# Summary

# Current situation and challenges in the rice production chain in Mato Grosso do Sul

*Carlos Magri Ferreira*

In 2007/08 Brazil produced 12.1 million metric tons of husked rice. From these, 1.5% (187 tons - IBGE, 2008a) came from the state of Mato Grosso do Sul. This amount wasn't enough to supply the needs of the state so it had to import from other states. Rice production and the planted area in the state, between 1990 and 2008, was marked by a 70% decrease in area and production stability, with a minimum of 182.4 thousand tons (Figure 1).

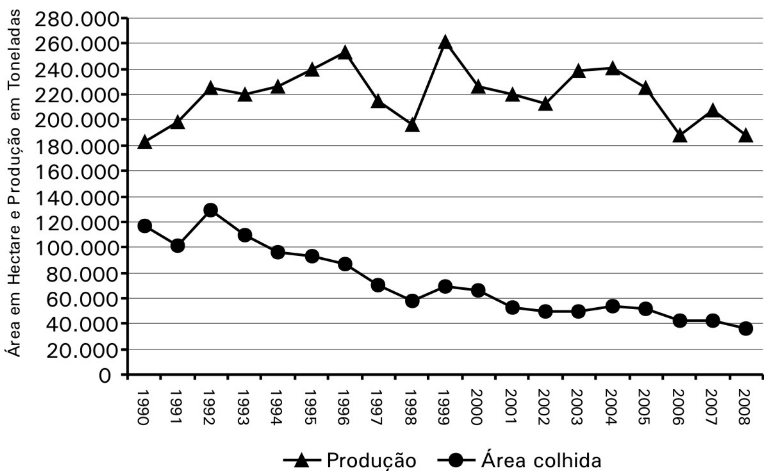


**Figure 1.** Rice production area in Mato Grosso do Sul between 1990 and 2008.
Source: IBGE (2008a).

On the other hand, as shown in Figure 2, rice growing in Mato Grosso do Sul has exhibited good performance in terms of productivity. In 2008, mean harvest in the state was 5.260 kg/ha, 25% above the national average (4.230 kg/ha), thus showing the potential of the region, with 16 major growing counties (Figures 3 and 4).

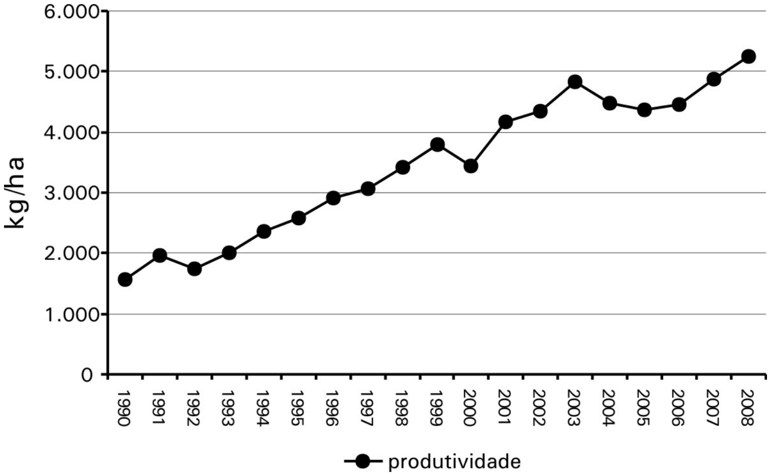


**Figure 2.** Mean Rice productivity in Mato Grosso do Sul, between 1990 and 2008.
Source: IBGE (2008a).

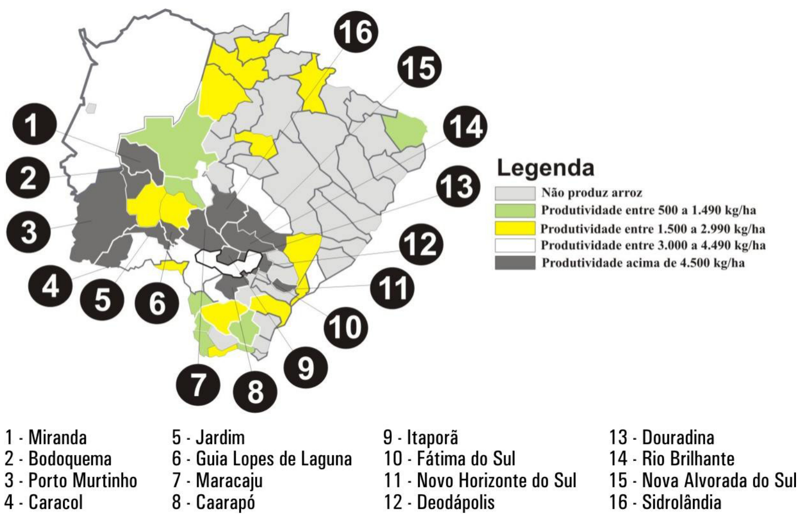


**Figure 3.** Rice productivity ranges and counties producing over 4,500 kg/ha in Mato Grosso do Sul, in 2006.
Source: IBGE (2008b).

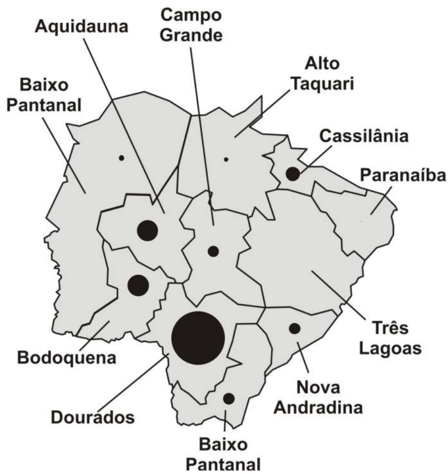


**Figure 4.** Rice production in 2006 in different regions of Mato Grosso do Sul. Circle sizes are proportional to the amount produced.
Source: IBGE (2008b).

The current food crisis worsens the problems of food importing states, creating difficulties for retailers and affecting the competitiveness of the local rice industry. The result has been bankruptcy and financial instability for those still in the business. Communities suffer with decreased job opportunities, a reduction in economic activities and shortage of goods, since rice processing industries stop supplying the local market and stop offering rice by-products that could be used by consumers directly or by other industries. Thus, farmers are denied the option to growing rice for lack of buyers.

A restructuring in the rice production chain in the state appears as an option in this time of crisis and, at first, may not indicate self-sufficiency in supply, but provide a better use of the potential of the region whose results will result in social and economic benefits.

To restructure rice production in Mato Grosso do Sul, a better relationship between the industry and farmers is vital, if problems are to be addressed collectively. That is, the production chain must be mobilized to pursue technologies and processes aimed at improving the quantity and quality of rice grown in the region, to maintain competitiveness.

To be more competitive, it is not enough for the rice production chain of Mato Grosso do Sul to concern itself with production techniques, as the bottlenecks go beyond production and, indeed, a proposal seeking to find solutions to the problems will require partnerships with research institutions and rural extension.

Competitiveness also depends on the production network. In order to explore the available farming areas and labor force it is important to carry out a diagnosis to identify existing bottlenecks. Diagnosis should include both the production of raw material in crops, its strengths and limitations, such as processing, as well as administration, managerial, financial and physical structures and marketing methods used in the agricultural industries. This knowledge and information will be used to find solutions collective or individual in a conscientious and strategic manner, aimed at minimizing issues that have been identified and gaining greater market share in other regions.

The revival process for the rice industry in the region must rely on sustainable development principles, since the goal is to provide food security, made possible by environmentally friendly production strategies, processing and distribution methods that respect cultural differences and ensure a competitive supply of rice both in terms of quantity and quality, to meet present and future needs of society. Another strategic issue is land sustainability, through which competitiveness respects the limits environmental resistance, and income generated by the production process is distributed equally among production chain players and rice crops contributes for balanced growth in the region.

The following are some of the challenges that farmers and the rice industry must overcome, given the interest in seeking to establish activities fostering the supply of good quality raw material in enough quantity to meet pre-established plans and ensure trademarks quality:

1) Designing a set of proposals for technologies aimed at improving the quality and quantity of paddy rice;
2) Installing, in partnership with public and private research and rural extension institutions rice cultivars assays and demonstration units;
3) Conducting technology transfer to all the activities along the supply chain;
4) Training technical advisors and workers in the rice sector;
5) Carrying out actions to recover and maintain the natural landscape, natural heritage and local values;
6) Improving the commercial performance of products at the local market and in other regions;

7) Developing marketing strategies, by carrying out studies aimed at setting goals in line with contemporary and global market trends;
8) Conducting research to identify potential markets and market niches for their products;
9) Organizing technical visits whereby farmers would go to processing industries and industrialists would visit rice fields;
10) Adapting or adopting more efficient business, marketing and sales techniques;
11) Strengthening rice competitiveness, brands, products and by-products in the local market and in other regions;
12) Designing basic marketing guidelines for the agricultural industries of the region;
13) Building product credibility and consumer loyalty to products offered;
14) Promoting more exchanges possibilities between industries and the community, especially with the retail market and other economic activities developed in the region and with other links of the supply chain;
15) Encouraging social responsibility and increasing the influence of rice growing in health conditions and housing, and in the ability to generate jobs and income;
16) Reducing costs and recovering the waste that is generated;
17) Developing strategies with connections to increase the level of added value and the use of products;
18) Developing risk assessment tools, fostering policies promoting the research and development of innovative solutions aimed at providing stability and balance among the several stages of the chain of production;
19) Encouraging the activities of federal, state and municipal agencies as well as of local nongovernmental organizations, related to the rice industry;
20) Encouraging, through rice growing, the search for a balanced regional development using natural resources in a sustainable way.

Compliance with the above items leads to good farming practices and better governance, which can transform the challenges presented by a sustainable rice crop in Mato Grosso do Sul into business opportunities.

# Climate

*Cláudio Lazzarotto*
*Silvando Carlos da Silva*
*Balbina Maria de Araújo Soriano*

Rice (*Oryza sativa* L.) is sensitive to environmental conditions and plant development and productivity are directly related to prevailing environmental components, especially solar radiation, humidity and temperature. According to Carmona et al. (2002), no cereal requires moisture and temperature as much rice. Yet, rice is grown in every continent, in a broad range of climates from the tropical to the temperate zones. In Brazil, the rice variety typically grown is adapted to the tropics, and is very sensitive to low temperatures, even the cultivars recommended for the south of the country.

Located between latitudes 17°13'40" S and 24°04'02" S, Mato Grosso do Sul has abundant sun light and receives a great deal of solar radiation. The climate is mostly tropical with a rainy season from October to April, and little rainfall from June to August. In May and September rainfall varies considerably presenting with transition rainfall patterns. Temperatures are high throughout the year, with the exception of the southern region of the state, where winter is characterized by mild to low temperatures with frequent episodes of frost. In general, relative air humidity is low in the winter and high in the summer. Exceptionally there are periods of low relative humidity in January or February.

Considering these climatic traits and cultivation under irrigation by flooding conditions, the season for sowing rice in Mato Grosso do Sul is determined by temperature. Solar radiation mainly determines the best period for taking advantage of intensive sunlight. Other meteorological elements complement environmental conditions, eventually causing some losses in the event of extreme anomalies.

To establish appropriate farming systems, which will result in higher productivity, a consequence of taking advantage of environmental conditions, it is important to know the agronomic and meteorological conditions in the different sites whose soil is considered adequate for irrigated rice. The next step it to prepare recommendations on the best sowing time.

Each climate component plays a role in the environmental conditioning for developing rice. However, this crop is extremely demanding in terms of temperature and solar radiation.

## Temperature

Temperature at inadequate levels affects the rice plant at every stage of its development. Extreme temperatures, when coinciding with the plant's highest sensitivity phase, affect the plant negatively. Damage is directly related to temperature intensity and the time it occurs. When exposed to 41 °C for two hours, susceptible varieties can exhibit up to 80% of reduced fertility in spikelets, and temperatures below 15 °C inhibit tillering (WREGE et al., 2001).

Temperatures below an adequate level delay seed germination, reduce plant growth, reduce the number of tillers, increase flower sterility, increase the period needed for grain formation, increase the total cycle of cultivars and extend the time until leaves appear (STRECK et al., 2006), among other morphological and physiological changes.

The low base temperature, i.e., the temperature below which rice stops metabolic activity is 11 oC (STRECK et al., 2006).

Among other negative impacts, temperatures above those tolerated by rice, negatively affect seed germination and seedling development (WREGE et al., 2001). They also reduce the viability of pollen grains and increase flower sterility. Additionally, higher temperatures intensify plant respiration, shorten their cycle and reduce productivity (WREGE et al., 2001).

Thermal requirements of rice vary according to the stage of the plant, with some variability in temperature needs among cultivars. In general, temperatures between 20 and 30 °C favor seed germination and seedling growth (WREGE et al., 2001). According to Sie et al. (1998), as quoted by Wrege et al. (2001), temperatures between 22 °C and 25 °C are suitable for plant growth up to the appearance of the fourth leaf. Tillering is optimized between 25 °C and 31 °C (FERRAZ, 1987), it is damaged when temperatures fall below 19 °C and practically does not occur at temperatures below 15° C. At anthesis, the most important temperature-related phase, optimum condition is between 30 and 33 °C. Spikelet sterility increases when temperatures rise above 29 °C. Temperatures between 20 °C and 25 °C are ideal for grain maturation.

In summary, the best temperature for rice growth remains between 20 °C and 38 °C, while optimal temperatures range from 29 °C to 32 °C.

Figure 1 shows the daily distribution of maximum, average and minimum temperatures in Mato Grosso do Sul. Notice that although the average air temperature rises above 20 °C from the end of August, only after the end of October average minimum temperatures go above 19 °C, which is the minimum ideal temperature for a good tillering. These conditions remain until mid-March when temperatures fall, increasing the risk for rice as time progresses.

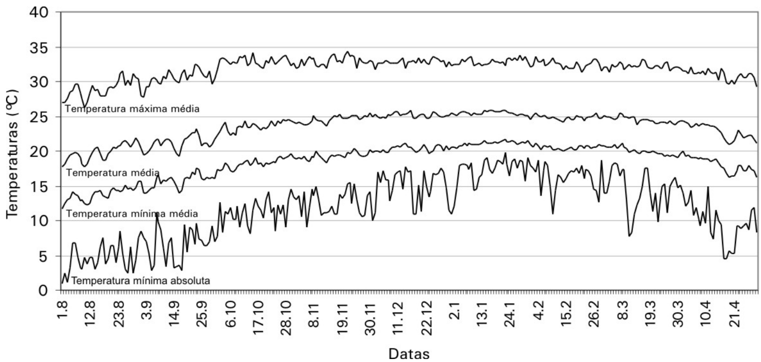


**Figure 1.** Daily distribution of maximum, average, and mean minimum and absolute minimum temperatures, from August to April in Mato Grosso do Sul.

## Solar Radiation

Solar radiation is one of the key environmental components in rice development. Solar radiation requirements by the rice crop varies from one phenological stage to another. During the growing season, solar radiation has little influence on yield and its components. However, productivity is strongly influenced by solar radiation during the reproductive and maturity stage, and there is a linear relationship between solar radiation and grain production.

In general, rice requires a minimum of 300 cal $cm^2$ $day^{-1}$ in the reproductive phase for a yield of more than 5 metric tons per $ha^{-1}$. Figure 2 shows that from October to March one can expect a minimum availability of 400 cal $cm^2$ $day^{-1}$ and mean radiation of more than 450 cal $cm^2$ $day^{-1}$.

Since radiation is most important during the maturation and reproduction stages, it is crucial that these stages of plant development coincide with the period of greatest radiation supply, i.e., from October 15 to February 28.

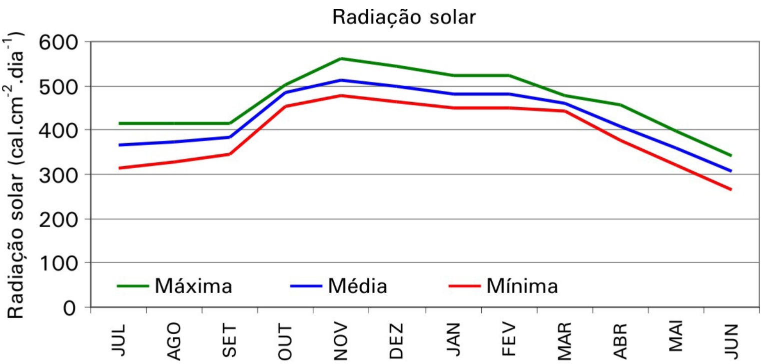

**Figura 2.** Maximum, mean and minimum incident solar radiation in Mato Grosso do Sul.

## Sowing season

Considering the thermal and solar radiation characteristics of Mato Grosso do Sul, the best time to sow to obtain high yields is between July 15 and November 15 in the center-north of the state, and in the areas surrounding the swampy region known as Pantanal. In the south region of the state, favorable dates are from September 15 to December 15.

# Soils

*Elaine Cristina Cardoso Fidalgo*
*Humberto Gonçalves dos Santos*
*Mário Luiz Diamante Áglio*

According to available information on soil types and the topography of Mato Grosso do Sul (MATO GROSSO DO SUL, 1988), the state presents a great diversity of favorable environments for growing irrigated rice. Environments with greater identified potential include arable lowlands whose soil types and features, and water availability make them suitable for cultivation under flooded conditions. In hydromorphic soils, originating from clayey and sandy sediments in areas located at higher altitudes, natural drainage is restricted. This condition of poorly drained soils, combined with the temperature and relative humidity conditions required by the rice plant result in the best environments for irrigated rice.

## Classes of soils best suited for irrigated rice

The state of Mato Grosso do Sul has large expanses of good floodplain soils, mostly glaysols (*tabatinga*, made of grayish clay that underwent a chemical reduction in iron content).

They occur in complex associations of haplic gleysols (former low humic gleys) and melanic gleysols (formerly humic gleys) shown in the map (Figure 1), all with low activity clay, dystrophic and eutrophic, with a clayish texture.

Other soils present in associations are fluvic neosols of medium and clayish texture (alluvial soils) and haplic organosols (semi-organic soils) with decomposed organic matter.

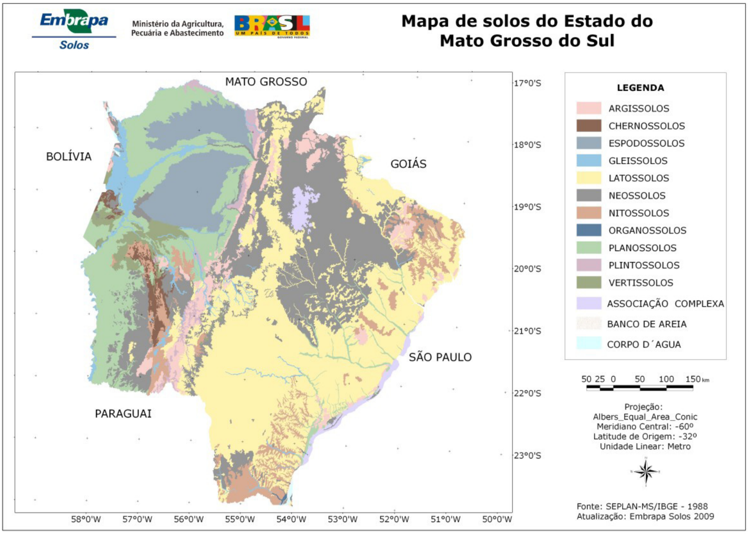


**Figure 1. Map of soils in the State of Mato Grosso do Sul, updated by Embrapa Soils.**

Other complex soil associations are also present, such as planosolic haplic gleysols and clayish textured eutrophic solodic planosolic soils and naturally fertile clayish textured carbonate and vertic mellanic gleysols. Vertic and carbonate soils are soils of very high natural fertility.

The most common classes of hydromorphic soils found in the studied area are described below:

## *Gleysols*

Gleysols are the most common soils in the lowlands of Mato Grosso do Sul. They are hydromorphic soils formed when moisture, temporary or permanent, is excessive. They present horizons of gray or neutral colors (gley horizons), usually 50 cm from the soil surface or just below the surface horizon (A horizon). The colors indicate that soils were formed in a reducing environment as a result of a high water table, present during most of the year. They can also present small reddish, dark or yellow patches caused by the mobilization and segregation of iron compounds in a reducing environment, which contrast with the neutral or grayish background characteristic of gleysols. According to the Brazilian Soil Classification System (SANTOS et al., 2006), gleysols in that area are subdivided into haplic and mellanic. Mellanic gleysols are those with a dark surface horizon, and high organic matter content, and haplic gleysols, including other gleysols not characterized as thiomorphic (sulfidic), salic or mellanic soils. In the State of Mato Grosso do Sul, the Gleysols are highly fertile. In general, they vary greatly regarding their traits, both in terms of depth and across the landscape, since they are alluvial in nature, characterized by a succession of layers of different nature.

## *Organosols*

Organosols are soils with abundant decomposed or semi-decomposed organic matter. For the most part, they are acid soils with low base saturation and often with high levels of exchangeable aluminum. When drained and cultivated, they may be subject to a marked subsidence (surface lowering) and gradual decrease in organic matter content. Important limitations regarding their use are low natural fertility, aeration deficiency and the fact that they present restriction to mechanization. They occur in association with gleysols.

## *Planosols*

Characteristically, this class of soil has as a textural B horizon with large increase of the A (or E) horizon clay to the B horizon, associated to dark or grayish colors, indicating low permeability. They are soils of variable fertility with close to neutral reaction and usually with low levels of organic matter and phosphorus deficiency. They are present in lowland flat reliefs in association with gleysols and fluvic neosols (alluvial soils) with limited drainage.

## *Fluvic neosols*

These soils are developed from recent sediments of heterogeneous nature. They are clayish and sandy, of varying texture, acidic, dystrophic, usually associated to floodplains soils such as gleysols, vertisols and planosols. Drainage is restricted and they are subject to temporary flooding. Those soils in Mato Grosso do Sul are the only neosols suitable for growing irrigated rice. Other neosols, such as Quartzipisamments, litholic and regosols, as well as cambisols, are not suitable for irrigated crops. Isolated fluvic neosols occur in approximately 6,550 km2 (BRAZIL, 1971), correspond to 1.83% of the state. The soils map in this paper shows that the neosol unit encompasses all neosols as well as the cambisols.

## Extent and distribution

The soil map of Mato Grosso do Sul (BRASIL, 1971), republished by SEPLAN-MS (MATO GROSSO DO SUL, 1988) and updated by Embrapa Soils according to the Brazilian Soil Classification System shows the best soil classes for irrigated rice along with their extensions and percentage distribution in the area (Figure 1 and Table 1). Gleysols, organosols, planosols and fluvic neosols occur along the lowlands of the counties of Bodoquena e Miranda, Antônio João, Bela Vista, Caarapó, Deodápolis, Douradina, Dourados, Fátima do Sul, Guia Lopes da Laguna, Itaporã, Jardim, Laguna, Carapã, Maracaju, Nova Alvorada do Sul, Ponta Porã, Rio Brilhante and Sidrolândia (LAZZAROTTO et al., 2005).

This evaluation didn't include hydromorphic soils (gleysols, planosols, neosols and organosols) found in the swampy wetlands, because of salinity restrictions, the presence of sodium and other soluble salts in the soil solution as well as climatic and environmental constraints.

**Table 1.** Absolute and relative areas of the main soil classes in Mato Grosso do Sul.

| *Soil Class* | *Absolute area (km$^2$)* | *Relative area in (%)* |
|---|---|---|
| Latosols | 121,413.47 | 34.00 |
| Plinthosols | 4,665.41 | 1.31 |
| Argisols | 16,769.12 | 4.69 |
| Neosols + Cambisols | 82,645.47 | 23.10 |
| Gleysols | 11,108.65 | 3.12 |
| Planosols | 49,905.86 | 14.00 |
| Vertisols | 7,313.00 | 2.05 |
| Organosols | 208.39 | 0.05 |
| Chernozem | 4,091.06 | 1.15 |
| Spodosols | 29,446.89 | 8.25 |
| Nitosols | 23,546.64 | 6.59 |
| Water bodies | 372.00 | 0.11 |
| Sand banks | 228.65 | 0.06 |
| Complex sig. | 5,409.39 | 1.52 |
| Totals | 357,124 | 100.00 |

# Soil leveling and preparation

*Darci Dias Azambuja*
*Sidenei Tambosi*

In western Mato Grosso do Sul (in the Miranda and Bodoquena counties) rice is predominantly planted in clayish soil. In that region, with warmer climate, a well-defined rainy season and a long dry season, soil preparation takes place from May to September. Occasionally drought and soil preparation extends through the month of October. Planting is done from July to October and the best yields are obtained when planting is done in August.

Seeding is done with no-till seeders, after the soil has been minimally prepared. After seeding in dry soil, a roller is used to improve contact between soil and rice seeds, thereby reducing the amount of uncovered seeds to prevent birds from eating them, which would consequently reduce crop yield. After soil preparation, the next step involves building *taipas* (wattle and daub walls) or *marachas*, using a laser level mounted on a farm tractor. This technique provides for a faster and more precise way to protect the crop. Vertical height varies from 4 to 8 cm, according to the topography of the area.

The use of broad-based wall maker (*entaipadeira*) has allowed farmers to plant over the *taipas* or *marachas*, to save time and improve the crop stand in the *leiveiros*, which are the areas adjacent to the *marachas*, with a consequent gain in productivity. This *entaipadeira* builds a lower taipa and a shallow *leiveiro* enabling uniform rice maturation.

Soil leveling provides for a uniform distribution of the water depth on the boards, reduces the incidence of blast and makes surface drainage easier. In addition to reducing water consumption, leveling helps soil moisture distribution in the root zone of plants in the case of the sub-irrigation of out-of-season crops. It also makes sowing more efficient, allows for better weed control, increases productivity and improves product quality.

## Leveling projects

The geographical location of irrigation and drainage projects in irrigated rice crops is critical, and the following aspects should be considered:

Access to the area; occurrence of floods and the behavior of rivers and streams; land topography; existing vegetation; physical and chemical analyses of the soil; analysis of the quality of the water used in the project; assessment of the available water flow; the need to build dams or reservoirs to store water for irrigation; the need to build dikes to protect against possible floods; building canals and drains; pumping stations; determining the size of collection and drainage units, when in place; design an internal road system; additional infrastructure work, such as gutters, galleries, spillways and bridges; location and design of the power grid; build landing strips for planes used for agriculture; drying and storage units; personnel housing and lodging; as well as a cafeteria and administration offices.

After the area which is going to be leveled is evaluated, the next step is to create a topographic map. During this phase, the size of the squares and plots, as well as the cutting and landfill volume for each plot are determined. This stage also involves calculating minimum and maximum height of the cut and landfill, drafting cost estimates for each stage and choosing the best cost-effective equipment available.

When leveling dry soil with laser equipment, usually one uses a heavy disc harrow to break up the soil to make cutting and transportation easier. The first equipment used in leveling is the scraper which promotes higher volume cuts and carries dirt from the highest to the lowest points. To improve equipment efficiency, the land should be devoid of vegetation otherwise dirt unloading by the scraper will not be uniform, and will result in a greater workload for the tractors. Flat-bottomed scrapers (floor parallel to the soil), perform better, because even when loaded they keep the soil surface at the programmed height and, with each pass, they correct the relief.

In the Miranda region, where vertisols are the norm, cost-benefit working parameters were set for this activity. It has been established that earthwork involving around 300 meters per hectare is beneficial, though some plots involve distances which are close to 500 meters. The height of cuts remains below 10 cm, on average, but 20-cm sections can occur in certain parts. However, it is best to avoid cuts of over 15 cm. After the scrapers finish preparing the land, the leveling buckets are brought in. They are used to level the land, correct any flaws and standardize height throughout the whole plot.

Leveling the areas where irrigated rice will be planted is an important factor in changing technological standards. It doesn’t matter whether it is done in dry or water-logged soil, with animal traction or with laser equipment. Leveling the soil surface and planning irrigation, drainage and road systems improve the use of the planted area, crop implementation and development. It also improves soil surface drainage, and makes it possible not only to use lower water levels but also to achieve a more uniform depth distribution. As a result, other crop management practices become easier.

Leveling enables farmers to use cleaner technologies. They can reduce the volume of water and power used; allow for early weed control, by using the minimum recommended amount of herbicides without having to resort to spraying herbicides on the water; keep the water for up to 30 days after herbicides, insecticides and fertilizers are applied and retain the water for up to 48 hours after the soil has been prepared in the pre-germinated system.

## Soil Preparation

Among other things, soil is prepared to provide satisfactory conditions for planting, seed germination, seedling emergence, plant development and production, but also for removing weeds, controlling erosion and decompacting the soil.

Soil preparation is done in two steps, primary and secondary, and uses one or more implements. Primary tillage involves greater soil depth, and usually requires plows or large disc harrows to break down the compacted layers, remove and bury the vegetation cover. Secondary tillage is more superficial, and used light disc harrows to decompact and level the soil, incorporate agrichemicals and eliminate weeds.

There are several farm equipment types, brands and models. They are used to perform these functions and till the soil in one or more operations. Often, several operations are performed by combining different types of equipment in a predefined order, according to desired goals. Different tillage practices are needed for different rice production systems. In addition to the production system, tillage practices vary with the texture, structure and degree of soil compaction, as well as with equipment availability. There are two different tillage systems used with irrigated rice: dry soil and water-logged soil tillage.

## Tillage season

Before preparing the soil, one should evaluate the possibility of using tractors and heavy machinery in the field. The ability of the soil to support and allow this equipment to work is heavily dependent on the existing moisture. The best time to prepare the soil is when a tractor, operating at minimum effort, provides the best possible result. This occurs at the point of brittleness, i.e., when soil moisture is such that, when compressed in the hand, it is easily molded, but when the force ceases, the sample crumbles easily.

When the soil is very humid, there is physical damage to its structure, especially in the groove left by the wheels of the tractor. The soil adheres to the working parts of the equipment, to the point of hindering the operation. On the other hand, tillage in very dry soil requires more harrowing work and, consequently, higher fuel and time consumption.

Tillage season can vary according to set goals. If the main goal is weed control or the incorporation of crop residues, tillage can be done well before sowing. In this case, the recommendation is to plow after the last harvest, and use disc harrows immediately before planting the new crop. A second alternative would be to incorporate plant material to the soil with the use of disc harrows and, 10 to 30 days later, plow the land.

Both in dry as in flooded soil, plowing must precede planting in about 30 days to allow for the decomposition of organic matter. Harrowing or final leveling should be done immediately before sowing.

## Plow and disc harrow performance

Power consumed during tillage varies with the various combinations of equipment or systems used. Selecting a tillage system depends on the power required by a specific piece of equipment, how this requirement varies in combination with other equipment and also on how it will affect water and soil conservation and crop production. In short, optimum soil preparation is the result of an ideal combination of soil conditions, which favor crop growth, with maximum production and nutrient availability at the lowest operating cost, especially in terms of energy expenditure.

Fuel consumption can be used as an index to compare power required for tillage, although many factors influence this figure. They are: soil texture, structure and water content; equipment type and status; work speed and tillage depth and the way tractor wheels move. Moreover, fuel consumption can be influenced by operator skill, the size of the area which will be planted and by the power of the tractor.

Fuel consumption per area worked is higher when using disc plows because of their smaller work capacity, contrary to the harrow, which requires less fuel and can do heavier work, a feature that makes it more suitable for lowlands.

It has been determined that when comparing fuel consumption, relative to soil volume moved per area, there is very little difference between different tillage equipment.

# Liming and fertilization

*Alberto Baêta dos Santos*
*Nand Kumar Fageria*

Most of lowland soils are acidic, a limiting factor for agricultural production. Theoretically, acidity is characterized by the content of hydrogen and aluminum in the soil. In practice, however, soil acidity is determined by many factors, such as nutritional deficiency and/or toxicity, decreased beneficial plant microbial activity and erosion. Additionally, acidity favors the incidence of diseases, especially fungal infections, which affect plant growth. Among the various management practices for acidic soils, the use of limestone is the most common and effective method. When liming, several factors must be taken into account: the kind of crop; soil pH, texture and organic matter content. Other factors to consider are limestone granulometry, treatment time and frequency, and the cost of the material used. Adequate levels of pH, and of base and aluminum saturation of lowland soils have been established for major crops and they should be used to determine the degree of soil acidity in lowlands and the consequent correction.

Liming effects various chemical transformations in the soil for that are important for the crop. Rice is very tolerant to acid soil. However, if planted in succession with soybeans or corn, soil base saturation should be between 60% and 65%.

The productivity of irrigated rice in Mato Grosso do Sul is mostly limited by nitrogen, phosphorus and potassium deficiency. It should be noted, however, that zinc deficiency has also been observed in some areas.

## Recommendations

Crop response to liming is the best criterion for recommending it. Recommendations should be made on the basis of the levels of aluminum, calcium and magnesium and the soil base saturation.

When the content of $Ca^{2}$ + + and $Mg^{2+}$ is less than 2 $cmol_c/kg^{-1}$ and the clay content is greater than 20%, the following formula is employed:

Lime need (L.N.) (t $ha^{-1}$) = 2 x Al + [ 2 – ( Ca + Mg )] x f

where: f = 100/ PRNT of lime.

For soils in which the clay content is over 20% and Ca + Mg greater than 2, the lime need is given by the formula:

L.N. (t $ha^{-1}$) = 2 x Al x f

When soil clay is less than 20%, the amount of lime to apply is given by the higher number found in the two formulas below:

L.N. (t $ha^{-1}$) = 2 x Al x f or L.N. (t $ha^{-1}$) = 2 – (Ca + Mg ) x f

It is worthwhile pointing out that sandy soils are generally of limited agricultural use because they have low cation exchange capacity, low water retention capacity and a greater susceptibility to erosion. One must consider that the liming regimen calculated by this method is insufficient to raise soil base saturation or soil pH to appropriate levels for most annual crops, both in the highlands (the Brazilian savana, or cerrado) and in lowlands.

Another base for recommending liming is using soil base saturation which, in terms of its chemical properties, is an important indication of soil acidity. In this case, the need for lime is calculated as follows:

L.N. (t $ha^{-1}$) = [$_{potencial}$CEC ( $V_2$ – $V_1$) / 100 ] x f1

where:

CEC = cation exchange capacity at pH 7 in $cmolc/kg^{-1}$;
$V_2$ = base saturation appropriate for the crop to be planted in %; and
$V_1$ = present soil base saturation in %.

# Fertilization

The productivity of irrigated rice in Mato Grosso do Sul is mostly limited by nitrogen, phosphorus and potassium deficiency. It should be noted, however, that zinc deficiency has also been observed in some areas.

## Nitrogen

Nitrogen is responsible for the increase in the foliar area of irrigated rice, which in turn increases the efficiency of solar radiation interception, photosynthetic rate and overall grain yield. When free from other limiting production factors, rice normally responds to nitrogen. If nitrogen is not applied in the right amount, at the right time, its deficiency will quickly become apparent in the crop. The main reasons for the nitrogen deficiency are losses by various processes; low application rates and insufficient soil organic matter due to successive cropping. Except for potassium, nitrogen is also the nutrient that the rice plant accumulates in larger quantities.

Leaching, volatilization and de-nitrification causes nitrogen loss. In this case, appropriate management is essential both to reduce the cost of production and to minimize the effects of environmental pollution. Nitrogen efficiency may be enhanced by the use of the appropriate dosage, at the appropriate time, the proper use of water, correct disease, pest and weed control measures and the use of adequate spacing and seeding density. Using cultivars with a high production potential and an efficient use of nitrogen is also an important component in producing rice.

### *Dosage*

The adequate dosage nitrogen is the amount that will offer maximum economic productivity, above which no crop response can justify increasing the amount of the nutrient being studied. Since nitrogen is a mobile nutrient, whose soil concentration can vary depending on climate, soil and prevailing weather, recommendations are based on crop response under field conditions. An Embrapa Rice and Beans field study showed a significant and quadratic response in grain yield when nitrogen was applied, during a three-year experiment (Figure 1).

In the first year, 90% of maximum yield 6,298 kilograms ha$^{-1}$; which was considered a economically feasible level, was obtained with the application of 120 kg ha$^{-1}$ of N. In the second and third years, this level was achieved by applying 90 kg and 78 kg ha$^{-1}$ N, respectively, corresponding to 6,345 kg ha$^{-1}$ and 5,203 kg ha$^{-1}$, respectively. The three year average showed that a 90% maximum yield of 5,731 kg ha$^{-1}$ was obtained with the application of 84 kg ha$^{-1}$ of N, which means that nitrogen had residual effects. Another field trial also demonstrated that rice responds significantly and in a quadratic manner to nitrogen (Figure 2). With up to 200 kg ha$^{-1}$ of nitrogen, crop response was significant. However, 90% of maximum productivity was obtained by applying 120 kg ha$^{-1}$ of nitrogen. On the basis of these results, the recommended amount of nitrogen for irrigated rice is 90 to 120 kg ha$^{-1}$.

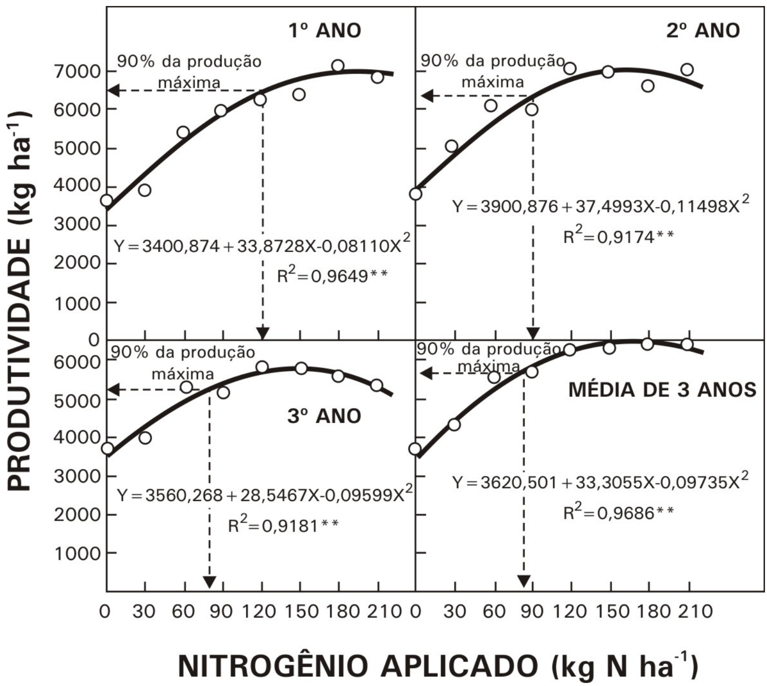


**Figure 1.** Relationship between applied nitrogen and grain yield.

In a study conducted in a vertisol, at the San Francisco farm, located in the county of Miranda, MS, when evaluating rice response to N rates combined with 60 and 120 kg ha$^{-1}$ of $K_2O$, the result was a maximum yield of 120 and 126 kg ha$^{-1}$ N, with the lowest and highest amounts of potassium as fertilizer, respectively. The same study showed that the maximum economic return was obtained with a joint application of nitrogen and potassium (113 kg ha$^{-1}$ of N and 120 kg ha$^{-1}$ of $K_2O$).

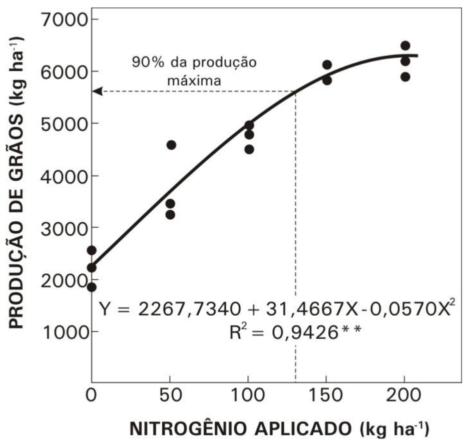


**Figure 2.** Response of irrigated rice to nitrogen.
Mean yield for 12 genotypes.

## *Application time*

Since nitrogen is a mobile nutrient in the soil-plant system, easily lost by leaching, volatilization and de-nitrification, multi-phase application throughout the crop cycle can increase its efficiency.

In experiments conducted at various sites in the tropical region, the highest grain yields were observed when nitrogen was applied at sowing time, together with phosphorus and potassium and in two applications.

Rice absorbs N throughout its cycle, but there are two critical development stages: tillering and primary flower differentiation. Thus, to achieve N absorption and uptake efficiency, the recommendation is to apply N at the time these events are taking place.

The first application of nitrogenated fertilizer as cover should occur no later than three days before the final flooding because the irrigation water makes it possible for the nitrogen to become incorporated into the soil, thereby increasing the time it continues to be available for the plant. Further applications should be made on the non-circulating water.

It has been shown that nitrogen applied at the time of booting and flowering did not increase grain yield, when compared to an earlier application, during the plant development stage. Earlier nitrogen application results in a higher number of panicles, one of the factors that determine productivity. Thus, it is important that at least part of the N should be applied up to 30 days after plant emergence.

The incidence of leaf blast may be increased when greater amounts of nitrogen are applied during sowing. If that is the case, the recommendation is to treat the seeds of susceptible cultivars. On the other hand, late application can favor the incidence of panicle blast.

## *Source of nitrogen*

Major sources of nitrogen are chemical fertilizers which present chemical and physical variations. These differences appear in the different ways each fertilizer reacts when in the soil. Their efficiency as a nitrogen source also varies.

Table 1 shows the main nitrogen fertilizers with their chemical formulas and nitrogen levels. In Brazil, the main sources of nitrogen used in rice are urea and ammonium sulfate. Nitrates are not recommended because they are easily lost by leaching and de-nitrification in flooded soils.

Both ammonium sulfate and urea are equally effective. Urea, however, is more cost-effective, since it contains 45% of nitrogen while ammonium sulfate contains only 21%. Ammonium sulfate, on the other hand, contains approximately 24% of sulfur, which can help correct any possible sulfur deficiency.

**Table 1.** Main nitrogenated fertilizers and some of their proprieties.

| *Fertilizer* | *Chemical formula* | *N content (%)* | *Water solubitity (%)* |
|---|---|---|---|
| Ammonium sulfate | $(NH_4)_2SO_4$ | 21 | 100 |
| Urea | $CO(NH_2)_2$ | 45 | 100 |
| Ammonium nitrate | $NH_4NO_3$ | 33 | 100 |
| Ammonium chloride | $NH_4Cl$ | 26 | 100 |
| Calcium cyanamid | $CaCN_2$ | 21 | 100 |
| Calcium nitrate | $Ca(NO_3)_2$ | 16 | 100 |
| Sodium nitrate | $NaNO_3$ | 16 | 100 |
| Anhydrous ammonium | $NH_3$ | 82 | 100 |
| Potassium nitrate | $KNO_3$ | 13 | 100 |
| Monoammonium phosphate | $NH_4H_2PO_4$ | 11 | 100 |
| Diammonium phosphate | $(NH4)_2H_2PO_4$ | 18 | 100 |

## Phosphorus

After nitrogen, phosphorus deficiency is another significant factor in hindering productivity of irrigated rice planted in the lowland soils of Brazil. In this case, deficiency is related to a naturally low content in the soil and the high fixation capacity of lowland soils. Phosphorus deficiency decreases the number of tillers and the leaf area, thereby decreasing the photosynthesis. Among other physiological and biochemical functions, this nutrient increases the number of panicles in rice plants. Most of the phosphorus accumulated in the plant is exported to the grains.

The need for phosphate can be assessed by analyzing both the soil and the leaf. Phosphate fertilization is recommended, however, on the basis of soil analysis results. The amount needed will depend on the residual effect of phosphorus in the soil, the productivity of the cultivar, the balance between the other essential nutrients (mostly nitrogen and potassium), the presence of clay, soil texture and organic matter, the extractor used and water management.

Phosphorus solubility increases in flooded soil. In acidic soils, like most of the lowland soils, iron and aluminum phosphates are the predominant forms. They release phosphorus when soil pH increases as a result of flooding. The increased solubility of iron phosphate is caused by the reduction of $Fe^{3+}$ to $Fe^{2+}$. The increased availability of phosphorus after flooding is connected to the amount of natural phosphorus in the soil fixated by the iron and aluminum oxides.

### *Dosage*

Since phosphorus is not a mobile nutrient in the soil, recommendations are based on the calibration of soil analysis and crop productivity. This means that when studying soil analysis calibration, it is necessary to create a wide range of phosphorus in the soil through the application of phosphate fertilizer and measure crop productivity in view of the phosphorus content in the soil.

The recommended dose of phosphorus is based on the outcome of the soil analysis (Table 2). In general, the appropriate level of phosphorus in the lowland soils of central Brazil is around 13 mg $kg^{-1}$ of soil.

**Table 2.** Recommended phosphate fertilization based on soil analysis, Mehlich 1 extractor.

| *Soil P content (mg kg)* | *Result interpretation (mg kg$^{-1}$)* | *Need of $P_2O_5$ (kg ha$^{-1}$)* |
|---|---|---|
| 0 – 2,6 | Very low | 150 |
| 2,6 – 8,8 | Low | 150 |
| 8,8 – 13,0 | Medium | 100 |
| >13 | High | 50 |

## *Application time*

Phosphorus is carried through the soil by diffusion. Therefore, to maintain soil fertility, phosphorus should be applied very close to the root system. This increases absorption efficiency. Due to its high nitrogen fixation capacity in acid soil, soluble phosphorus as single or triple superphosphate should be applied in the furrow at the time of sowing.

## *Sources of phosphorus*

Major sources of soil phosphorus replacement are the chemical fertilizers listed in Table 3. Phosphate fertilizer efficiency is determined mainly by its physical and chemical properties and by how it interacts with the soil. In addition to formulated fertilizers, single and triple superphosphates are also used as sources of phosphorus in annual crops such as rice, corn and soybeans.
For these crops, natural phosphates are the most inexpensive source of this nutrient, but they are inferior to superphosphates, which usually contains 18% to 40% of $P_2O_5$, and solubility in 2% citric acid ranges from 1% to 16%. It is worthwhile pointing out that the expression phosphorus availability is applied to phosphate fertilizers and includes phosphorus solubility in 2%citric acid.

**Table 3.** Major phosphate fertilizers and some of their properties.

| *Fertilizer* | *Chemical formula* | *$P_2O_5$ content (%)* | *Water solubility (%)* |
|---|---|---|---|
| Phosphoric acid | $H_3PO_4$ | 55 | 100 |
| Diammonium phosphate | $(NH_4)_2HPO_4$ | 53 | 100 |
| Single superphosphate | $Ca(H_2PO_4)_2.\ H_2O,\ CaSO_4.H_2O$ | 20 | 85 |
| Triple superphosphate | $Ca(H_2PO_4)_2.\ H_2O$ | 45 | 87 |
| Dicalcium phosphate | $CaHPO_4,\ CaHPO_4.2H_2O$ | 40 | 4 |
| Calcium meta-phosphate | $Ca(PO_3)_2$ | 62 | 4 |
| Monoammonium phosphate | $NH_4H_2PO_4$ | 48 | 100 |
| Thermophosphate (BZ-Yoorin) | - | 18 | 16 in 2% citric acid |

When agronomic and economic contexts are taken into consideration, the best strategy is to use natural phosphates for soil correction and soluble sourced phosphates for soil maintenance. Broadcast fertilization using larger quantities should be used for natural phosphates and they should be incorporated. They are more efficient in acidic soils because of its solubility at low soil pH. Their efficiency drops significantly when applied on soils corrected with limestone.

## Potassium

Potassium is an important nutrient for plants in various physiological and biochemical processes determining crop productivity. Interest in K fertilization increased with the introduction of cultivars with a high yield potential and the effects of this element in reducing diseases affecting irrigated rice, especially rice blast and brown spot. In order to maintain nutritional balance the amount of potassium has also increased, since modern cultivars need more nitrogen and phosphorus.

Potassium is mobile in the plant and K deficiency first appears in older leaves. Rice response to potassium is not as significant as in the case of nitrogen and phosphorus because of the high soil content and the possibility of releasing the fraction of non-exchangeable potassium to the soil solution. However, potassium is accumulated in rice fields, especially by modern cultivars, in greater quantity, relative to other essential nutrients. Thus, successive or intensive crops may suffer from K deficiency, if appropriate measures are not taken. In addition to being absorbed by the crop, potassium can be lost by leaching and soil erosion. Part of it can become fixate to the soil, depending on soil mineralogy and texture. In rice, 85% to 90% of the potassium accumulated in the plant is found in the straw. Therefore, the incorporation of crop residues can help recycling efforts. However, as rice straw has a high C/N ratio (> 50), one should be careful with respect to the time elapsed between incorporation of crop residues and the sowing of the subsequent crop. At harvest, for a normal production, upwards of 6,000 kg $ha^{-1}$ of grains, the appropriate potassium content in the straw is around 17 g $kg^{-1}$ or 1.7% while in the grains one should expect to see around 2.6 g $kg^{-1}$ or 0.26%. To produce one ton of grain, irrigated rice accumulates potassium at 35 kg to 40 kg range in the straw and the grains, depending on productivity and on the cultivar used.

Approximately 40% to 45% of the potassium applied is recovered by the crop. The same happens with nitrogen. On average, potassium use efficiency (kg of grain produced per kg of potassium accumulated) is lower, relative to nitrogen and phosphorus. Rice response to potassium depends on the way water is managed and the appropriate balance of other nutrients, especially nitrogen and phosphorus.

## *Dosage*

Since most of the K is carried away by a diffusion process in the soil-plant system, potassium is considered a very mobile nutrient in the soil. Recommendations for K fertilization are also made on the basis of soil analysis. On average, when soil potassium content is greater than 50 mg $kg^{-1}$ of the soil (500 mmol $dm^{-3}$ or 50 ppm), as extracted with Mehlich 1 (0.05 N HCl + 0,025N $H_2SO_4$), rice does not respond to potassium. In this case, the recommended dose is 60 to 70 kg $ha^{-1}$ of $K_2O$. However, when the potassium content is less than 50 mg $kg^{-1}$ of soil, 100 to 120 kg $ha^{-1}$ of $K_2O$ should be applied.

## *Application time*

Because of Potassium moves by diffusion in the soil, potassium fertilizers are usually applied in the furrow, when sowing. However, in tropical soils, where rainfall is abundant, or in flooded rice fields, the possibility of leaching and erosion losses exists. Loss by leaching is higher in soils with a low cation exchange capacity (CEC) and in soils with a low clay content. In sandy soils, with a clay content below 20%, some potassium may be applied directly on the soil along with nitrogen, to prevent leaching and improve the absorption efficiency.

## *Potassium sources*

There is much controversy on potassium sources. Potassium chloride and formulated fertilizers (NPK) are the most common sources. Though more expensive than chloride, potassium sulfate is also effective in supplying potassium with the advantage of also providing sulfur. The major potassium sources are presented in Table 4.

**Table 4.** Major potassium fertilizers and some of their properties.

| *Fertilizer* | *Chemical formula* | *$K_2O$ content (%)* | *Water solubility (%)* |
|---|---|---|---|
| Potassium chloride | KCl | 60 | 100 |
| Potassium sulfate | $K_2SO_4$ | 50 | 100 |
| Potassium magnesium sulfate | $K_2SO_4.2MgSO_4$ | 23 | 100 |
| Potassium nitrate | $KNO_3$ | 44 | 100 |

## Zinc

Zinc deficiency in irrigated rice is related to a naturally low soil zinc content, increased pH caused by flooding, liming acid soils, the use of modern cultivars requiring greater amounts of nutrients and soil erosion. Critical zinc level in plants ranges from 20 to 50 mg $kg^{-1}$, depending on plant age. In the soil, the critical level is 1 to 2 mg $kg^{-1}$, depending on the extractor used, clay content and soil pH. Zinc deficiency can be corrected with the application of 3 to 6 kg $ha^{-1}$ of zinc in sandy soils and 10 to 12 kg $ha^{-1}$ in clayey and loam soils. The best source of zinc is the highly water soluble zinc sulfate. Zinc can be applied in the furrow along with the basic fertilizer. If zinc deficiency appears during the crop cycle, zinc sulfate must be applied on the leaves at 0.5%. If the deficiency is very severe, zinc must be applied again 10 to 12 days after the first application.

# Cultivars

*Veridiano dos Anjos Cutrim*
*Orlando Peixoto de Morais*

Along with good practices, an important point for rice to succeed is cultivar selection. Research institutions are always releasing new rice cultivars as part of their breeding programs seeking to incorporate features that will lead to higher productivity, improved quality at a lower cost. As Breseghello et al. (1998) explained, there is no ideal cultivar, but cultivars with qualities that must be used properly for best results.

When choosing a cultivar, one needs to analyze its characteristics, such as cycle, plant height, resistance to diseases, grain quality and productivity. The aim is to optimize use within the desired agricultural system.

Except for the BRS Tropical, the rice cultivars listed in Table 1 are the most frequently used in Mato Grosso do Sul. BRS Tropical is the newest cultivar. It was only registered for this and other states in 2008, but the cultivar already has an inventory of basic seeds which can meet the demand.

The following are some traits for cultivars offered by institutions which developed and have registered them at SNPC – Serviço Nacional de Proteção de Cultivares (National Service for Cultivar Protection). Information on cultivars developed by Irga and Epagri were obtained on trials conducted in Rio Grande do Sul and Santa Catarina, respectively (SOCIEDADE BRASILEIRA DE ARROZ IRRIGADO, 2007 - Brazilian Society of Irrigated Rice), and therefore may not be reproducible in Mato Grosso do Sul, mainly those traits related to the vegetative cycle and disease resistance.

**Table 1.** Properties of irrigated rice cultivars recommended for Mato Grosso do Sul.

| | Epagri/Embrapa | | Epagri | | | | | Embrapa | | | | Irga | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cultivar | SCSBRS | Tio | Epagri | Epagri | Epagri | SCS 114 | Epagri | | BRS | BRS | BRS | IRGA | IRGA | IRGA | IRGA | IRGA |
| Name | Piracema | Taka | 108 | 109 | 112 | Andosan | 115CL | Taim | Ouro-minas | Jaçanã | Tropical | 417 | 418 | 419 | 420 | 422CL |
| Year released | | 2002 | 1995 | 1996 | 2000 | 2005 | 2007 | 1991 | 2002 | 2007 | 2008 | 1995 | 1999 | 1999 | 1999 | 2002 |
| **Cycle** | **M** | **L** | **L** | **L** | **L** | **L** | **M** | **M** | **M** | **E** | **L** | **E** | **E** | **E** | **E** | **M** |
| Mean flowering (days) | 95 | 111 | 107 | 107 | 108 | 105 | 100 | 95 | 100 | 80 | 110 | 83 | 80 | 83 | 80 | 85 |
| Maturation (days) | 125 | 141 | 142 | 142 | 138 | 140 | 135 | 130 | 130 | 115 | 140 | 115 | 115 | 120 | 120 | 121 |
| Natural seed shattering | R | I | I | I | I | I | I | I | I | I | I | I | Es | Es | Es | I |
| Lodging resistance | R | R | R | R | R | R | MR | R | R | R | R | R | R | R | R | R |
| Iron toxicity | MS | MS | R | R | MS | MR | R | MT | R | NI | NI | S | MR | R | | S |
| Rice water weevil | MR | NI | NI | NI | NI | NI | NI | MR | NI | NI | NI | NI | NI | NI | NI | NI |
| Leaf blast | S | S | S | MR | S | MR | MR | MR | MS | MR | MR | MS | MR | MR | MR | MS |
| Panicle blast | MS | NI | MR | MR | NI | MR | MR | MR | MS | MR | MR | MS | MR | MR | MR | MS |
| Leaf scald disease | NI | NI | NI | NI | NI | NI | NI | MS | MR | MR | MR | MS | MS | MS | MS | NI |
| Grain discoloration | NI | NI | NI | NI | NI | NI | NI | MS | MS | MS | MR | MS | MS | MS | MS | MS |
| Brown spot | NI | NI | NI | NI | NI | NI | NI | MR | MS | MS | MR | MS | MS | MS | MS | NI |
| Sheath blight | NI | NI | NI | NI | NI | NI | NI | MS | NI | NI | NI | MS | MS | MS | MS | NI |
| Grain class | LF | LF | LF | LF | LF | LF | LF | LF | LF | LF | LF | LF | LF | LF | LF | LF |
| Head grain yield | 62 | 63 | 68 | 68 | 62 | 63 | 61 | 65 | 55 | 60 | 62 | 62 | 63 | 63 | 62 | 61 |

Cycle: E – Early; M – Medium; L – Late
Natural seed shattering: D – Difficult; I – Intermediary; Es – Easy
Grain class: LT – Long Thin
Other characteristics: R – Resistant; MR – Medium Resistant; MT – Medium Tolerant; MS – Medium Susceptible;
S – Susceptible; NI – No Information

Cultivars:

- **SCSBRS Piracema** – Medium-cycle cultivar (130 days), modern architecture, intermediary size, lodging resistant and good yield potential. It is moderately susceptible to leaf blast. The grains are long, thin, they have a good appearance and the head grain yield is high. The cultivar is recommended for the entire state.
- **Epagri 108** – Long-cycle cultivar (140 days), short, resistant to lodging and to indirect iron toxicity. It is moderately resistant to panicle blast, considering the currently prevalent breeds in Santa Catarina where it was developed. The grains are long, thin, with a high processing efficiency and good cooking qualities.
- **Epagri 109** – Very similar to cultivar 108, with a long cycle (142 days), resistant to lodging and indirect iron toxicity. It is moderately resistant to blast breeds found in Santa Catarina.
- **Epagri 112** – Long-cycle cultivar (138 days), short and resistant to lodging. Not recommended in areas with a history of iron indirect toxicity and blast, since it is moderately susceptible to these two factors. It is very sensitive to extreme temperatures, so planting should be done within the preferred period.
- **Tio Taka** – Long-cycle cultivar (140 days), short, lodging resistant, good tillering capacity and high yield potential, high industrial yield grains and good cooking qualities. It is moderately susceptible to indirect iron toxicity.
- **SCS 114 Andosan** – A cultivar that stands out for yield stability in the different environments in which it was tested, because of the high quality grains both for processed and parboiled rice, and also for the high productivity. It presents a 140-day cycle, from sowing to maturity, and is moderately resistant to indirect iron toxicity and blast.
- **SCS 115 CL** – Medium-cycle cultivar (130-135 days), good for the "Clearfield" production system. "Clearfield" controls red rice (it is resistant to the herbicide "Only"), with excellent agronomic performance. However, the relative height (110cm) suggests caution when using nitrogen-based fertilizers. It is resistant to iron toxicity and moderately resistant to blast. It is appropriate for direct processing (white rice) or parboiled rice.
- **IRGA 417** – Short-cycle cultivar (115 days), short in height, high yield, excellent grain quality and high initial seedling vigor. It is easily adaptable to different production regions. It is susceptible to iron toxicity, panicle blast and brown spot.
- **IRGA 418** – Early-cycle cultivar, higher than the 417 variety. It displays good initial seedling vigor, high yield and blast resistance. Main limitations are lack of production stability and industrial grain yield. Seeds shatter easily and presents an intermediary reaction to iron toxicity.

- **IRGA 419** – Short-cycle cultivar (120 days), with hairless leaves and grains. It is resistant to iron toxicity blast and susceptible to staining of grains. Threshing of grains is considered easy.
- **IRGA 420** – This cultivar very similar to the IRGA 419, but with a slightly shorter cycle and higher yield potential.
- **IRGA 422CL** – This cultivar is derived from the IRGA 417 by backcrossing. It differs in the sense that it has a longer cycle, the culinary quality of the grains is not as good and it is tolerant to the herbicide “Only.” It is recommended for the “Clearfield” cultivation system, whose main endpoint is to control red rice.
- **Taim** – Medium-cycle cultivar with a high production capacity. The grains are long-thin, awn free smooth clear hulls. BRS 7 Taim has genes of the TETEP cultivar which gives it better reaction to the blast breeds currently found in Rio Grande do Sul, where it was developed.
- **BRS Ourominas** – M-edium-cycle cultivar (130 days), short, lodging resistant, good tillering capacity and high yield potential. It is moderately resistant to leaf blast and the grains are long, glassy, thin, and present a high whole grain yield during processing. They have an excellent cooking quality and short post-harvest maturation period.
- **BRS Jaçanã** – Short-cycle cultivar (120 days), combining the features of modern plant architecture, lodging resistance, high productive capacity, long-thin grains, excellent industrial and cooking quality and short post-harvest maturation period. It is moderately resistant to blast and moderately susceptible to brown spot. It has good stability with respect to harvest and can be harvested within 25 to 45 days after average flowering.
- **BRS Tropical** – Cultivar widely adapted to the tropical lowlands of Brazil. The architecture is of a modern plant, with erect leaves and plant height of 110 cm, despite having shown resistance to lodging. Caution is advised in relation to nitrogen fertilization. In the region of Miranda, where planting takes place in early August, flowering period lasts 110 days, maybe less in other regions of the state with later sowing. The cultivar has a high yield, long-thin grains of excellent industrial and cooking quality and a short post-harvest maturation period. It is moderately resistant to blast and to brown spot. It has good harvest stability and can be harvested between 25 and 53 days after average flowering. Yield is high, provided there is no rehydration during the period.

# Good seed production practices

*Mariana Cruzick de Souza Magaldi*
*Jaime Roberto Fonseca*

The result of long years of study and experimentation, seeds are probably the inputs with higher added value since they carry within them genetic variety. Commercial seeds are produced under strict quality standards to ensure that growers will have the best performance in the field, thereby maximizing the benefits of other inputs such as fertilizers and pesticides.

Commercial seed production is controlled by strict standards set at state level. In the state of Mato Grosso do Sul, standards are set by the Comissão Estadual de Sementes e Mudas - CESM / MS (State Seed and Seedling Commission), while national standards can be found on the webpage of the Ministry of Agriculture, Livestock and Supply at: http://extranet .agricultura.gov.br/sislegis-consulta/servlet/VisualizarAnexo? Id = 10807th

It is worthwhile pointing out, however, that the advantages of commercial seeds are not always fully exploited by farmers. Only about 30% of irrigated rice growers buy commercial seeds for planting. Most plant their own seed.

The good rice seed production practices presented below are used to produce commercial seeds, but can also be very useful in improving the quality of the seeds themselves.

Crops intended for seed production are managed similarly to those for grain production. They differ, however, in certain technical practices and legal issues that require special care as detailed below.

## Site selection

Several environmental factors must be considered when selecting a site to produce seeds. Low light, rapid changes in temperature and high relative humidity are not favorable to obtaining good quality seeds and highly favorable to diseases (SANTOS; RABELO, 2008). Adverse weather conditions can be alleviated by planting seeds at differentiated times. The choice of the seeding time aims at providing the best conditions for the crop to develop well throughout the plant cycle, and will make it possible to adjust the crop to the climatic conditions in the region, which are favorable to production, both in terms of seed quantity and quality (VON PINHO, 1998).

Before determining the site for producing irrigated rice seeds, it is important to know its history with regards to the cultivars used previously to prevent mixing varieties by the emergence of volunteer plants, the degree of infestation with weeds and the fallow period (VIEIRA et al., 2006). Depending on the seeding system adopted, some places may become unfeasible for seed production, mainly due to the presence of red rice and black rice, which are more robust than the cultivated rice variety, seeds shatter very easily the seeds show prolonged dormancy, and remain viable in the soil for several years (VIEIRA et al., 2006). Furthermore, the herbicides used to control these weeds are not very efficient. Therefore, areas highly infested with red and black rice should be avoided when planting is done in dry soil that is subsequently flooded. To capitalize on these areas for seed production, the recommendation is to plant pre-germinated seeds or use the practice of transplanting seedlings. Both of these practices should be combined with weed control.

The area chosen should have a crop rotation plan to reduce the pest population and diseases.

It is important to remember that in addition to the serious damage that diseases cause to productivity and quality, some of these diseases can be transmitted by seeds.

## Cultivar selection

Choice of cultivars should be guided by recommendations made by researchers and market characteristics. The morphologic and agronomic description is an indispensable tool in inspecting the production fields, in the quality control laboratory and in the seed industry as a whole. Productivity, quality and market are important factors in choosing a cultivar and they should be in line with the wishes of farmers, the industry and consumers (VIEIRA et al., 2006).

Rice seeds have a post-harvest dormancy period that usually lasts four to five months in temperate regions (SANTOS; RABELO, 2008). However, in tropical Mato Grosso do Sul, this period varies from one to two months. Remember that there are also differences in the degree of dormancy among cultivars.

Physical and genetic purity are essential in maintaining quality and ensuring trait transfer from one generation to another. Seeds produced in Brazil are classified into four categories: genetic, basic, certified (C1 and C2) and seeds with an unproven origin (S1 and S2). With the exception of te genetic seed, the other categories are obtained by the multiplication of the preceding class (VIEIRA et al., 2006).

## Production systems

A production system used for the higher seed classes (genetic and basic), is the multiplication of panicles per line. In this system, the selected panicles, representing the desired genotype, are sown in individual rows. The seeds are placed 5 to 10 cm apart and the rows are 30 to 40 cm apart. Lines with atypical plants are eliminated and the homogeneous lines are harvested together (VIEIRA et al., 2006).

Another system used for seed production is manual or mechanized transplant of seedlings. It is recommended especially for regions where new areas are not available for seed production, or where the areas being used are infested with red or black rice as well as volunteer plants. In this case, seedlings are obtained from selected panicles and transferred individually. The area should be prepared in a similar manner to areas used for sowing of pre-germinated seeds, with transplantation done in the mud to prevent the emergence of volunteer plants from seeds found in the field. The seeding density rate should be low in order to facilitate the observation of individual plants during field surveys and the eradication of atypical plants.

Seeds should be treated with insecticide and fungicide. Disease control, such as panicle blast and grain discoloration should be done preventively by means of two spray applications, one at booting and the other at flowering. Pests should also be kept under control by spraying whenever necessary.

Weeds should be controlled as they constitute a major problem for seed production. They compete for sunlight, water and nutrients and hinder harvest operations (BRESEGHELLO et al., 2001).

## Field inspection and weed eradication

Field inspection is considered the most important operation in seed production. It is then that the inspector has the opportunity to observe the plant population at different developmental stages. These inspections, if done at the right times ensure that effective and necessary actions will be taken to avoid the genetic and physical contamination of the crop. Field inspections determine whether the crop:

a) Has been planted with seeds of known and acceptable purity and origin.
b) Has been grown on land that meets desired requirements.
c) has been properly isolated.
d) Has been adequately cleaned.
e) Is uniform in terms of the cultivar traits.
f) Has been properly harvested to avoid mechanical blending.
g) Has been grown in accordance with the basic requirements demanded by the crop (spacing, density, fertilization, pest control, etc.) (VON PINHO et al., 1999).

The practice of carefully and systematically examining the seed production field to remove unwanted plants is called roguing. This operation, which provides for the elimination of all contaminating plants (atypical) is critical to obtain seeds that have the highest degree of varietal, genetic and physical purity (SANTOS; RABELO, 2008).

## Harvesting

Seeds reach physiological maturity between 30 and 35 days after flowering. This timing coincides with the maximum degree of potential vigor and germination power. Nevertheless, at that moment the seed is not in the ideal point for being harvested because of its high moisture content. To avoid large moisture fluctuations of seeds exposed in the field and reduce problems caused by grain cracking, harvest should be done when the seeds present between 18 and 23% humidity. This minimizes the problem of natural seed shattering, which is quite high for some cultivars.

Delay in harvest is also detrimental to seed quality. The rice that remains in the field after the harvesting point is subject to fluctuations in temperature and moisture. They are also susceptible to diseases, pests and predators, which will bring about harmful consequences to seed quality (VIEIRA et al., 2006).

## Machinery and equipment cleaning

One of the most important practices seen in seed production is machinery and equipment cleaning, either during the field stage or after harvest.

In the field, the main sources of contamination are found in the equipment used in tillage, planting and harvesting. All the machinery used should be scrupulously cleaned before starting operations and whenever there is a change of cultivar.

During harvest, in addition to thoroughly cleaning the equipment, the first bags should be discarded, every time a new cultivar is harvested.

## Plant variety purity

A mixture of plant varieties and seeds from weeds that can take place in a seed lot are from other cultivars that remained in the field or in the machinery and equipment used by the farmer in preceding years. Among the weeds, red rice is one most damaging and difficult to control.

The result of a given seed production system that shows the presence of red rice is not fit for use. The difficulty in controlling or eradicating plant variety mixtures and red rice is related to the fact that this plant is of the same species as cultivated rice. Therefore, it cannot be controlled by herbicides. The good news is that the new varieties and hybrids being introduced in Rio Grande do Sul show tolerance for some herbicides, which will enable both red and black rice to be controlled. It is expected that very soon these technologies will also be made available in Mato Grosso do Sul.

The dissemination of red rice seeds from one area to another or from one region to another, occurs primarily by contaminated seed lots. If these lots have a single grain of red rice for each 500 g, they can contaminate 1 ha with 200 red rice seeds.

In addition to these, red rice crosses easily with crop rice, and transfers undesirable traits such as the color of the pericarp and a high percentage seed shattering to the commercial varieties. They generate weeds with the same physical dimensions as the cultivar. As a result, they are impossible to identify in the field or to separate during processing. The implementation of integrated control measures, including preventive, farming, physical and chemical actions, can help control red rice (SANTOS; RABELO, 2008).

## Drying

Drying is a routine operation in the production of rice seeds harvested while still presenting higher than recommended humidity for safe storage. This operation aims at reducing moisture content to around 13%, thus preserving their physiological quality (SANTOS; RABELO, 2008).

Seed drying is often confused with drying the product for consumption, which is also harvested with a high humidity content, to increase industrial yield. However, not only the equipment used for drying, but also the optimum temperature are different, depending on the purpose which the product is intended to serve. The temperature is an extremely important variable in drying both seeds and grains. When seeds are dried at high temperatures, especially when humidity is still very high, they lose physiological quality (BRAGANTINI, 2006).

Another factor to consider is that in regions with a humid climate, even seeds that have already been dried and stored can reabsorb moisture from the atmosphere at levels that can compromise their quality.

Besides knowing the best moisture levels for seed storage, it is important to know how to dry and to store them safely.

## Processing

Rice seed lots come from the field along with undesirable material such as straw, soil, parts of other plants, weed seeds and seeds of other crops. This material must be removed before the seeds are sold or planted.

Seed processing includes, therefore, a whole set of operations which the seed is submitted to, since it enters the processing facilities, to the packaging and distribution stages. The aim is to improve seed appearance and purity as well as to fight pests and disease (BRAGANTINI, 2006).

Each step involved in the beneficiation process (pre-cleaning, cleaning, sorting and bagging) uses specific machines and equipment that will separate the rice from the contaminants.

Seed processing is carried out on the basis of the differences found in the physical characteristics that exist between the rice seed and the impurities that are collected by the harvester. These differences are detected by special equipment that can establish a distinction between seeds and impurities. When using screens, the separation process relies on differences in size. When the air flow method is used, the different elements are separated by weight.

Other tools commonly used in processing rice seeds are the gravity table that separates by detecting specific differences in weight and the honeycomb cylinder that separates seeds from broken grains on the basis of length.

It is worthwhile pointing out that low-density seeds are not vigorous while high-density ones will give rise to vigorous plants which will give a higher yield.

# Planting, Irrigation and Drainage

*Alberto Baêta dos Santos*

Two major systems are used for planting rice: no-till and transplant. In Mato Grosso do Sul growers favor the no-till system on dry soil. In this case an efficient management of weeds becomes critical, since permanent flooding is only performed about three weeks after rice seedlings emerge.

Ideally, one should use a seeder with soil compacting devices to compact the soil along the planting rows, which will results in higher germination rates and uniform emergence. Otherwise, a compactor roll should be used in an operation called rolling. Depending on the soil management system used, planting in rows can be done equally in prepared soil, unprepared soil or in a minimum tillage method.

The most adequate system calls for spacing around 17 to 20 cm and a population of 50 seedlings per meter of row. This represents an 80 kg to 120 kg $ha^{-1}$ in seeds. A very high plant population favors blast incidence and severity.

## Irrigation

Irrigation of rice by continuous flooding with static water is the most commonly used method in Mato Grosso do Sul, both on leveled land and in areas of wetlands, where it is not possible to control the water. Few farms use running water.

Intermittent flooding is not a popular method in Mato Grosso do Sul. With the use of static water, the temperature of the irrigating water often rises above 35º C, damaging the crop. Both the use of running water and intermittent flooding helps to minimize this problem. Notice that intermittent flooding should not be used when the rice starts flowering since the absence of water at this stage of the crop favors the incidence of panicle blast.

## Water consumption

Water use by crops depends mainly on the height of the water table that depends on the level of the rivers that, in turn, are affected by the rainfall regime. Thus, with little rain, that usually being in January, the amount of irrigation required is around 4.0 to 4.5 liters per hectare. It is important to remember that 4.0 L s-1 ha-1 are approximately equivalent to 35 mm of rain. It is therefore necessary to adjust the size of the planted area to the possibility of providing the required irrigation treatment in this most critical period. In years with Indian summers or with a very irregular rainfall distribution, many farms cannot afford to provide the required amount of water. In these farms, especially when that period coincides with the reproductive phase, this condition favors the incidence of panicle blast.

On the other hand, excess water in the crop early in the plant development affects germination, drowns the seedlings and inhibits tillering. Excessive water should be removed from the site within 48 hours, at the most. In order to achieve this, one must scale the size of the plant beds, especially during total leveling when horizontal draining is slower.

## Management

If the soil water content is not enough for germination to take place should be irrigated immediately after planting for a period not exceeding 24 hours. Otherwise the grower will run the risk that the seeds with rot. Irrigation itself should begin about 20 days after seedlings emerge.
Delay in the onset of flooding favors leaf blast and reduces yield.

Water depth affects rice productivity. Whenever possible it should be kept at around 10 cm. Greater depths are better controlling weeds, but they reduce tillering, predispose plants to lodging and increase losses due to evaporation and percolation.

## Suspending irrigation

Irrigation is needed at least up to 20 days after panicles emerge. After that period it should be suspended and this should take place 10 to 15 days before harvest.

# Weeds in Irrigated Rice

*André Andres*

In addition to lowering grain productivity and quality, rice weeds make industrial processing more expensive and they depreciate the rice that has been processed.

Competition between weeds and rice only happens when environmental resources are used beyond the capacity of the ecosystem to make them available (BERKOWITZ, 1988). Simultaneous demand for resources such as water, light and nutrients is the base of the competition between rice and weeds (RADOSEVICH, HOLT, 1984; AMPONG-NYARKO; DE DATTA, 1991). This competition starts early in the development of the crop and can causes losses of over 80%.

In flooded plantations, yield losses in rice due to competition caused by weeds vary with the farming system selected (conventional, minimum or no tillage and a pre-germinated and seedling transplanting mix); the cultivars used (cycle and height); soil fertility; weeds present (species, density, duration and time of occurrence) and with the crop management. In non-controlled areas, productivity can be so affected as to cause the loss of the whole crop.

The principal weeds in flooded rice fields in Brazil are normally classified as having narrow or broad leaves. Representatives of narrow leaves are red rice (*Oryza sativa*), barnyard grass (*Echinochloa sp*), Southern cutgrass and Peruvian watergrass (*Leersia hexandra* and *Luziola peruviana*), the sedges known as smallflower umbrella-sedge or the yellow nutsedge, *Cyperus* *difformis*, *C. esculentus*, *C. ferax*, *C. iria* and *C. laetus*. Recently the presence of *capim papuã – Alexander grass* (*Brachiaria plantaginea*), the Jamaican crabgrass (*Digitaria horizontalis*) and wiregrass (*Eleusine indica*) were identified. Some areas reported the presence of the West Indian marsh grass (*Hymenachne amplexicaulis*), muraino grass (*Ischaemum rugosum*), Mexican sprangletop (*Leptochloa uninervia*), fall panicgrass (*Panicum dichotomiflorum*), knot grass (*Paspalum distichum*), water paspalum (*P. modestum*). Broad leaf weeds include the joint vetch (*Aeschynomene sp*) and, in some areas with steeper slopes, morning glories (*Ipomoea spp*.), smartweed (*Polygonum hydropiperoides*) and alligatorweed (*Alternanthera philoxeroides*). The water weeds found mainly in crops grown in the pre-germinated system are the fimbry (*Fimbristylis miliaceae*), the California arrowhead and the Guyanese arrowhead (*Sagittaria montevidensis* and *S. guayanensis*), the water hyacinth (*Eichornia crassipes*), the mud plantain (*Heteranthera reniformis*), and the primrose willows (*Ludwigia elegans, L. longifolia and L. octovalvis*).

Among the weeds named above, the barnyard grass has been the subject of many studies. The competition posed by this grass reduces productivity (Figures 1, 2 and 3), and this reduction will depend on the number of plants in the planted area (ANDRADE, 1982; ANDRES; MENEZES, 1997, GOMES et al., 2001). Andres and Menezes (1997) found that each barnyard grass plant reduces the productivity of rice in 64 kg $ha^{-1}$. On the other hand, Eberhardt et al. (1999) wrote that the damage caused to rice yield by the competition of barnyard grass is higher in crops with high-yield potential, relative to the damage noted in crops with a low-yield potential.

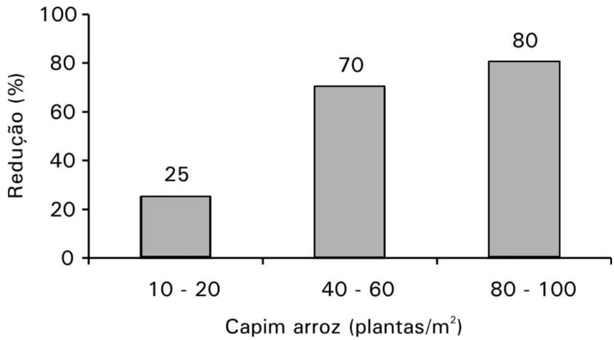


**Figure 1.** Yield reduction in the Bluebelle cultivar as a function of barnyard grass density.
Source: adapted from Andrade (1982).

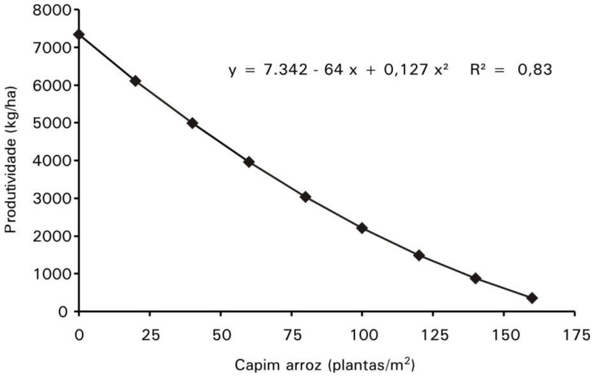


**Figure 2.** Rice yield as a result of the presence of barnyard grass.
Source: Andres e Menezes (1997).

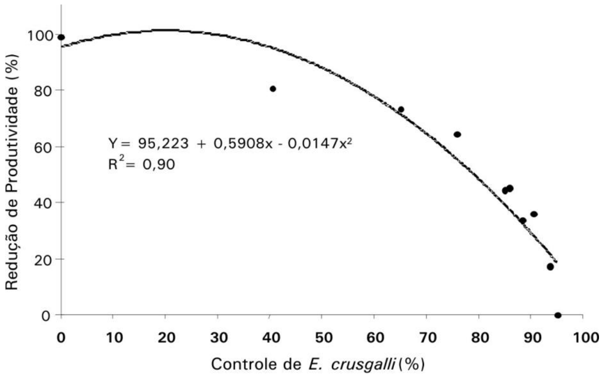


**Figure 3.** Relationship between control of Echinochloa crusgalli and reduced productivity of irrigated rice, BRS Chui cultivar.
Source: Gomes et al. (2001).

Depending on the level of infestation, the *joint vetch* (*Aeschynomene rudis*) is a very competitive weed and can compromise productivity when not controlled properly. Menezes et al. (2001) found a more significant reduction in productivity in populations of two to 18 plants per m$^2$ with a 13.5 and 34.7% reduction in populations of 2 and 75 plants per m$^2$, respectively, compared to plots free of *joint vetch*. Schwanke et al. (2001) found that the negative interference of *joint vetch* (*A. denticulata*) causes a 26% reduction in rice production.

While studying the effect of sedges in irrigated rice, Keeley (1987) found reductions of the order of 2 and 59%, with infestations of 150 and 750 plants per m² of *Cyperus iria*. A 55.8% reduction in rice productivity (BR-IRGA 409 cultivar), was found by Machado and Bizzi (2000), with a mixed population of little bell (*Ipomoea triloba* - 8 plants/m²) and ricefield flatsedge (*C. iria* -123 plants/m² and *C. esculentus* - 65 plants/m²).

In irrigated rice, the critical competition period begins on the 10th day (ANDRES et al., 2008) (Figure 4) and continues up to the 45th day after rice (ISHIY; LOVATO, 1974) emerges (DAE). During that time the rice must be kept free of barnyard grass. Thus, the later the control is instituted, the lower the productivity (MENEZES, ANDRES, 1997) (Figure 5).

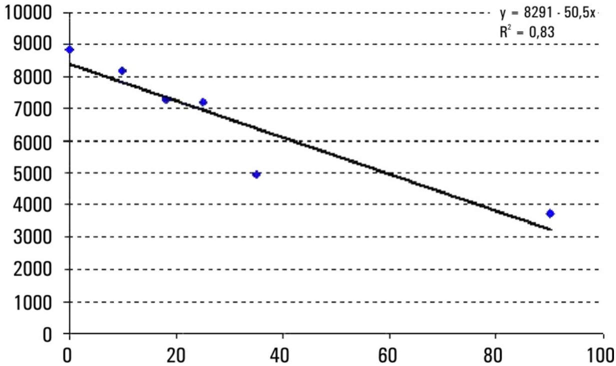


**Figure 4.** Yield of the BRS Querencia cultivar, related to coexistence/ days with weeds.
Source: Andres et al. (2008).

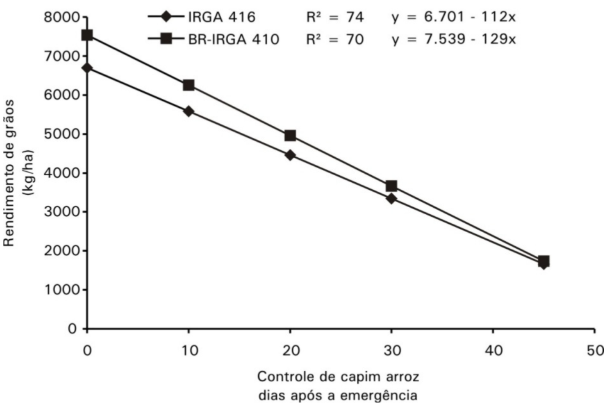


**Figure 5.** Yield of two rice cultivars, as related to the time in which control me-asures for barnyard grass were implemented.
Source: Menezes e Andres (1997).

The result of rice and weed interferences is a decrease in productivity and an increase in the production and dispersal of dissemimules through irrigation water.

## Main weed species found in lowland soils

a) *Sagittaria guayanensis* (Guyanese arrowhead), *Sagittaria montevidensis* (the California arrowhead) and *Ipomoea triloba* (littlebell) shown in Figures 6, 7, 8 and 9.

In addition to the initial competition for elements that are vital for rice to develop, these annual weeds also prevent combines from performing adequately and cause grain quality to depreciate.

**Figure 6.** *S. guyanensis* plants.

**Figure 7.** *S. montevidensis* seedling.

**Figure 8.** *S. montevidensis* plant.

**Figure 9.** *S. montevidensis* inflorecence.

b) *Cyperacea*

Currently, the species of the *Cyperus* genus occur in all the rice growing regions of the state, especially the north coast, central depression, the western border and the south coast, where we note a predominance of *Cyperus ferax* (*tiriricão, junquinho três quinas – flatsedge*) (Figures 10 and 11), *Cyperus difformis* (*junquinho, junça, três quinas – variable flatsedge*) (Figures 12 and 13), *Cyperus esculentus* (*junquinho, tiririca amarela – yellow nutsegde*) (Figures 14 and 15), *Cyperus iria* (*junquinho, três quinas and junça – ricefield flatsedge*) (Figures 16 and 17), *Cyperus laetus* (*junquinha, três quinas* and *tiririçã*) (Figure 18) and *Fimbristylis miliacea* (*cuminho, pelunco, junquinho* – grass-like fimbry) (Figures 19 and 20).

**Figure 10.** *C. ferax* infestation.

**Figure 11.** *C. ferax* inflorescence.

**Figure 12.** *C. difformis* and *S. montevidensis* infestation.

**Figure 13.** *C. difformis* inflorescence.

**Figure 14.** *Cyperus esculentus.*

**Figure 15.** *C. esculentus* infestation.

**Figure 16.** *C. iria* inflorescence.

**Figure 17.** *Cyperus iria* infestation.

**Figure 18.** *C. laetus* infestation.

**Figure 19.** *Fimbristylis miliacea.*

**Figure 20.** *Fimbristylis miliacea* infestation.

Family: *Fabaceae*

*Fabaceae* are annual plants whole prevalence has increased considerably in rice fields, in recent years. In addition to causing major disruptions during harvest and resulting in the depreciation of rice seed quality, it is difficult to eliminate them during the processing stage, even when special screens are used.

Under field conditions, germination is staggered, even in flooded soil. This feature makes control costly and difficult, since specific spraying becomes necessary.

a) *Aeschynomene denticulata* (Angiquinho, corticeirinha – *joint vetch*).

This weed is native of South America and is found in irrigated rice fields. It is a vigorous, erect annual or perennial summer growing legume, herb or shrub with branches and a glandular pubescent stem with small projections and reproduces through seeds. The leaves are sensitive when touched or in the absence of light (Figures 21 and 22).

**Figure 21.** *A. denticulata* seedling.

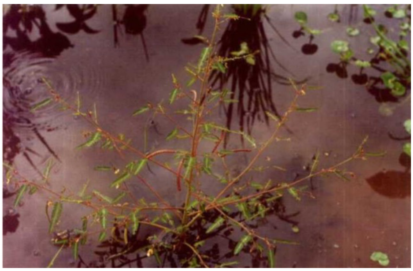

**Figure 22.** *A. denticulata* plant.

b) *Ammania coccinea* (Amania, pinheirinho, coral - *Long-leaved loosestrife*), Figure 23.

**Figure 23.** *Ammania coccinea* plant.

c) *Thalia geniculata* (Caeté, tália - bent alligator-flag).

d) *Ludwigia* spp. (Figures 24 and 25).

Most species of this genus have four sepals and petals (tetrameric), hence the common name (in Portuguese, cruz-de-Malta) since it resembles the Maltese cross. Most common *ludwigiae* in irrigated rice fields are the *Ludwigia elegans, Ludwigia leptocarpa, L. longifolia and L. octovalvis.*

**Figure 24.** *Ludwigia* sp. shoots.

**Figure 25.** *Ludwigia major* plant.

e) *Brachiaria plantaginea* (papuã, capim-papuã, capim-marmelada - Alexander grass), Figure 26, and *Brachiaria plathyphylla* (papuã-do-banhado, capim taquarinha - *broadleaf signalgrass*), Figure 27.

**Figure 26.** *Brachiaria plantaginea* infestation.

**Figure 27.** *Brachiaria plathyphylla* plants.

*f) Digitaria ciliaris* (milhã, capim-colchão - Southern crabgrass) and *Digitaria horizontalis (*milhã, capim-colchão - Jamaican crabgrass).

g) *Echinochloa* spp. (capim-arroz, crista-de-galo, capituva, capim-jaú - bamyard grass), Figura 28.

**Figure 28.** Barnyard grass inflorescence.

The vast majority of weeds occurring in rice fields belong to the genus *Echinochloa.*

Native of Europe and Asia (India), they are herbaceous, erect and their biological cycle lasts 100 to 120 days. Literature still does not have a clear characterization of the various taxonomic units of barnyard grass since it is very difficult to make accurate identification of the species in this genus. There is considerable polymorphism within the same species and, additionally, to complicate matters, there is natural interbreeding resulting in hybrids that don't show defined characteristics (KISSMANN; GROTH, 1999). Because of this complexity some botanists have decided to call it the *Echinochloa* complex.

Main species of barnyard grass:

- *Echinochloa crusgalli* (L.) Beauv. var. *crusgalli.*
- *Echinochloa crusgalli* (L.) Beauv. var. *cruspavonis* (H.B.K.) Hitch.
- *Echinochloa crusgalli* (L.) Beauv. var. *orizicola* (Vasing) Ohwi.
- *Echinochloa crusgalli* (L.) Beauv. var. *zelayensis* (H.B.K.) Hitch.
- *Echinochloa crusgalli* (L.) Beauv. var. *mitis*.
- *Echinochloa colonum* (L.) Link.
- *Echinochloa polystachya* (H.B.K.) var. p*olystachya*.
- *Echinochloa polystachya* (H.B.K.) var. s*pectabilis* (Nees) Mart. Crov.
- *Echinochloa helodes* (Hack.) Parodi.
- *Echinochloa colonum* – Capim-arroz, cartuchinho, capituva, capim-da-colônia.
- *Echinochloa crusgalli* – Capim-arroz, barbudinho, crista-de-galo, capituva.
- *Echinochloa helodes* - Capim-arroz.

In Brazil five varieties of *E. crusgalli* have been described. Each variety has many ecotypes with minor morphological differences. They are annual herbaceous plants, erect and reproduce through seeds. Polymorphism is present even within the same variety. The stems are either round or flat.

*Eriochloa punctata – Capim-de-várzea, capim* (Lowland grass, grass).

*Hymenachne amplexicaulis – Capim capivara, capim-de açúde, grama de lagoa* (West Indian marsh grass).

*Leersia hexandra – Grama boiadeira, grama do brejo* (Southern cutgrass).

These are perennial, emergent aquatic plants. They occur in humid and flooded or poorly drained soils, infesting channels and flooded fields. They reproduce and shoots arise from decumbent and immersed stems. In moist but not flooded soil the plant grows in dense, matlike clumps (cespitose) with a tendency to be upright. The stems are thin and hollow and lodge easily. In flooded areas the stalks form flexible branches of varying lengths that float in water, hence the Portuguese name, *grama boiadeira*, or floating grass. Inflorescence in relatively small panicles with ascending branches, and no basal spikelets.

In winter the plant decreases its physiological activity and, consequently, growth. This weed is rapidly growing in importance for the rice crop. Poor control has caused the problem to disseminate.

*Leptochloa uninervia – Capim mimoso, capim nangá* (Mexican sprangletop)
*Luziola peruviana – Grama boiadeira, pastinho d'agua* (Peruvian watergrass).

They are perennial, stoloniferous, semi-floating aquatic weeds found in wet and flooded lands including rice fields. It reproduces through seeds and stolons. Growth is vegetative during the colder months and they bloom at higher temperatures. Leaves are basal and cauline and are also found above inflorescences. The ligule is membranous and slightly ciliated. Inflorescence is found in panicles and display unisexual and unifloral spikelets, the male are generally terminal and the female axillary. The plant can be easily taken for a *Leersia.* The difference is apparent in the vegetative phase, since *Luziola* has rough leaves and short-truncated ligules while *Leersia* has smooth leaves and ligules are longer and not very wide.

*Oryza sativa* L. – red rice.

Red rice, also known as black or weed rice, receives its name from the reddish-brown color of the pericarp of the grain. Red rice is currently the number one weed in irrigated rice and it is responsible for causing decreased productivity and grain quality. Since it belongs to the same species of crop rice (*Oryza sativa*), the two have similar genetic, morphological and biochemical traits, making it a difficult weed to control. The different ecotypes of red rice found in rice crops present variable morphological and physiological traits. The habits of red rice are similar to those for crop rice, which makes it easy for the weed to become interspersed with the crop rice in the field. It can be an earlier crop, depending on the cultivar used. The life cycle of is shorter, and it grows more, making it more susceptible to lodging, losing grain easily. Among the weeds found in irrigated rice crops red rice (Figure 29) is one of the most significant, both in quantitative and qualitative terms.

**Figure 29.** Red rice.

*Panicum dichtomiflorum* - Capim-do-banhado (fall panicgrass).

*Paspalum distichum* - Grama-de-ponta, grama-doce (knot grass) (Figura 30).

**Figure 30.** *Paspalum distichum* plant.

*Polygonum hidropiperoides* - Erva-de-bicho (smartweed) (Figura 31).

**Figure 31.** *Polygonum hidropiperoides.*

*Eichornia crassipes*– Aguapé (water hyacinth) (Figura 32).

**Figure 32.** *Eichornia crassipes* infestation near a lake.

*Heteranthera reniformis* - Aguapé mirim, agrião-do-brejo, hortelã-do-brejo (mud plantain) (Figura 33).

A perennial, herbaceous, amphibious, subcarneous weed with a great deal of water in plant tissues. Since it is amphibious it can live both in water and in saturated soils. Reproduction is by seeds that only germinate in water-saturated soils. The rooting is in the ground, but the area is flooded, the plant detaches itself and floats. Vegetative propagation also occurs with large groups of plants forming extensive floating mats that affect the development of rice plants, especially in crop systems with flooding takes place before sowing (pre-germinated and a mix with pre-germinated) or seedling transplant. In adult plants, leaves are reniform with a cordate to invaginating base. Inflorescence is in spikes with three to seven flowers. The spike is protected by a green cylindrical acuminate spathe, which is slit laterally all the way to the base of the inflorescence. The blue-white flowers emerge from this slit.

**Figure 33.** *H. reniformis* plants.

*Pontederia cordata* - Aguapé, rainha-dos-lagos, murerê (pickerelweed) (Figura 34).

**Figure 34.** Pontederia cordata.

## Weed management

The goal of weed management is to find alternatives to minimize the losses they cause. It is clear that the arguments favoring the use of chemicals in rice are convenience, speed and the fact that they are efficient, when compared to mechanical control methods.

In the past 10 years, research has shown that efficiency is one of the key parameters among the recommended herbicides, in contrast to chemicals used in the 70's. Concomitantly, EMBRAPA, and other research institutions, has shows that it is possible to reduce herbicide use in 20%, by combining crop management practices. This undoubtedly results in a significant reduction in production costs with the consequent smaller impact on the environment.

It should be noted that over 90% of herbicide applications on rice are focused on the post-emergence stage, where most of the information on crop development, water consumption, the growing stage of weeds and, especially, environmental conditions such as humidity air, air temperature, among others can be obtained. Studies performed by EMBRAPA show that a change in the application time, to the period immediately after sowing may, among other benefits, minimize the side effect of “contamination” in non-target places by dilution, after water has entered the crop.

Optimization of weed control in irrigated rice starts by using high-quality seeds concomitantly to the selection of a site with lower rates of infestation. Weed control can be optimized both in economic and environmental grounds by using alternative crop systems rather than conventional ones.

The no-tillage and minimum tillage systems employed for decades in agriculture have, among other benefits, lowered dependence on chemicals because they consume less power (less use of machinery). In these systems herbicides are applied before sowing. Research has shown that these systems may allow the use of more than one product (glyphosate and a pre-emergence acting chemical), to minimize the number of applications during the crop cycle, thus improving the efficiency of previously chosen chemicals.

The pre-germinated rice system has a unique model of weed control which can be accomplished by using herbicides after sowing in drained soil (spraying) or mixed directly in the irrigation water (spraying or “blessing”). In “drained soil”, water is removed around 15 days after sowing, and the herbicides sprayed on the weeds on dry soil. In this case, the recommendation is to flood the crop according to the mode of action of the agrichemicals. Important to note that this method requires more water and the irrigation process per se must be agile. In “blessing” system herbicides can be used under any weather condition. Moreover, the method requires less water. In this case, the agrichemical is applied directly into the irrigation water when the weeds have two to three leaves, usually 10 to 15 days after sowing. While the herbicide acts, irrigation water must remain stagnant and must not be removed, which is beneficial to the environment.

The list of recommended herbicide with their formulation, concentration, amount and time of application are listed in Tables 1, 2 and 3.

**Table 1.** Herbicides registered and recommended for weed control in rice fields.

| Active ingredient | Brand name | Formulation[1] and concentration ($g.L^{-1}$ ou $kg^{-1}$) | Registered dose for the commercial product (kg or $L.ha^{-1}$) | Time/Mode of application[2] | Toxicological class[3] | Environmental class[4] | Safety interval (days) |
|---|---|---|---|---|---|---|---|
| Azimsulfuron | Gulliver9 | WG 500 | 10 – 12 g | Post | III | III | 15 |
| Bentazon | Basagran 60010 | SL 600 | 1,2 – 1,6 | Post | III | III | 60 |
| Bispyribac-sodium | Nominee 400 SC12 | SC 400 | 100 – 125 mL | Post | II | III | 118 |
| Clefoxydim | Aura6 | EC 200 | 0,75 – 0,85 | Post | I | II | 75 |
| Clomazone | Gamit | EC 500 | 0,8 – 1,4 | Pre | II | II | NE5 |
| Cyhalofop-butyl | Clincher13 | EC 180 | 1,0 – 1,75 | Post | I | II | 77 |
| Cyclosulfamuron | Invest | WG 700 | 57 g | Post | II | II | 111 |
| 2,4 –D7 | Aminol 806 | SL 806 | 0,5 – 1,5 | Post | I | III | NE |
| | DMA 806 BR | SL 806 | 0,3 | Post | I | III | NE |
| | Deferon | EC 502 | 0,6 – 1,2 | (Pre)/ Post | II | NA | NE |
| Ethoxysulfuron | Gladium | WG 600 | 100 - 133 g | Post | III | III | 50 |
| Fenoxaprop-p-ethyl | Starice | EC 69 | 0,8 – 1,0 | Post | II | II | 80 |
| Glyphosate | Glion | SL 480 | 1,0 – 6,0 | Post (ervas) | IV | II | NE |
| | Roundup | SL 480 | 0,5 – 6,0 | Post (ervas) | IV | III | NE |
| Imazapic + imazethapyr | Only8 | SL 25 + 75 | 1,0 – 1,5 | Pre (rest)/Post (rest.) | III | III | 60 |
| Metsulfuron-methyl | Ally9 | WG 600 | 3,3 g | Post | III | III | 30 |
| Oxadiazon | Ronstar 250 BR | EC 250 | 3,0 - 4,0 | Pre/Post | II | III | NE |
| Pendimethalin | Herbadox | EC 500 | 2,5 – 3,5 | Pre | III | II | NE |
| Penoxsulam | Ricer13 | SC 240 | 0,1 - 0,25 | Pre/Post | II | III | 98 |
| Propanil | Grassaid | EC 360 | 8,0 – 10,0 | Post | II | II | 80 |
| | Propanil Milênia | EC 360 | 8,0 – 12,0 | Post | I | II | 80 |
| | Propanin 450 | EC 450 | 8,0 | Post | II | II | 80 |
| | Stam 480 | EC 480 | 7,5 – 10,0 | Post | I | II | 80 |
| Propanil + 2,4–D | Herbanil 368 | EC 340 + 28 | 8,0 | Post | I | II | 80 |

Source: adapted from the Sociedade Sul-Brasileira de Arroz Irrigado (2007).

**Table 2.** Susceptibility of the main weed species to herbicides sprayed on irrigated rice.

| *Main weed species* | *Ally* | *Arrozan* | *Aura* | *Basagran* | *Clincher* | *2,4-D*[1] | *Facet* | *Gamit* | *Gladium* | *Grascarb* | *Gulliver* | *Herbadox* | *Herbanil* | *Invest* | *Nominee* | *Only*[6] | *Ricer* | *Propanil*[2] | *Ronstar* | *Satanil* | *Saturn* | *Sirius* | *Stampyr* | *Starice/Whip S* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aeschynomene* (Angiquinho) | C | SI | NC | NC | NC | C | C | C | C | SI | NC | NC | C | C | C | SI | C | C[3] | NC | SI | NC | SI | C | NC |
| *Brachiaria* (Papuã) | NC | C | C | NC | C | C | NC | C | NC | SI | NC | C | C | C | SI | SI | NC | C | C | SI | SI | NC | SI | C |
| *Cyperus* (Junquinho)[4] | SI | C[3] | NC | C[3] | NC | C | SI | SI | C | SI | C | NC | C | C | C | SI | C | C[3] | NC | C[3] | C | C | C | NC |
| *Digitaria* (Milhã) | NC | C | C | NC | C | NC | NC | C | NC | SI | NC | C | C | C | SI | SI | NC | C | C | C | C | NC | SI | C |
| *Echinochloa* (Capim-arroz) | NC | C | C | NC | C | NC | C[5] | C | NC | C | NC | C | C | C | C | SI | C | C | C | C | C | NC | C | C |
| *Fimbristylis* (Cuminho)[4] | SI | SI | NC | SI | NC | SI | NC | SI | C | SI | C | SI | SI | SI | C | SI | C | C[3] | SI | SI | SI | C | SI | NC |
| *Heteranthera* (Aguapé) | C | SI | NC | SI | NC | SI | NC | SI | SI | SI | NC | SI | SI | SI | C | SI | C | SI | C | SI | SI | C | SI | SI |
| *Ischaemum* (Capim-macho) | SI | SI | NC | NC | NC | NC | SI | SI | SI | SI | NC | SI | SI | NC | SI | SI | C | C | SI | SI | SI | SI | SI | C |
| *Oryza sativa* (Arroz -vermelho) | NC | NC | NC | NC | NC | NC | NC | NC | NC | NC | NC | NC | NC | NC | NC | C[4] | NC | NC | SI | NC | SI | NC | NC | NC |
| *Sagittaria montevidensis*[4] (Sagitária) | SI | NC | NC | SI | NC | SI | NC | SI | C | NC | C | SI | SI | SI | C | SI | C | NC | NC | NC | NC | C | SI | NC |

C= Over 90% control; NC = Non-controlled; SI = No Information; [1]Aminal 806; Deferon, DMA 806 BR; Herbi D-480; U-46 D Fluid; [2]Grassaid; Herbi=propanin; Propanil Ferson; Propanil Milenia; Propanin 450; Stam 360; Stam 480; [3]Controlled weeds in the early stages of development; [4]Resistance to ALS inhibitor herbicides verified in Santa Catarina; [5]Resistance to quinclorac verified in Santa Catarina and in Rio Grande do Sul; [6]Herbicode recommended only for cultivars that are resistant to herbicides of the imidazolinone class.

Source: adapted from the Sociedade Sul-Brasileira de Arroz Irrigado (2007).

**Table 3.** Susceptibility of the main weeds species of to herbicides applied in "blessing" on irrigated rice.

| Main weeds | Ally | Facet | Gamit | Gladium | Invest | Ricer | Satanil | Saturn | Sirius |
|---|---|---|---|---|---|---|---|---|---|
| Aeschynomene (Angiquinho/joint vetch) | C | C | SI | SI | C | C | SI | NC | SI |
| Cyperus (Junquinho/sedges)[2] | NC | NC | SI | SI | C | C | SI | SI | C[1] |
| Echinochloa (Capim-arroz/barnyard grass)[3] | NC | C1 | C | SI | NC | C | C[1] | C | C[1] |
| Fimbristyllis miliacea (Cuminho/fimbry)[2] | NC | NC | NC | C | C | C | C[1] | C | C[1] |
| Heteranthera reniformis (Aguapé/mud plantain) | C | NC | SI | SI | C | C | C[1] | C | C[1] |
| Ischaemum rugosum (Capim-macho/muraino grass) | NC | NC | SI | SI | NC | C | C | C | C[1] |
| Sagittaria montevidensis (Sagitária/ California arrow head)[2] | C | NC | NC | C | C | C | NC | NC | C |

C= Over 90% control; NC = Non-controlled; SI = No Information;
[1]Controlled weeds in the early stages of development;
[2]Resistance to ALS inhibitor herbicides verified in Santa Catarina;
[3]Resistance to quinclorac verified in Santa Catarina and in Rio Grande do Sul.
Source: adapted from the Sociedade Sul-Brasileira de Arroz Irrigado (2007).

## Weed management in different irrigated rice systems

The occurrence of weeds in rice fields will vary according to the crop system used. In general, in crop systems where the soil is flooded before it is prepared for planting (pre-germinated and seedling transplant) aquatic species such as the California arrow head (Sagitária - *Sagittaria* spp.), the mud plantain (agrião-do-brejo – *Heteranthera reniformis),* sedges known as smallflower umbrella-sedge or the yellow nutsedge *(junquinhos – Cyperus* spp.), the long-leaved loosestrife (amânia – *Ammania coccinea*), pickerelweed (aguapé-do-banhado – *Pontederia cordata*) and the primrose willows (cruz-de-malta – *Ludwigia* spp) are the prevailing weeds. Recommended management includes using herbicides that are specific for the existing flora. Among the products surveyed, the following are worthy of notice: azimsulfuron, etoxysulfuron, cychlosulfamuron, metsulfuron, molinate, oxadyazon, oxyfluorfen, pyrazosulfuron, propanil + molinate, thyobencarb, propanil + thyobencarb and quinchlorac. In places where farming is done on dry soil (conventional system) before flooding, most of the weeds are annual grasses (red rice, barnyard grass, Alexander grass, Southern crabgrass). They are followed by joint vetch and flatsedge that emerge when moisture increases. The final flooding of the crop may bring about an increase of the aquatic flora, especially in empty spaces and along the plot edges or walls. There are several alternatives to effect chemical control (Tables 1, 2 and 3).

Another peculiar situation is found in places with limited drainage or in which the micro relief was not adequately corrected, causing the area to be covered with water even during the autumn-winter seasons. This environment is favorable for weeds such as the *gramas boiadeiras*, the Southern cutgrass and Peruvian watergrass (*Leersia hexandra, Luziola peruviana)*, *grama lombo-branco*, the water paspalum (*Paspalum modestum*) and other perennial grasses. They grow vigorously in these conditions, thus making it difficult to establish the next rice crop. Studies have shown that weed desiccation doesn't always offer the best results in terms of control. Among the options listed as those that provide the best management practices for these areas are crop rotation, efficient drainage, micro relief correction during fallow periods, soil mobilization during summer, soil preparation during autumn (dry season) and sequential applications of glyphosate or sulfosate-based herbicides (LAMEGO et al., 2001).

## Weed resistance to herbicides

Worldwide, about 30 weed species associated with irrigated rice are resistant to herbicides. This resistance is expressed against broader spectrum herbicides, such as propanil and the more recent ones, such as the sulfonylureas.

According to the Comitê Brasileiro de Resistência de Plantas to herbicides (Brazilian Committee on Plant Resistance to Herbicides) (SOCIEDADE BRASILEIRA DA CIÊNCIA DAS PLANTAS DANINHAS, 2000), the selection of weeds that are resistant to herbicides is an evolutionary process, in response to repeated applications of the same class or family of herbicides. We see an increased frequency of resistant biotypes manifesting a genetic change in the weed population (Figure 35). This fact takes place prior to application of herbicides. Thus, weed tolerance to herbicides is different from resistance because tolerance is an inherent trait of the plant and exists even before the first herbicide application in the area. Resistance, on the other hand (Figure 36) is a trait acquired by weed ecotypes within a given population, caused by selection pressure, a result of successive applications of the same herbicide or of herbicides with the same mechanism of action (CHRISTOFFOLETI et al. 1994; MEROTTO JUNIOR et al., 1998).

**Figure 35.** Control of red rice in genetically- modified rice.

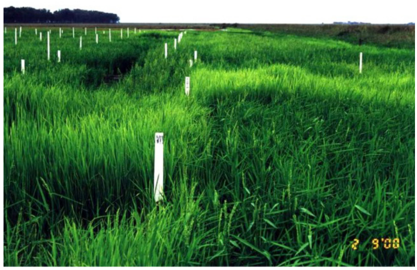

**Figure 36.** Control of red rice in a rice field presenting resistance to herbicides of the imidazolinone group.

In southern Brazil, weed resistance to herbicides is an additional problem for the management of irrigated rice fields. Chemical control is the preferred method for weed control in over 95% of these fields, in association with the conventional planting system, which prevails in this region and is found in over 60% of the rice-growing farms. Thus, intensive use of a predominant planting system combined with the continued use of herbicide with the same mode of action has favored the growth of resistant weeds. Weed resistance to herbicides commonly used in rice has been determined by several research and teaching institutions as EMBRAPA Clima Temperado (EMBRAPA Temperate Climate), Epagri, Irga and the Universities of Rio Grande do Sul, Pelotas and Santa Maria, the three in the state of Rio Grande do Sul, as per the list below.

a. Capim-arroz (Barnyard grass): resistant to quinclorac and ALS inhibitors;
b. Arroz-vermelho (Red rice): resistant to ALS inhibitors, imazethapyr + imazapic;
c. Sagitária (Arrowhead): resistant to azimsulfurone, bispyribac, cyclosulfamurone, ethoxysulfurone, metsulfurone, pyrazosulfurone;
d. Cuminho (sedges) and *Cyperus difformis* (tiririca - flatsedge): resistant toazimsulfuron, bispyribac cyclosulfamuron, ethoxysulfuron, pyrazosulfuron.

See below some preventive measures indicated to delay the development of weed resistance to herbicides (SOCIEDADE SUL-BRASILEIRA DE ARROZ IRRIGADO, 2007):

- always use good quality rice seeds free of red rice (preferably certified seeds);
- monitor changes in weed populations found in the crop;
- prefer crop rotation as this practice encourages the alternation of herbicides (and mechanisms of action) used in the area;
- prefer to use different types of herbicides to avoid using the same active principle sequentially, on the same field;
- use herbicides with different mechanisms of action in association, or employ them sequentially;
- use integrated weed management intensively, especially when certain species escape chemical control.

Once resistance has been found, delay sowing, crop treatment and harvesting of the problem area. Clean all the equipment used thoroughly to prevent dissemination of these seeds to other areas in the same property. See an expert to clear any pending doubts on the right management practice for any problem areas.

# Diseases and Control Methods

*Valácia Lemes da Silva Lobo*
*Marta Cristina Corsi de Filippi*
*Anne Sitarama Prabhu*

Throughout its cycle, rice may be affected by diseases that reduce both yield and grain quality. Disease intensity depends on several factors, such as the presence of the pathogen, a favorable environment and cultivar susceptibility. More than 80 pathogen-induced diseases, including fungi, bacteria, viruses and nematodes, have been reported in the literature, and affect this crop in different countries. The goal of using integrated management to control rice diseases is to minimize losses in productivity by bringing down the infection rate to tolerable levels. This kind of management requires a set of preventive measures whose components are genetic resistance of the cultivar, planting systems and chemical control. The endpoint is to increase product quantity and quality by reducing the pathogen population to tolerable levels by cost-effective measures with minimal negative environmental impacts.

It is understood that these aspects are essential for the proper implementation of integrated pest management, and consists in the following preventive measures: 1) genetic resistance, 2) farming practices and 3) chemical control. The correct choice of the cultivar farming practices for each region will maximize the effect of chemical control which must be adopted as a precautionary measure.

The diseases that have the highest negative economic importance in rice fields in the state of Mato Grosso do Sul are rice blast (*Magnaporthe oryzae*), brown spot (*Bipolaris oryzae*), grain discoloration (a pathogens complex), leaf scald (*Monographella albescens*) and sheath blight (*Rhizoctonia solani*). Several aspects related to each of these diseases will be discussed in this section: 1) symptoms, 2) the pathogen, and 3) favorable factors and, 4) options for control measures.

## Blast

Rice blast, caused by the fungus *Magnaporthe oryzae* is the principal disease affecting this crop, not only in the State of Mato Grosso do Sul, but in every rice-producing area of Brazil and the world. The disease causes significant losses in yield of susceptible cultivars, especially when environmental conditions are favorable to the development of the pathogens.

### *Symptoms*

The disease may occur from the seedling stage until maturation. Symptoms first appear on the leaves, where small brownish necrotic lesions are noted. They evolve, increasing in size, and become elliptical, with brown margins and gray or whitish center (Figure 1). Under favorable conditions, lesions coalesce, causing the death of leaves and often of the whole plant. Symptoms in nodes and internodes usually appear during the maturation stage.

**Figure 1.** Leaf blast.

The infection in the first node below the panicle blast is referred to as the panicle neck blast (Figure 2). Several parts of the panicle, such as the rachis, the primary and secondary branches and pedicels are also infected. When infection occurs before the milky grain stage, the entire panicle may die and take on a yellow straw-like color. Later infections will only affect the infected parts.

**Figure 2.** Panicle blast.

All stages of the disease, from spore germination to the appearance of lesions, are largely influenced by climatic factors such as leaf wetting by rain or by the deposition of dew. The ideal temperature for the rapid development of blast is between 20° C and 25° C. Infection is accelerated when relative humidity rises above 93%.

The plant is most susceptible to leaf blast during the vegetative phase. Increased resistance is observed when the plant is 55 to 60 days old, and that means that the top leaves are less severely affected. The grain filling stage, when it goes from a milky to doughy grain, 10 to 20 days after heading, is the most susceptible to blast. Rainfall during this stage helps to reduce the severity of panicle blast. Nutritional imbalance, particularly nitrogen in excessive doses, increases the severity of leaf and panicle blast. The application of nitrogen in the furrow when planting also increases the severity of blast significantly, when compared with split application of nitrogen

## *Control*

Blast can be adequately controlled by using cultivars which resistant or moderately resistant to the disease. For susceptible cultivars, the best treatment for leaf blast is a foliar fungicide during the early onset of symptoms; and two spray applications to protect against the panicle blast, the first application should be made on the late booting phase of and another at the time of heading, in association with the following farming management practices: 1) soil leveling to facilitate irrigation, 2) good soil preparation, 3) balanced fertilization, 4) using quality seeds, both with regards to their physiological and sanitary traits, 5) weed control; 6) incorporation of crop residues, 7) destruction of volunteer and sick plants; 8) planting at uniform depths to prevent infection outbreaks, 9) change cultivars every three to four years; 10) staged sowing time, and 11) sowing density between 80 and 120 kg $ha^{-1}$ about 17 cm apart.

The combined adoption of these farming practices and resistant cultivars reduces the use of agrichemicals and the consequent environmental damage and production costs.

## Brown spot

Brown spot, caused by the fungus *Bipolaris oryzae* is a common rice disease, which has been gaining economic importance throughout Brazil. This fungus is also a major causative agent of grain discoloration. The disease affects seedlings, especially in crops sown at the beginning of the rainy season and adult plants close to maturity, causing losses of the order of 12% to 30% in grain weight. Seeds infected by *B. oryzae* suffer a significant reduction in germination. In general, affected grains also cause losses in milling yield.

### *Symptoms*

Brown spot attacks coleoptiles, leaves, the sheath, panicle ramifications, glumellas and grains. Symptoms are usually manifest in leaves immediately after flowering and, later, in the glumellas and grains. In leaves, symptoms are circular to oval lesions of pale brown color with grayish or whitish center and brown to reddish margins (Figure 3). Lesions in the sheaths are similar to the typical lesions found in leaves. In grains, spots are dark brown and often coalesce, covering the whole grain. Infections in spikelets cause infertility when the disease appears soon after heading.

**Figure 3.** Foliar brown spot.

Infected seeds and crop residues are a source of primary *inoculum*. The fungus is found inside the seed, causing discoloration and wrinkling. The disease is favored by temperatures between 20° C and 30° C and a high relative humidity (> 89%). Stress caused by excess water or draught, low soil fertility, especially with regards to fertilization with potassium and the use of very high or low levels of nitrogen also increase plant susceptibility to brown spot.

### *Control*

Seed treatment with fungicides reduces initial inoculation, effectively controlling primary infection in seedlings. Foliar application of fungicides with protective action has been effective, but the use of systemic fungicides at the beginning of heading protects grains and enhances their quality. Crops intended for seed production require two applications, the first before heading and the second seven to ten days later. Fertilization with calcium silicate can reduce the incidence of the disease.

## Grain discoloration

Discoloration is caused by a group of fungal or bacterial pathogens and is considered one of the most important problems for rice, after blast. Glumelle blight is one of the most important diseases of the grain discoloration complex. It reduces production and grain quality. Decrease in panicle weight varies from 22% to 45% and the milling yield can be reduced in up to 14% in years affected by epidemics.

### *Symptoms*

Discoloration appears since the beginning of heading and continues until the ripening stage. Symptoms vary greatly depending on the predominant pathogen, stage of infection and climatic conditions. Glumelle blight manifests itself during heading, with reddish-brown spots on the spikelets. The white ovals spots with brown edges appear when the infection occurs during the milky and doughy stage, after heading (Figure 4).

The main pathogens causing grain discoloration are the *Dreschslera oryzae* (Breda de Haan) Subram & Jain*, Phoma sorghina* (Sacc.) Boerema, Dorenbosch & Van Kesteren, *Alternaria padwickii* (Ganguly) Ellis, *Pyricularia grisea* (Sacc.) Cooke, *Microdochium oryzae* (Hashioki YOKOGAVA) Samuels and Hallet, *Sarocladium oryzae* (Sawada) W. Gams, in addition to different species of

*Drechslera, Curvularia, Nigrospora, Fusarium, Coniothynium*, *Epicoccum, Phythomyces* and *Chaetomium.* Among the bacteria causing grain discoloration are *Pseudomonas fuscovagina* and *Erwinia* sp. It is difficult to identify, by the symptoms alone, which microorganism is responsible for causing grain discoloration and an accurate identification of the pathogens present in the plant can only be done in a laboratory.

**Figure 4.** Grain spots.

Rainfall and high humidity during grain formation favor the appearance of this disease. Other factors include lodging, which causes panicles to get in contact with the soil, and the presence of the stink bug or paddy bug (*Oebalus poecillus*), which creates a pathway into the plant for the microorganisms.

### *Control*

Using healthy seeds is one way to control this pest. Seed treatment with fungicides increases plant vigor and stand, in addition to helping decrease initial inoculation. Chemical control should be done preventively with one or more applications, preferably with systemic fungicides. The first application should be made at the end of the booting and the beginning of heading stage, and the second, 10 days after the first application.

## Leaf scald

The presence of leaf scald, caused by the fungus *Microdochium oryzae* (Hashioki & Yokogi) Samuels & Hallett has been noticed, at significant levels, throughout

Brazil. This disease is typical of places where high temperatures are associated to prolonged periods with dew or continuous rainfall. The disease arrests plant growth early in the booting stage especially in years with heavy rainfall.

## *Symptoms*

Typical symptoms start at the apex of the leaves or on the edges of the leaf blade. The spots do not have well-defined margins and are initially olive green (Figure 5). Then, the affected areas present a succession of concentric bands. The lesions coalesce, causing necrosis and death of the infected leaves. A field affected by the disease presents a generalized yellowish discoloration and the tips of the leaves are dry. When environmental conditions do not favor the development of the disease, the leaves show numerous small pale-brown pits, which can result in a misdiagnosis. Similar symptoms are produced in the sheaths. In grains, the symptoms are small spots the size of a pinhead and, in severe cases, one can see a reddish-brown discoloration of the glumes.

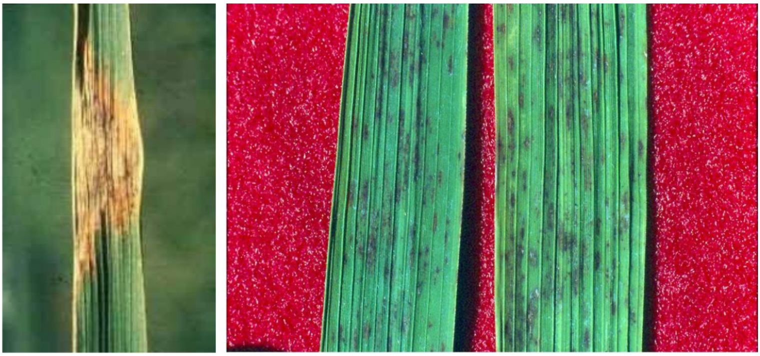

**Figure 5.** Leaf scald.

The main sources of the primary *inoculum* are infected seeds and crop residues. Disease development is favored by wetting the leaves, either by rain or prolonged periods with dew during the maximum tillering and booting stages, by close spacing of the plants and the application of excessive amounts of nitrogen-based fertilizer.

## *Control*

Control measures include using healthy seeds. Crop rotation and proper irrigation management reduce the incidence of the disease. There is no information on the economic feasibility of chemical control.

## Sheath blight

Sheath blight, caused by the fungus *Rhizoctonia solani* Kühn (anamorph) and *Thanatephorus cucumeris* (AB Frank) Donk (teleomorph), has the potential to cause serious damage to the productivity of irrigated rice.

### *Symptoms*

The disease usually affects sheaths and stems (Figure 6-A) and is characterized by ovoid, ellipsoidal or rounded pale white-gray with brown spots with well-defined edges. In severe cases, the leaves present with similar spots, which are irregularly shaped (Figure 6B). The incidence of sheath results in partial or total drying of the leaves, causing the plant to lodge.


**Figure 6.** Sheath blight symptoms (*Rhizoctonia solani*) on rice leaves.

The disease is soil-borne and *Rhizoctonia solani* survives in soil in the form of sclerotia and mycelia in crop residues, the primary *inoculum.* The fungus spreads rapidly by the water used for irrigation and by land preparation during plowing. It infects several common grasses, such as weeds in irrigated rice fields, as well as several legumes, such as soybean. The disease advances rapidly during heading and grain filling. A high percentage of organic matter (3-4%), high nitrogen levels and high plant density contribute to increase the severity of the disease. Damage caused by insects such as stem borers and stink bugs predispose the plant to infection by *R. solani* and other soil fungi such as *Sclerotium oryzae, Sclerotium rolfsii* and *Fusarium* sp.

## *Control*

Efficient measures against sheath blight include good drainage during the fallow period, balanced fertilization, seeding rate between 80 and 120 $kg.ha^{-1}$ and a rational use of herbicides. Rotating rice with other grasses such as maize and sorghum may reduce the incidence of the disease. However, rotation with soybean or watermelon may increase the *inoculum* in the soil. Seed treatment with fungicide is effective. In the United States, blight control is achieved by spraying the field twice with fungicides. First, between stem internode elongation and panicle initiation, ranging from 2.5 cm to 5.0 cm at the sheath, and second, at 80% to 90% of heading.

Good farming practices combined with resistant cultivars reduce the use of chemicals and, consequently, the environmental damage they cause. Production costs will also be decreased. This technology, which is already available, should be considered when treating crops because it provides an effective tool to manage the disease. Results include higher productivity and a better end product, which was produced at a lower cost in an environmentally safe matrix.

# Major Pests and Management Recommendations

*José Alexandre Freitas Barrigossi*
*José Francisco da Silva Martins*

Rice pest management begins with the identification of the species and an accurate diagnosis of the injury caused by the pest, to estimate the damage potential. It is very important to make a proper association of the injury to its causal agent and to the developmental stage of the plant affected by the pest. Figure 1 shows the developmental stages of the rice plant and lists the species most likely to occur during a given stage, and cause economic damage. This section provides more detailed information on each species and at the end, a list of pesticides registered with the Ministry of Agriculture, Livestock and Supply (Tables 1 and 2).

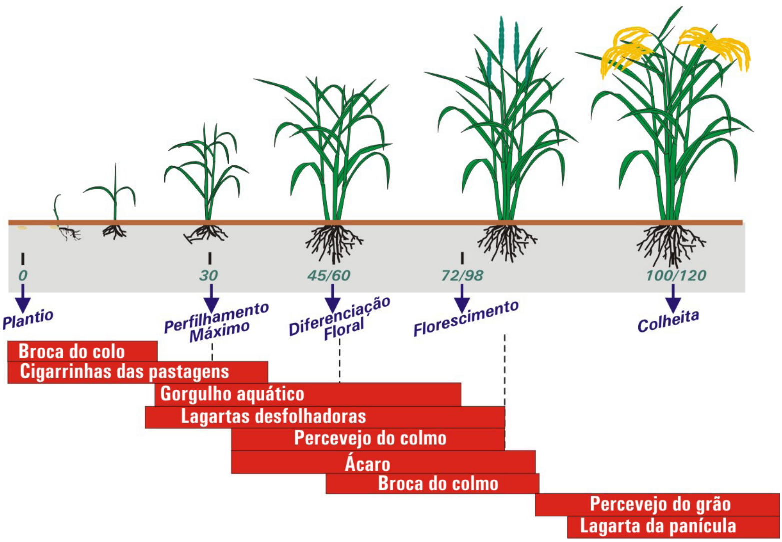


**Figure 1.** Developmental stages of rice plants and occurrence of major pests.

## Lesser cornstalk borer, *Elasmopalpus lignosellus* (Zeller, 1848)

Broca do colo, also known as lagarta-elasmo (in Portuguese), the *Elasmopalpus lignosellus* Zeller is one of the most important pests attacking rice in the initial phase of development. Adults are small moths measuring 8-10 mm in length. The females lay eggs in the soil or directly on the rice plants. A female can oviposit over 100 eggs that hatch in 4 days. The larvae perforate the basal stalk area near the soil surface (Figure 2). Five to seven days later, the rice plants start showing symptoms of a "dead heart" (Figure 3). A single larva can kill several rice stalks. Pupation occurs inside a cocoon that remains attached to the plant. Its life cycle lasts 22-27 days (FERREIRA, 2006).

A larva can attack from five to ten stems of young plants and may seriously compromise the stand if conditions prior to irrigation are favorable. If preventive control is absent and bugs are attacking the plants the recommendation is to take samples the crop. Chemical control should be started when there is risk of a drop in the number of stalks below 20 stems. $m^{-1}$ or 100 stems per square meter or, still, when 5% of the stems are affected prior to irrigation.

**Figure 2**. Adult (left) and larva (right) of *Elasmopalpus lignosellus*.

**Figure 3**. Damage caused by the lesser cornstalk borer.

Among the pests attacking rice, the grass spittle bug (*Deois flavopicta*) is the most common one and it becomes more important when infestation occurs before the maximum tillering stage. Adults measure 10 mm, are black with three yellow spots on the wings (Figure 4). When feeding, the pest introduces toxins that result in yellow leaves with white tips and wilted tips. Severe infestations result in dry leaves and plant death (FERREIRA, 1998).

Managing the grass spittle bug involves monitoring the pasture area surrounding the planted field, especially if the rice plants are less than 25 days old. The population of spittle bugs in pastures can be easily detected by the presence of nymphs wrapped in white foam. Preventive control measures include advancing or delaying sowing time so that a spittle bug outbreak will not coincide with the susceptible stage of the plants. It is possible to effect chemical control with systemic insecticide via the seed or by spraying the field, when inspection reveals the presence of one spittle bug per 30 plants.

**Figure 4**. Adult grass spittle bug *Deois flavopicta* (Stal, 1854).

## *Rice water weevil, Oryzophagus oryzae (Costa Lima, 1936)*

The water weevil is found in virtually every area where irrigated rice is planted in Brazil. Adults and larvae can cause a great deal of damage to rice and losses will depend on the intensity of the infestation and the planting system used.

In crops planted by sowing in dry soil as it is done in Mato Grosso do Sul, damage inflicted on leaves by adult weevils, does not have great economic importance, in general. In this system, the main damage is caused by larvae that emerge from the tenth day after the paddies are flooded and start to feed on the root system of the rice plant. Plants attacked by this pest are short and present with a yellowish discoloration. Symptoms can be mistaken for nitrogen deficiency, iron toxicity or salinity.

The effect of the *O. oryzae* larvae on grain production can be influenced by seeding time and the highest losses are seen in fields planted earlier. Although two generations usually occur during the crop cycle, the first generation often causes more damage than the second one because it occurs in the early stages of the plant development, when the plant's root system is still underdeveloped. After the stage of panicle differentiation, larvae control does not result in a positive response in terms of productivity.

It is possible to manage the rice water weevil through practices such as cleaning irrigation canals; improving soil condition and soil leveling to prevent pest aggregation; providing additional nitrogen fertilization in crops that have been affected to help the damaged root system to recover and destruction of crop residues combat the pest and its hosts. In areas with a history of high infestations, we recommend the use of seeds treated with insecticide. In crops with no preventive chemical treatment, control can be done on the basis of data from random samples aimed at detecting scars left on the leaves by weevils feeding on the last leaf developed or on the basis of the number of larvae. Samples should be taken in lines parallel to paddy edges or along irrigation canals, 10 to 20 meters apart, and about 50 meters distant within the rows. Sampling leaves with feeding scars left by the weevils on younger leaves must be done three to four days after flooding and the each sample must include 20 plants. At that time, if 16% of plants show signs of weevil feeding on the last leaf (Figure 5), production is expected to be reduced by 100 kg $ha^{-1}$ or 1.5% in untreated areas. If this percentage (16%) of affected plants is not found, sampling must be repeated after 10 to 12 days, at which time, 8% of affected leaves will be taken to require control (FERREIRA, 2006).

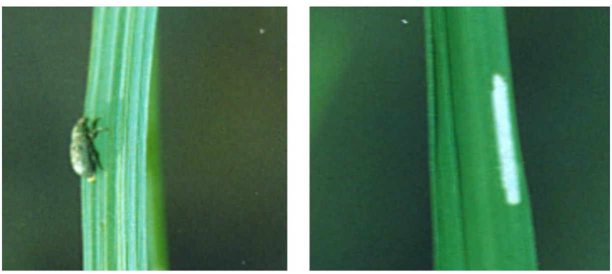

**Figure 5.** Adult waterwe-evil and scar left on the rice leaf.

Sampling for the presence of larvae in the roots should start 10 to 15 days after irrigation. A 10 cm wide x 20 cm high metal or plastic cylinder (Figure 6) is used as a sampling tool. Chemical control should be applied when two to three larvae, on average, are found among the roots and on the soil collected by the sampling cylinder. (MARTINS et al., 2004).

**Figure 6.** Cylinder used to sample for rice water weevil larvae, and plants with larvae.

## Fall armyworm, *Spodoptera frugiperda*

The fall armyworm is a polyphagous pest that occurs in every states in Brazil (Figure 7). In irrigated rice, the critical damage period occurs between seedling emergence and flooding, when the armyworms cut the plants close to the ground and can destroy large rice fields. The worm can attack the aerial part of the rice plant and damage is inflicted by reducing the foliar surface of young or developed plants when the flag leaf is compromised (FERREIRA, 2006).

**Figure 7.** The fall armyworm *Spodoptera frugiperda*.

Depending on climatic conditions, the fall armyworm, *S. frugiperda*, takes 20 days on average to become fully developed and during this time consumes approximately 156 $cm^2$ of leaves. The last three instars are responsible for more than 90% of the total leaf area consumed.

To control this pest, the crop should be monitored since the early stages. The fields should be investigated on a weekly basis and sampling should be done along the diagonal lines, with a 0.5 x 0.5 m thick wire frame. Crops must be treated when the presence of 5 caterpillars per square meter is detected. In subsequent steps, rice fields should be treated when leaves in the vegetative and reproductive stages present a 25% and 15% reduction of the leaf blades and the armyworm remain in active (FERREIRA; BARRIGOSSI, 2001).

An alternative to chemical control is introducing practices, such as flooding infested fields for two to three days. Another possibility is to take advantage of the natural mortality caused by biological agents such as parasitoids and predators such as spiders, stink bugs and birds, among others. When weather conditions are favorable, microorganisms such as the *Nomura rileyi* (Figure 8) and *Beauveria bassiana* fungi can control the fall armyworm spontaneously. Biological control with fungi and bacteria (*Bacillus thuringiensis*) can also be implemented, along with commercial formulations.

**Figure 8.** The fall armyworm Spodoptera frugiperda parasitized by*Nomurea rileyi.*

## Rice stink bug*, Tibraca limbativentris* (Stal, 1860)

The rice stink bug causes a great deal of damage to the plant and the high incidence seen in some years has caused production losses estimated to be between 5% and 80%.

Damage is caused by partial or total death of the central part of the stalk as result of insect feeding, beginning with the $2^{nd}$ nymph instar. Insect bites at the base of the plants in the vegetative stage causes the appearance of symptoms known as “dead heart” and, during the reproductive period, “white panicle”. In the place where the bug introduces its stylet-like mouth parts into the leaf sheath it leaves a small brown spot, coinciding with the internal strangulation of the stem (Figure 9). Infestations during the reproductive stage increase the number of broken and chalky grains. One bug per square meter, in the vegetative stage can cause a 58.7 kg $ha^{-1}$ reduction of in grain production. The same level of infestation in the reproductive stage, causes losses equivalent to 65.2 kg $ha^{-1}$.

**Figure 9.** Adult bug *Tibraca limbativentris* (left) and discoloration and rice stem necrosis caused by feeding (right).

Under favorable conditions for the insect, it is estimated that each nymph of the $4^{th}$ and $5^{th}$ instars and each adult established in 30 and 65-day old crops are able to cause, in the subsequent 35 days, six dead-hearts and five white-panicles, respectively.

Controlling the rice stink bug requires regular sampling of the fields starting 35 days after the plants emerge. Sampling can be done with a 1 meter x 1 meter frame. The frame should be placed at random all the bugs inside are counted and the total is recorded on a spreadsheet. After sampling is completed, the next step is to calculate average infestation to determine the need for control. Control is recommended when results indicate the presence of an average of 0.5 adult bugs per square meter during tillering and 1.0 adult bugs per square meter during the reproductive stage. Another option is to sample with an insect net. The field should be treated when an average of 0.3 to 0.5 bug, or more, are collected on each net pass, before and after twelve o'clock noon, respectively (FERREIRA; BARRIGOSSI, 2001).

In addition to monitoring the field, it is important to adopt practices that will contribute to the reduction of the natural population of pests, such as cleaning irrigation channels and areas around the field to reduce opportunities for refuge during the fallow period and destroying crop residues after harvest. Biological control can be used by creating opportunities for the preservation of natural enemies. Furthermore, the stink bug is very susceptible to several species of fungi such as the *Metarhizium anisopliae* and *Beauveria bassiana*. Studies conducted in Miranda, in the State of Mato Grosso do Sul, showed spraying *Metarhizium anisopliae* can kill about 30% of individuals leaving the field after harvest.

## Spider mite, *Schizotetranychus oryzae* (Rossi de Simons)

Mites are small arthropods more closely related to spiders than to insects. Adults are very small, greenish-yellow, with dark spots and approximately 0.8 mm long. They are located mainly on the dorsal surface of the leaves where one can find eggs and larvae among the cobweb threads (Figure 10). When feeding, they introduce their stylet-like mouth parts in the cells causing characteristic lesions on the upper surface of the leaves (MORAES; FLECHTMANN, 2008). In irrigated crops, populations of spider mites increase during periods of hot and dry weather and can cause severe damage to the rice plants and compromise grain yield (Figure 11). However, conditions that are favorable to mite outbreaks in irrigated rice fields do not happen very often.

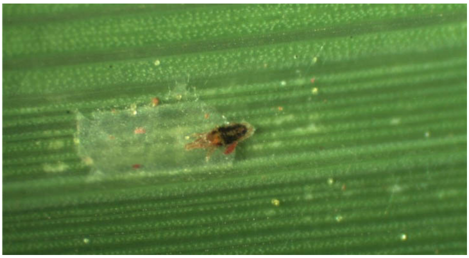

**Figure 10.** Rice leaf with egg, cobweb and damage caused by mite feeding. *Schizotetranychus oryzae.*

**Figure 11.** Severely infested crop with dry and discolored leaves due to *Schizotetranychus oryzae*.

Spider mite management includes careful observation of prevailing environmental conditions and the stage of crop development. Monitoring should start at the edge of the field, where infestation is more likely to start. The leaves should be examined for the presence of discoloration. The injury caused by the mite resembles others made by various stressors, including the chlorosis, which is characteristic of nutrient imbalance and herbicide toxicity. Therefore, the presence of mites should be confirmed with the aid of a magnifying glass. In rice, mite control is restricted to the application of chemicals. Since mites are very likely to develop resistance to acaricides, it is very important to use chemicals in rotation, if more than one application is needed during the crop cycle. Currently, there are no records of *Schizotetranychus oryzae* populations resistant to acaricides.

## Sugarcane borer, *Diatraea saccharalis* (Fabr., 1794)

The sugarcane borer is an insect with a high potential severity and is found in rice fields, most years, in small populations (Figure 12). In addition to rice, the borer has several other native and cultivated hosts. The damage is caused by the larvae that penetrate the stem. They consume the spongy tissue and destroy the growing points, causing the death of the central portion of the stem. When this occurs during the vegetative phase, it produces symptoms known as “dead heart”. When the attack occurs during the panicle formation and heading it causes the death of the flag leaf and spikelet sterility, forming what is known as “white panicle”. When pulled, it detaches itself easily from the plant. A 2% to 3% reduction in production is estimated for each 1% of white panicles. This is because the number of stems with visible symptoms of attack by the borer is less than the number of stems actually infested, but that, overall, contributes to reduce plant vigor, the number of tillers and increase the percentage of empty spikelets.

Sugarcane borer management should focus on farming practices. Measures include avoiding asynchrony (staggered planting) in nearby areas and excess use of nitrogen fertilizer because there are indications that the damage is highly correlated to an increase of nitrogen. Fields should be kept free from insect host plants and crop residues should be destroyed after harvest. The borer has many natural enemies like the egg parasitoids, *Telenomus* sp. and *Trichogramma* and *Apanteles flavipes* parasitoids. *Coleomegilla maculata* seems to be the most important egg oviposition predator (FERREIRA; BARRIGOSSI, 2002).



**Figure 12.** Adult, oviposition and *Diatraea saccharalis.*

## Rice stink bug or paddy bug, *Oebalus poecilus* (Dallas, 1851)

The paddy bug (Figure 13), both in the young and adult form feed on shoots, but is more harmful to the panicles. They separate their feeding activity and about 30% of the bites damage the ramifications of the rachis and the remaining 70% damage the spikelets, in whose glumes one can see signs of feeding left by the insect (Figure 14).

**Figure 13.** Rice stink bug *Oebalus poecilus*.

**Figure 14.** Grains discolored by *Oebalus* spp. bites.

Damage inflicted by these bugs can be qualitative and quantitative, depending on the stage of spikelet development during infestation and the period of time bugs keep on feeding on the panicle.

An attack immediately after flowers are fertilized result in spikelets that are completely empty (quantitative loss). When the bug appears during the milky stage, in addition to causing partial or total removal of spikelet content (quantitative loss), it favors the action of associated microorganisms that increase the incidence grain discoloration and reduces the germination power of the seed (qualitative loss). Attacks in subsequent stages result in lighter spikelets, with discolorations. Upon processing, it is possible to see stains on the endosperm on the spots bitten by the bug, which cause it to break during the process. When they don't break, they show discolored patches of different sizes, which reduces the commercial value of the product (Figure 14).

Between harvests, adult bugs hide under straw or wood, under the bark, at the base of plants and in soil fissures. Early in the rainy season they come to life and can be found feeding on developing seeds in their various native host plants found in the vicinity or within the crop itself where they mate and the first oviposition takes place. The time of this oviposition can be determined by squeezing some females. If they are ready, the eggs come out through an opening at the end of the abdomen. When the rice field begins to bloom, the bugs start moving towards the plants, and occupy the panicles.

The non-hibernating *O. poecilus* females live an average of 15 days, during which they perform 13 ovipositions with 15 eggs each. The duration of the phases of the life cycle of both species is strongly influenced by temperature. It decreases when in the 20-30° C range. The egg stage at 25° C, lasts 5-6 days. Nymphs and adults remain still and enclosed by the leaves and stems of the plant in the early hours and hottest part of the day. The bugs start their activity between 8-9 AM and 3-4 PM. Normally adults can fly short distances of 20 to 50 meters, but under very favorable conditions, in warm windless nights, they can fly up to 250 meters.

Studies on the spatial and temporal distribution of *O. poecilus* in rice fields showed that most of the bug population is distributed at random and invade the crop from the time the plant starts to flower until the milky grain stage. This indicates that field monitoring for control purposes must start during the early flowering stage and should continue with weekly samplings or every 3-4 days, when the level of the pest population is close to the control threshold. Samples should preferably be taken early in the morning or in late afternoon, avoiding the hottest hours of the day (11AM-4PM).

The field should be sampled at random, starting near the borders and taking samples at points approximately 100 meters apart in fields of up to 15 hectares. Use a standard entomological collection net with 0.38 m diameter, 0.80m depth with a 1 m-long cable (Figure 15) for that purpose. At each sampling point make 10 net sweeps, one to two steps apart (BARRIGOSSI, 2008).

**Figure 15.** Sampling for stink bugs in an irrigated rice field.

The number of bugs collected during each sample (ten net sweeps) should be recorded on a spreadsheet so at the end of the procedure one can calculate mean crop infestation and determine the need for control. Control must be initiated when an average of five bugs are trapped in ten sweeps, during the first two weeks after the onset of flowering and 10 stink bugs in the following two weeks.

As complementary control measures, the following must be considered:

1. Avoid staggered planting of rice in nearby areas;
2. Control weeds effectively since many of them are excellent hosts for the pest (*Digitaria spp., Echinochloa spp*);
3. Avoid accumulation of straw and other plant material on the edges of the field as they could harbor the pest during off-season;
4. Watch out for early and late seedings. The former can act as trap crop as an attraction point for bugs which will migrate from sites used as shelter during winter into the crops. A late seeding means they are the last fields to flourish and so they harbor the bugs leaving the fields that have already been harvested;
5. Avoid applying broad-spectrum insecticides before flowering to preserve natural enemies. There are important nymph and adult predators and several egg parasitoids that help keep the bug population below the economic damage level;
6. Do not institute preventive chemical control, since these agents do not have a prolonged residual effect. Additionally, pesticides destroy natural enemies, increase production cost and can leave residues in the grains;
7. Sample the fields when the first panicles appear and implement chemical control only when the bug population reaches the control level.

## Armyworm, *Pseudaletia adultera* (Schaus, 1894) and *Pseudaletia sequax* (Flanclemont, 1951)

The moths of both species oviposit on leaves or stems where they are attached by a sticky substance that also serves to protect them from natural enemies. The worm feed on leaves and panicles and this type of attack usually is the most significant because, in addition to the parts they consume, they cut down most of the spikelets (FERREIRA, 2006). Fully developed, the worms measure about 40 mm and feature longitudinal stripes on the body. On the *P. sequax* these stripes are light-brown and in the *P. adultera*, dark brown. Pupation occurs in the soil, under dirt clods, crop residues or between rice stalks (Figure 16).

**Figure 16.** Armyworm (*Pseudaletia* sp.).

Armyworm management has been especially hindered by the lack of registered insecticides that can be used for chemical control. Since this insect has only recently been shown to be of importance for rice, there is little information about its bioecology and means to control incidence in this environment.

## Earthworms (Annelida: *Oligochaeta*)

Earthworms feed on organic matter found on the soil and have established a close mutual relationship with microorganisms for their digestion. Earthworms in general are considered beneficial for their role played in mineralizing organic waste and providing nutrients for plants. Moreover, earthworm activity promotes changes in the physical structure of the soil (JAMES, BROWN, 2006).

Despite their importance in mineralizing the soil and nutrient movement in irrigated rice fields (GRANT; SEEGERS, 1985), earthworms have not been sufficiently studied in this environment. Therefore, little is known about the species, population density, ecology and the impact they cause to rice. The growth of the population of some water species in the rice fields of Mato Grosso do Sul has caused some problems for growers. Three species were identified (Dr. George G. Brown - Embrapa Florestas), and samples collected showed that two of them were more abundantly present.

In Miranda, specifically in the San Francisco farm, the predominant type is a big greenish earthworm belonging to the *Criodrilidae* family (Figure 17). Recently the population of this earthworm has increased, even though the causes for this growth remain unknown. The earthworm's constant revolving the soil activity inflict mechanical damage to the roots of rice plants, resulting in the fact that plants with thinner stems come loose and lodge easily under rain and wind.

**Figure 17**. Green earthworm *Criodrilidae* (left) and a dirt mound lot of land resulting from its activity in an irrigated rice field (right); (Fazenda San Francisco, Miranda-MS).

In addition to the mechanical damage to roots in the deeper parts of the rice paddies where the water levels are higher, the worms build mounds of soil around the rice plants which affect harvesting operations. As the plants under these conditions lodge easily, the operator must position the harvesting platform very close to the ground. Under these conditions, when the platform touch the mound, the rice plants are torn away, rather than cut, and this causes mud to enter the harvesting equipment, and mix with grains. The result is that the product becomes depreciated (Figure 18). Production in highly infested paddies may be smaller than in paddies not infested with this worm. In Rio Brilhante two earthworms species predominate: one is small and very thin and belongs to the genus *Eukerria*, and the family *Octenodrilidae*, and the other is medium-sized and fatter, and belongs to the genus *Glossoscolex*, family *Glossoscolecidae* (Figure 19 A). These worms coexist in rice fields and cause less damage to rice than those found in the Miranda region. Because they are much smaller in size than those worms prevalent in Miranda, they cause less impact. They cause the soil to become more compact and closer to the stems of rice plants (Figure 19 B) and cause bioturbation of the soil in the root zone which weakens the roots of the plants and cause lodging.

**Figure 18.** Signs left by the harvester when hitting mounds built by earthworms (Fazenda San Francisco, Miranda-MS).


**Figure 19.** Red earthworm *Glossoscolecidae* (A) and mud accumulation around rice stalks B). Fazenda Passa Quatro, Rio Brilhante, MS..

**Tabela 1.** Produtos com registro no Ministério da Agricultura, Pecuária e Abastecimento e para tratamento de sementes de arroz irrigado, visando o controle das pragas que atacam a cultura na fase inicial do desenvolvimento.

| Nome Comercial | Nome Técnico | Grupo Químico | Classe Tóxicológica[1] | Classificação Ambiental | Indicação | Dose/100 kg de sementes | Registrante |
|---|---|---|---|---|---|---|---|
| Cruiser 350 FS | Tiametoxan | Neonicot inóide | III | III | Bicheira da raiz | 300-400g | SYNGENTA |
| | | | | | Cigarrinha das pastagens | 200-400g | |
| | | | | | Lagarta elasmo | 300-400g | |
| | | | | | Cigarrinha das pastagens | 200-400g | |
| Cruiser 700 | Tiametoxam | Neonicotinoide | III | III | Bicheira da raiz | 150-200 g | SYNGENTA |
| | | | | | Cigarrinha das pastagens | 100-200 g | |
| | | | | | Lagarta elasmo | 150-200 g | |
| Gaucho | Imidacloprid | Neonecotinoide | III | III | Bicheira da raiz | 300 g | BAYER |
| Gaucho FS | Imidacloprid | Neonecotinoide | III | III | Bicheira da raiz | 350 mL | BAYER |
| Standak | Fipronil | Pirazol | III | II | Bicheira da raiz | 200-250 mL | BASF |

Toxicological class: I = Extremely toxic; II = Highly toxic; III = Moderately toxic; IV = Not very toxic.

**Table 2.** Products registered at the Ministry of Agriculture, Livestock and Supply for controlling rice pests.

| Brand name | Tecnical name | Chemical group | Toxicological class[1] | Environmental class | Indication | Dose/100 kg of seeds | Registered by |
|---|---|---|---|---|---|---|---|
| Actara 10 GR | Tiametoxam | Neonicotinóide | III | III | Bicheira da raiz | 10 - 15 Kg/ha | SYNGENTA |
| Actara 250 WG | Tiametoxam | Neonicotinóide | III | III | Bic heira da raiz | 100 – 150 g/ha | SYNGENTA |
| Actara 250 WG | Tiametoxam | Neonicotinóide | III | III | Percevejo-do-colmo | 100 – 150 g/ha | SYNGENTA |
| Arrivo 200 EC | Cipermetrina | Piretróide | III | II | Lagarta-da-folha | 50 a 75 mL/ha | FMC |
| Bulldock 125 SC | Beta-ciflutrina | Pieretróide | II | II | Bicheira da raiz | 50 mL/ha | BAYER |
| Bulldock 125 SC | Beta-ciflutrina | Pieretróide | II | II | Lagarta-da-folha | 30 mL/ha | BAYER |
| Curbix 200 SC | Etiprole | Fenilpirazol | III | II | Bicheira da raiz | 125–250 mL/ha | BAYER |
| Engeo Pleno | Tiametoxam + Lambda - cialotrina | Neonicotinóide + Piretróide | III | I | Percevejo-do-grão | 150- 200 mL/ha | SYNGENTA |
| Furadan 100 GR | Carbofurano | Metilcarbamato | III | II | Bicheira-da-raiz | 2,5 a 4 kg/ha | FMC |
| Furadan 50 GR | Carbofurano | Metilcarbamato | III | II | Bicheira-da-raiz | 8 kg/ha | FMC |
| Klap | Fipronil | Pirazol | III | II | Bicheira-da-raiz | 60mL/ha | BASF |
| Laser 100 G | Benfuracarbe | Metilcarbamato | III | III | Bicheira-da-raiz | 10 – 20 kg/ha | IHARABRAS |
| Malathiom 500 CE | Malationa | Organofosforado | III | ** | Curuquerê dos capinzais | 2,6 L/ha | ACTION S.A. |
| Sultox | | | | | Lagarta-da-folha | 2,6 L/ha | |
| | | | | | Percevejo-do-colmo | 1,3- 2 L/ha | |
| | | | | | Percevejo-do-grão | 1,3- 2 L/ha | |
| | | | | | | 1,3- 2 L/ha | |
| Talcord | Permetrina | Piretróide | III | II | Lagarta - da - folha | 80mL/ha | BASF |

[1]*Toxicological class: I = Extremely toxic; II = Highly toxic; III = Moderately toxic; IV = Not very toxic.*

* *Registro Decreto 24.114/34*

** *- Em adequação a lei nº 7.802/89*

# Use of Pesticides

*José Alexandre Freitas Barrigossi*

## Legislation

According to the federal law 7802 of 11 July 1989, pesticide are the products and the agents of physical, chemical or biological processes. They are intended for use in the production, storage and in the farming products processing sectors, on grasslands, for the protection of native or planted forests and other ecosystems. They are also intended for use in urban, water and industrial environments, for the purpose of changing the composition of the flora and the fauna to preserve them from the detrimental action of living harmful organisms. The legislation regulates activities carried out with pesticides in the country, from production or import operations to the final destination of waste and packaging materials. The provisions of this law were regulated by Decree No. 4074 of 4 January 2002. Other aspects related to the use of pesticides included in the legislation are: classification, certification of service providers, transportation, application, worker safety and the final disposal of waste and empty packaging materials.

In 2005, the Ministry of Labor created the Regulatory Standard for Occupational Safety and Health in Agriculture, Livestock, Forestry, Forest Use and Aquaculture (NR 31), and established the principles that must be observed in the organization and in the work environment of any activity related to agriculture, including industrial activities developed in the rural environment. NR 31 establishes procedures and requirements that have to be met with respect to the use of pesticides in agriculture by employers and employees.

The main agrichemicals used in upland rice crops are pesticides, herbicides and fungicides.

## Classification

The toxicity of most pesticides is expressed in figures which refer to the Mean Lethal Dose ($LD_{50}$) taken orally, represented in milligrams of active ingredient of the product per kilogram of body weight required to kill 50% of the population of rats or other test animal. The $LD_{50}$ is used to establish safety measures that must be followed to reduce the risk that the product may pose to human health. Pesticides are grouped into classes according to their toxicity (Table 1).

**Table 1.** Toxicology classes of pesticides based on the $DL_{50}$[1].

| | | |
|---|---|---|
| Class I | Extremely toxic ($DL_{50}$ < 50 mg/kg of live weight) | Bright red |
| Class II | Highly toxic ($DL_{50}$ of 50 mg to 500 mg/kg of live weight) | Intense yellow |
| Class III | Moderately toxic ($DL_{50}$ of 500 mg to 5.000 mg/kg of live weight) | Intense blue |
| Class IV | Slightly toxic ($DL_{50}$ > 5,000 mg/kg of live weight) | Intense green |

[1]A: Lethal dose ($LD_{50}$) is the dose of a substance, in mg/kg of live weight, which needs to be ingested or administered to kill at least 50% of a study population.

## Labeling

The product label is the main form of communication between the manufacturer and users. The information on the label is the result of years of research and tests on the product before it is authorized by the Ministry of Agriculture, Livestock and Supply (MAPA) for sale. Therefore, before handling any agrichemical, the user must read the label carefully. The following information must be printed on the package or attached to it:

. pests controlled by the pesticide;
. crops in which the pesticide can be applied;
. recommended dosages for each situation;
. toxicological classification;
. the way in which the pesticide may be used;
. the place where the pesticide can be applied;
. application time: pre-planting, pre-emergence or post-emergence;
. safety interval, i.e., the time interval in days between application and har-

vest. This is essential to ensure that the level of pesticide residues present in the food are not above the maximum level authorized by the Ministry of Health The marketing of agricultural products containing pesticide residues at levels above the ceiling established by the Ministry is unlawful;

- if the pesticide can be mixed with other agents frequently used in similar situations, and
- if the pesticide may cause injury to crops it is recommended for.

## Application

The effectiveness of pesticides to control pests, diseases and weeds depends on how it is applied. Pesticide misuse, in addition to representing waste, can contaminate people and the environment. Thus, equipment used to apply pesticides is as important as the actual pesticide. Many problems resulting from the application of pesticides, such as drift, irregular coverage and failure to reach the target, are due to the equipment used. When choosing the equipment to apply the pesticide, it is important to verify if it is efficient. Other factors include costs, and how easy it is to use and clean. Most agrichemicals are applied in the form of sprayed liquid solutions or suspensions. Before loading the equipment with the agrichemical agent, it should be calibrated or adjusted so that it will apply the correct amount in the desired location. These steps should be repeated whenever a different agent is used or a different dosage is applied. There are several ways to calibrate this type of equipment. It is important to choose a reliable and easy method. Any equipment must be calibrated prior to use because:

- equipment for agricultural use differ. Small differences can result in large variations in the actual dose applied, generate inefficient control and cause problems to the environment; and
- the wear and tear of the sprinkler nozzles increases the flow and changes the agrichemical distribution pattern, thus increasing the risk of damaging the crop.

Another measure that must be implemented on a regular basis refers to maintenance and cleaning. This measure is important for two reasons:

- an economic reason - proper equipment maintenance, in addition to reducing the need for replacement parts, facilitates the application of agrichemical. In order for any piece of equipment to be well calibrated it should be in good working order;

. a health-related reason - equipment retain product residue in different parts (tanks, hoses and nozzles) and on the surface, and there is always the risk that such residues can contaminate people and animals. Correct cleaning reduces the risk of contamination and poisoning.

## Precautions while using agrichemicals

To be used in agriculture, agrichemicals must be registered at the MAPA for the crop and for the target pest. Misuse can cause many harmful effects to humans, the wildlife, fish and other desirable organisms that inhabit or visit the rice fields to feed. To reduce the risk of contamination and impact on the environment, in addition to the measures printed on the labels, the following precautions should be taken:

. select the correct agrichemical for the target organism, taking into account the level of infestation and the place where the product will be applied;
. use the agrichemical at the recommended dose;
. observe local restrictions on the use of agrichemicals;
. should there be restrictions, the user must apply for a permit from the competent authorities. Permits can be requested at the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis – IBAMA (Brazilian Institute for the Environment and Renweable Natural Resources), the local Department for the Environment of the Environmental Agency;
. agrichemicals should be applied only when weather conditions are favorable: weak winds or on windless days, to prevent the drift which could contaminating areas adjacent to the fields and canals, and,
. always respect the safety interval.

## Residue and packaging disposal

Agrichemical residues and empty packaging material should be disposed of in compliance with the applicable legislation. Improper disposal of pesticide residues can result in serious harm to humans, animals and the environment. These residues include leftover pesticides, empty containers and products contaminated with pesticides.

Empty containers should be sent to a center for empty packaging collection in the region. Triple washing of equipment and packaging is a procedure that must be followed prior to sending the empty package to its final destination. The same procedure should be performed for cleaning equipment used to apply the agrichemical.

The following procedure should be followed for triple washing of agrichemical containers:

. empty the packaging material completely, allowing the liquid to run into the sprayer tank;
. add water to 25% of the capacity of the package/container;
. close and shake the container for 30 seconds;
. pour the water into the sprayer tank;
. repeat the rinsing procedure at least twice, and
. pierce the package/container to ensure that it won't be reused for other purposes.

## Good management practices

In this context, good management practices (GMP) refers to practices that help reduce the potential risk that any agrichemical agent will be carried by water and reach local springs. The GMPs listed below, when incorporated into the regular farming operation, can reduce the adverse impact on the environment and human health:

. **Integrated pest management (IPM)** – IPM consists in the use of all means of control, chemical or not, in such a way as to reduce production losses caused by pests. Agrichemicals should be considered as are one of the possible resources against pests that should only be used only when economically feasible. In other words, the expected loss caused by pests should be greater than the cost incurred in controlling them. Thus, pest monitoring and sampling should constitute a regular farming practice to see if the level of infestation justifies control, whether by application of insecticide or other control measures such as the use of traps or biological agents.

**Establishing a protected area between the crop and the most sensitive areas** – The contamination of water sources occurs by migration of pesticides through water. Farm zoning should indicate the sites that are the most vulnerable to contamination of these resources. Depressions in the terrain or lakes act as a funnel concentrating rainwater and facilitating the entry of agrichemical residues into the underground water. In these cases, one must create and maintain a buffer zone, with vegetation, around the planted area, to reduce agrichemical runoff to those locations. Such a buffer zone, formed with natural or planted vegetation, located at the interface of the planted field and natural water reservoirs serves as a barrier to contamination.

**Use of alternative methods of pest control** -Typically, pest control requires less effort than what is actually made to reduce the losses. In many cases, a combination of farming practices, which can deter pest infestation and preserve natural enemies are preventive measures that are as efficient as or more efficient than the use of agrichemicals. Moreover, in recent years, consumer and industries are increasingly asking for products from a agrichemical-free environment or one in which they are used sparingly.

# Harvest

*José Geraldo da Silva*

## Harvesting time

Harvesting at the right time is crucial in obtaining higher yield and a product of better quality. Rice reaches the required point of maturity when two thirds of the grains of the panicles are ripe. Although this phase is easily determined visually, it can also be based on the grains' moisture content which should preferably be between 16 and 23% for most cultivars (FONSECA et al. 1979).

An early harvest, when the grain moisture content is still high, increases the percentage of malformed and chalky grains. A late harvest, when the moisture content is low, affects production by a natural shattering and the grains crack, thereby reducing whole grain yield during processing.

Some cultivars are very demanding in terms of the harvest time. Lack of information regarding this requirement may result in significant losses during processing.

## Harvesting equipment

Different types of harvesting equipment can be used in this crop, from the small-sized ones, pulled by a tractor to self-propelled combines equipped with harvesting decks, up to 6 meters wide, which perform cutting, gathering, threshing and grain cleaning operations.

Rice combines harvest and thresh the plants in a single operation. Special machines designed to work in soggy terrain, as is found in irrigated crops, are equipped with rice tires or dual tires, which will allow for more surface contact with the ground. Harvesters may also be belted and equipment with rubber crawler tracks. They are fitted with plant cutting, and feeding mechanisms; threshing, grain separation, cleaning, transportation and storage. They also have special components to ensure they will continue to operate properly under different conditions and terrains, such as lowlands.

Harvesting irrigated rice efficiently, among other measures, requires:

. equipping the harvester with rubber crawler tracks so it can operate in soggy terrain;
. controlling the reel speed so as not to exceed 25% of the forward speed;
. using a rotating threshing cylinder (with beaters or teeth) which revolves at 500-700 rpm;
. adjusting the aperture between the concave and threshing cylinder for maximum efficiency during threshing and to ensure minimal grain damage and loss, and
. avoiding excessive operating speeds since this increases losses substantially.

The conventional mechanism that cuts and gathers the plants is called the cutting platform. Since the stems are cut below the panicle, away from the ground, the best platform for rice is the rigid platform, without a flexible cutter bar. The platform features: a plant row separator, which separates the harvest area; a reel that pushes the standing crop against the cutter bar with serrated blades; and a feeding auger to transport the plant to the feeder canal of the threshing unit. The reel/combine displacement speed ratio must be less than 1.25 to minimize grain loss on the platform. It is important to emphasize that, while harvesting rice, approximately 70% of losses take place on the cutting platform.

An alternative to the cutting platform, which produces less straw at the straw walker output is the grain picking platform, whose main component is a cylinder with polypropylene teeth. The cylinder works by scraping the panicle from the base to the apex. As it turns, the grains are pulled out and thrown back toward the feeding auger, which drives them to the threshing unit feeder line. The picking platform makes it possible to change the displacement speed and, consequently, the combine feeding rate so as not to overloading the mechanisms.

The feeding tray feeds the cut crop into the threshing unit, which strips the grain and performs primary separation. More than 90% of the grains are separated from the panicles during threshing. The unit components are the threshing drum or cylinder and the concave which must have teeth for this crop. The peripheral speed of the threshing drum varies with the grain moisture content, and in general, the speed is 20-25 m $s^{-1}$, with the drum rotating at 500-700 rpm.

After threshing, the stem and part of the grains fed into the separation mechanism, made of the back beater, extension of the concave, straw walker and straw walker curtains. The beater is a rotary deflector that performs a second striping of the cut crop against the length of the concave, leading the plants to the straw walker for the final separation. The curtains help in standardizing the material in the straw walker which unloads the straw on the ground and takes the remaining grains to the cleaning mechanism. To facilitate immediate tillage for the next crop, rice combines must work with a straw chopper and spreader. The straw chopper is also crucial to growing a ratoon crop.

The grains separated by the concave and the straw walker, as well as any impurities are taken by the grain pan to the cleaning unit which is composed by an upper sieve, a rethreshing mechanism, a lower sieve and a fan. The upper sieve pre-cleans the grains that go on to fall onto the lower sieve. The rethreshing unit, placed at the end of the upper sieve, retains the non-threshed grains, while the lower sieve performs the final cleaning. The fan blows on the sieves, and helps to eliminate impurities from grains by density difference.

The clean grains are transported by augers and belts to the bulk tank or bagging platform. Non-threshed grains are reclaimed by the rethreshing unit and, redirected to the primary threshing unit.

## Losses

Losses often occur in two distinct moments, before and during harvest. Prior to harvest, factors that cause loss are: natural threshing; lodging; attacks by birds; excessive rainfall; winds; prolonged moisture stress and damage by diseases and insects. They all induce a reduction in the grain mass and cause depreciation. Natural threshing, which depends on the genetic constitution of the cultivar and the deleterious action of the wind, rain or Indian summers, is something that cannot be controlled by growers.

When rice is being harvested, the impact of plants against the cutting platform causes variable degrees of loss that will depend on the threshing characteristics of the cultivar, grain moisture content, the presence of weeds and the state of maintenance of the combine and how it is operated. Combines should not be operated at speeds that are incompatible with reel rotation since this may cause premature threshing or gathering failures, greatly increasing these losses.

Losses in the threshing unit are higher when the opening of the threshing cylinder and the concave are not properly adjusted. Inadequate adjustments of these mechanisms result in incomplete threshing and most of the grains stay in the panicles. Sieve separation becomes more difficult and grains are more likely to crack, which reduces the percentage of whole grains.

Losses also occur in the sieves due to poor regulation of air flow, sieve opening and positioning. In the straw walker, losses may result from obstruction, inadequate regulation and excessive combine speed or from crop conditions, such as the high incidence of weeds and immature grains with grains with a high moisture content.

## Determining grain loss

Grain loss during harvest can be assessed in terms of total or specific loss (FONSECA, SILVA, 1997).

Determining total loss – this expression refers to grain loss in a single stage, which takes place after the combine is operated, following these steps: (a) after the crop is harvested, a rectangular (1 $m^2$) area is chosen at random. The site is marked in such a way that the longest side corresponds to the width of the cutting platform; (b) grains from this demarcated area are them collected, including those caught in the ramifications of the panicle; (c) grain mass is calculated and the loss is transformed in kg $ha^{-1}$, according to equation 1 below:

Equation 1 - Loss (kg $ha^{-1}$) = grain mass (g) x 10

Alternatively, loss can be quantified according to the detailed guidelines found in Table 1, below. It is also possible to use the plastic volume meter cup (Figure 1). This cup is graded specifically for rice and is a simple, convenient and accurate way to measure losses, eliminating the work of counting or weighing grains.

It is important to emphasize that grain loss should be assessed in at least four sites of the plantation.

**Table 1.** Minimum and maximum losses according to the number of rice grains per m$^2$ found in fields after harvest.

| Grains ($n^o$ $m^{-2}$) | Rice Loss (kg $ha^{-1}$) Minimum* | Rice Loss (kg $ha^{-1}$) Maximum* | Grains ($n^o$ $m^{-2}$) | Rice Loss (kg $ha^{-1}$) Minimum* | Rice Loss (kg $ha^{-1}$) Maximum* |
|---|---|---|---|---|---|
| 50 | 12,9 | 17,8 | 550 | 141,9 | 195,8 |
| 100 | 25,8 | 35,6 | 600 | 154,8 | 213,6 |
| 150 | 38,7 | 53,4 | 650 | 167,7 | 231,4 |
| 200 | 51,6 | 71,2 | 700 | 180,6 | 249,2 |
| 250 | 64,5 | 89,0 | 750 | 193,5 | 267,0 |
| 300 | 77,4 | 106,8 | 800 | 206,4 | 284,8 |
| 350 | 90,3 | 124,6 | 850 | 219,3 | 302,6 |
| 400 | 103,2 | 142,4 | 900 | 232,2 | 320,4 |
| 450 | 116,1 | 160,2 | 950 | 245,1 | 338,2 |
| 500 | 129,0 | 178,0 | 1.000 | 258,0 | 356,0 |

* For 100 rice seeds, the minimum and maximum masses were, respectively, 2.58 g and 3.56 g.


**Figure 1.** Rice grain loss meter used in harvest.

**Determining specific losses** – This makes it possible to identify specific losses at the cutting platform, the straw walker and the combine sieves on a individualized basis.

## *Loss at the cutting deck*

(a) during harvest stop the combine anywhere in the property and turn off the cutting platform mechanism;

(b) raise the platform and pull the combine back to a distance which is equivalent to its length (4-5 meters);

(c) demarcate a 1 $m^2$ (1 x 1 meter) area in front of the tracks left by the tires;

(d) collect any grain found in the demarcated area;

(e) determine grain mass and calculate the loss in kg $ha^{-1}$ using equation 1 above;

(f) repeat these procedures in four locations planted with the crop.

### *Loss at the straw walker*

(a) use a wood and cloth frame (similar to a hospital gurney) 0.5 meter wide and 1.2 meters long;

(b) place the frame on a representative location in the field and wait for the combine to pass;

(c) as the combine passes, make sure the frame stays in place to collect what the straw walker unloads;

(d) separate grain from chaff and determine grain mass;

(e) calculate the loss in kg $ha^{-1}$ using equation 2:

Equation 2: loss (kg $ha^{-1}$) = grain mass (g) x 20/width of the cutter bar (in meters)

### *Loss at the sieves*

Loss at the sieves is determined by adopting the same procedure described above. Using the same wooden and cloth frame, collect grains falling from the straw walker and from the sieves. Once the mass of grains lost at the straw walker has been determined, subtract this figure from the total to obtain loss at the sieves.

Loss caused by internal mechanisms can also be quantified by subtracting the figure representing the loss at the cutting platform from the total.

This investigation to determine loss at the straw walker and the sieves must be performed in at least four places.

## Technical recommendations

To avoid unnecessary losses, some factors must be taken into consideration, before beginning harvesting operations.

### *Harvesting time*

Avoid harvesting in the morning when the grains are still moist with dew. In the event of rain, wait until the rice is dry, otherwise the wet plant may cause the combine to become obstructed.

### *Grain moisture content*

The ideal moisture content of grains for most rice cultivars is 16-23%. In practice, since growers don't always have the equipment to determine moisture content in the field, check for a change of color in the glumes. Ideally, harvesting should begin when two thirds of the grains in the panicle are mature. Biting grains or squeezing them with the fingernails can also serve as a useful indication. If the grain flattens, the rice is still immature; if it breaks, it is in the semi-hard phase and harvest can begin. In regions subjected to heavy rainfall, where the harvest is often done while the grain moisture content is still very high, the product must undergo drying immediately to preserve quality during storage.

### *Harvester adjustment and maintenance*

Higher yields at lower costs are possible, if the instructions found in the operator manual that comes with every combine are followed. External and internal mechanisms should be regulated adequately. The state of conservation of the combine is also an important factor that must be considered. Before starting up, check for faulty blades, missing reel parts and other irregularities in the threshing and fan mechanisms. The reel speed should be enough to pull the plants into the machine and should be up to 25% faster than the harvester speed. Operating the combine at excessive speeds can cause premature engine wear and increases the risk of accidents.

When there is lodging, reduce the operating speed and adjust the reel so that it is lower and more forward than it would be when harvesting normal crops. It should always be parallel to the blades. Harvesting along the direction of the lodging is a more efficient practice and, because of that sometimes it sometimes necessary to harvest in a single direction, even though this may result in smaller operating efficiency.

To harvest irrigated rice efficiently, the following measures should be observed, among others: use a combine with rubber crawler tracks, which are better for soggy terrain; threshing drums should rotate at 500-700 rpm; regulate the opening between the concave and the threshing drum for maximum threshing efficiency and minimal grain damage and loss and avoid excessive operating speed as this increases losses substantially.

## Final drainage

It is very important to know the best time to drain the crop before harvest, in irrigated crops. Even though early drainage saves water, it can cause decreased productivity. The kind of soil and the cultivar used will determine the best time to drain the fields and usually it should take place ten days before harvest. This practice will make it easier for the combines to move around the field to ensure a higher yield without causing productivity loss and without compromising grain quality.

In addition to these recommendations, whose aims are to cut down on losses during harvest and to minimize damages to the final product, the grower must also see to it that the subsequent post-harvest stages, such as transportation, drying, cleaning, processing and grain and seed preservation, are also performed according to the best practices, so they don’t contribute to increase losses.

# Ratoon Crops

*Alberto Baêta dos Santos*

Ratoon crops are an alternative to increase yield in the flooded rice cropping system, which consists in using stem re-grown after harvest. Ratoon crops contribute to increase rice production per area unit, with a better cost/benefit ratio, or by maintaining productivity at reduced cost. Well-managed farms get up to 22 60-kilogram bags $ha^{-1}$, in a 55 day-cycle, with production costs equivalent to five to nine bags. However, research has shown that technology can raise this yield expressively and this has encouraged farmers to use this practice in extensive areas.

In the low and medium Itajaí Valley regions, and in the northern coast of Santa Catarina, intensive cropping systems made it possible for farmers to have two rice crops a year using short-cycle cultivars. Currently, the second crop has been eliminated in about 80% of the planted area, representing approximately 25 thousand hectares or 20% of the state. Farmers are preferring ratoon crops with grain productivity going up to 4,000 kg $ha^{-1}$ in up to 110-day cycles. Ratoon production costs include only water, urea and diesel fuel used in mowing or preparing the ratoon and harvesting it. An additional 2,770 kilograms $ha^{-1}$ has been gained in the 2002/2003 harvest, on average, when the region started adopting the ratoon technique.

Ratoon crops make it possible to increase the productivity of wetlands with quality. It decreases machine use seasonality and increases the use of the labor force, thereby increasing farmers' income. Ratoon will gain in importance when there is water to anticipate the planting of the main rice crop and for farmers who do not plant soybean seeds during winter.

## Determinant factors for ratoon crops

### *Planning*

A successful ratoon crop requires planning. The farmer must plan the rice production system, from establishing the main crop to the second harvest. Only ratoon genotypes with a recognized production capacity must be used. Since ratoon represents a percentage of the productivity of the major crop, it is important to use selected areas.

### *Choice of cultivars*

Cultivars behave differently regarding production and the origin of tillers in ratoon systems and, consequently, in terms of productive potential. Some cultivars form tillers in every stem node, while others formed shoots only at the lower nodes. Early-development cultivars may behave better than medium-cycle ones in places where climatic conditions limit ratoon development. However, under favorable conditions, medium-cycle cultivars are more organic than short-cycle cultivars, both as main crops and in ratoon systems. In most genotypes, productivity components, number of panicles per area, number of grains per panicle and the 100-grain mass are decreased, hence, ratoon productivity, as compared to their use as main crops. Among these components, the number of grains per panicle showed the greatest difference between the two crops, with a reduction of around 50%. Thus, to increase productivity in a ratoon system, this component needs to be increased, either through plant breeding or by using crop management techniques.

Studies performed in various regions of Brazil showed that the relationship between the productivity of ratoon crops, relative to main crops, with the use of different rice cultivars and strains ranges from 5-89%. Most studies have not shown a positive and significant correlation between productivity of grains used as main crops and in the ratoon system. Agronomic traits that best correlate with productivity are, in the main crop, plant height and harvest index, while in ratoon systems, these traits are number of panicles per square meter. In ratoon crops, rice seeds CNA 3771 and BRS Formoso, both medium-cycle seeds, demonstrated had adequate levels of productivity, 3,053 kg $ha^{-1}$ and 2,702 kg $ha^{-1}$, respectively, which fully justifies the use of this farming practice.

Ratoon systems should use genotypes with a recognized productive capacity in both crops. Some rice cultivars may have high productivity in conventional systems, as main crops, may not be productive in a ratoon system, as is the case with Metica 1. Others, such as BRS Formoso and BRS Ourominas have exhibited a high production potential in both crops. Under favorable conditions, medium-cycled cultivars are more organic than those with a short cycle, both as main crops and in ratoon systems.

## *Climatic factors*

Among the climatic factors affecting rice growth and development, temperature and light have been reported as the most influential on ratoon behavior, particularly with regards to tillering. Depending on crop phase, low and high temperatures are both critical. Values below 20 ºC and above 35 ºC can cause adverse effects.

## *Main crop management*

The genetic constitution of the cultivar, the environment, and main crop management have a direct effect on growth and development and, consequently, ratoon productivity. In general, farming practices affecting plant growth also affect ratoon growth. However, some specific practices determine, to a large extent, the success of a ratoon crop. Production capacity is influenced by sowing, planting system, plant population, water and fertilizer management, and harvesting system. In a ratoon crop, cultivars respond in a different way to practices used in main crops.

## *Sowing time*

Different sowing times expose main crop and ratoon plants to different daytime duration, temperature and light conditions which, in turn, influence ratoon behavior. Deciding on planting time requires many factors to be taken into consideration and one of them is the prevailing climate conditions in the region and availability of water for irrigation.

In the state of Rio de Janeiro, in the middle and lower Itajaí Valley region and in the northern coast of Santa Catarina, planting in September resulted in the highest grain productivity for the ratoon crop. For the Goiânia-GO region, the most favorable period for planting the ratoon crop was August to October. In that region, it is possible to achieve intensive planting in floodplains with ratoon rice. In the North and Northeast of Brazil, rice can be grown throughout the year, so sowing does not limit ratoon rice planting. An example is the State of Tocantins, with two well-defined rainfall regimes: the

May to September period, characterized by very little rainfall, and considered the dry season, and the October to April period, characterized by a higher incidence of rain, when irrigated rice is predominantly grown. Since during the beginning of the recommended planting season, from October to December, the level of groundwater and rivers is low in most areas, sowing depends on rainfall. Generally speaking, the sowing period for the main crop which will favor the ratoon crop the most, correspond to the period in which planting is recommended for that region.

Rice solar radiation needs vary according to the plant's developmental stage. Solar radiation during the reproductive phase has a greater effect on grain productivity, relative to the vegetative and maturity phases.

## Planting system

The two methods used in rice crops are the no till system, in dry or wet soil, and transplanting. Although their effects on ratoon behavior have not been fully studied, the vast majority of studies on the best use of ratoon rice were done with no till planting in dry soil. One of the advantages of no till planting for ratoon, relative to transplanting, is the large number of plants per area unit. As result, fewer tillers in ratoon plants are needed to produce a large number of tillers per area unit. To increase the potential of tillers on transplanted ratoon rice, the plant population in the main crop can be increased by reduced spacing. Regardless of the tillage system, an appropriate population of plants is a prerequisite for a productive ratoon crop.

### *Plant population*

Plant population per area unit is given by a combination of spacing and number of plants in the line. Plant competition for nutrients, water and light is largely determined by these factors. The plant population may be an important factor affecting ratoon behavior, since its tillers arise from dormant shoots found in main crop stubbles.

Larger plant populations in the main crop increase the number of tillers per area unit, also increasing the potential number of tillers in the ratoon rice. That notwithstanding, this increase is not sufficient to increase the ratoon plant population, since a higher number of plants can also mean a higher number of non viable tillers. Despite being a factor in the number of non viable tillers found in the ratoon crop, plant population may not have a significant effect in grain productivity.

No significant effects have been noticed on ratoon grain productivity, with row spacing with the transplanting method and with seeding density in the main crop. Thus, as far as ratoon crops are concerned, the recommendation of a plant population in a production system consisting of a single irrigated rice harvest is valid.

### *Fertilizer management*

Soil fertility affects, directly or indirectly, the growth and productivity in ratoon crops. Nitrogen and phosphorus significantly affect ratoon growth and phosphorus is particularly important for promoting good root development. Fertilizer requirements varies widely in ratoon crops. Some studies indicate that ratoon crop growth depends on the type, composition and amount of fertilizer used. They also indicate that different types of fertilizers are needed, not only in the main crop, but also in the ratoon crop. In general, if the main crop was treated with adequate amounts of phosphorus and potassium, these nutrients are not required for the ratoon crop.

The amounts, mode and time of application of fertilizers from appropriate sources are important for obtaining high grain productivity in the main crop, which will necessarily reflect in the ratoon crop productivity. To get a productive system in both crops, farmers must base the amount of fertilizer used, as well as mode and time of application on soil analysis results, as recommended for irrigated rice.

## Harvesting system

Another important point to consider in planning is main crop harvest, especially in terms of time, cutting height and harvesting equipment. The harvesting system used influences ratoon behavior regarding productivity and product quality. It is important to prevent unnecessary “passes” of the combine and bulk trucks so as not to cause excessive damage to the rice plants, since the combine tracks can affect up to 38% of the total cultivated area.

### *Harvest season*

The time needed for grain forming and filling is 30-40 days. This difference results mainly from variations in air temperature, with little influence of the cultivar cycle. Grains go through the milky, pasty and hard mass phases until they reach physiological maturity, in which the highest content of dry matter is present. At this stage, the seeds will be practically separated from the mother plant and remain stored under field conditions. Physiological maturity is defined as the period in which the translocation of photosynthates ceases. Thereafter, the plant triggers mechanisms that will cause seeds to dehydrate. During this process, seeds undergo morphological and physiological changes, such as changes in size, water content, dry matter accumulation, germination and vigor. Rice could theoretically be harvested at this stage, as long as conditions for immediate drying were provided, since moisture content, at approximately 30%, is still high. For a good result with the ratoon crop, the best time for harvesting the main crop is when stems are still green. Harvesting delays result in a decreased ratoon cycle time and productivity.

### *Cutting height*

Stubble height determines the number of shoots that can be used for tillering and the source of ratoon tillers. Cutting height effect over the ratoon vigor vary and depend on the cultivar chosen. Some cultivars have a higher number of tillers in the upper nodes, while in others, these tillers are found in the nodes at the base, not affected by cutting height.

Some of the ratoon plant traits which are greatly affected by cutting height are grain productivity, tillering and cycle duration.

A shorter cutting height of main crop plants lengthens the ratoon cycle which, together with a delayed harvest time, can cause the crop to grow under less favorable weather conditions that will affect productivity, especially in medium-cycle genotypes. Most studies show that the best results were obtained with cutting heights around 20 cm. Under field conditions, the stems cut very low may remain submerged for a long period of time, especially in areas which were not leveled. This condition causes them to rot and prevent flowering. Manual harvesting is made easier when the plants are cut higher.

### *Harvesting equipment*

Harvesting the main crop with combines equipped with straw choppers (Figure 1) results in higher productivity and a higher grain hulling yield for the ratoon crop, relative to harvesting done without the chopper. When a combine without straw choppers is used, a trail of straw is left behind (Figure 2). In addition to hindering tiller growth, this condition can cause diseases do appear. Therefore, straw choppers are highly recommended.

**Figure 1.** Ratoon crop in which the main crop was harvested with combines equipped with a straw chopper.

After harvesting the main crop in Mato Grosso do Sul, some farmers fit their tractors with iron wheels (Figure 3), which cause the rice stems to bend. The purpose is to standardize flowering and obtain better grain quality from the ratoon crop.

**Figure 2.** Irrigated rice ratoon crop in which the main crop was harvested with combines not equipped with a straw chopper.


**Figure 3.** Equipment used by farmers after harvesting the main rice crop in Mato Grosso do Sul.

## *Ratoon management*

Farming practices promoting a rapid and uniform flowering are especially important. Most important among those used in ratoon crops, which affect the behavior of the rice plant, are nitrogen fertilization, water management and plant treatment.

### *Nitrogen fertilization*

Among the commonly used soil nutrients, nitrogen is, without a doubt, the element that is responsible for the greatest response in ratoon rice crops. Adequate amounts of phosphorus and potassium applied to the main crop have prompted a significant increase in ratoon productivity. This shows that they remain available to promote growth and development. Nitrogen should be applied to the ratoon crop soon after the main crop is harvested, to achieve earlier flowering and healthier tillers, factors that are known to increases grain productivity. Increased ratoon response is obtained by applying 56 kg ha$^{-1}$ of nitrogen (Figure 4) immediately after harvesting the main crop (Figure 5).

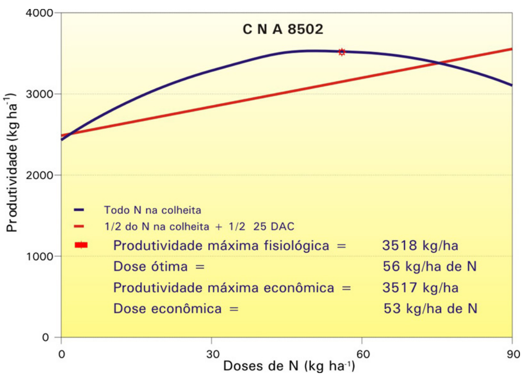


**Figure 4.** Irrigated ratoon rice response to nitrogen fertilization.

**Figure 5.** Nitrogen fertilization in the ratoon rice field immediately after the main crop was harvested.

## Water management

The water needed for irrigation must be adequately managed, in order for the ratoon crop to be successful, even if approximately only 60% of the water normally used by the main crop is required. Ratoon rice fields are obtained when flooding starts nine days after harvesting the main crop (Figure 6), a practice that saves up to 14% of water.

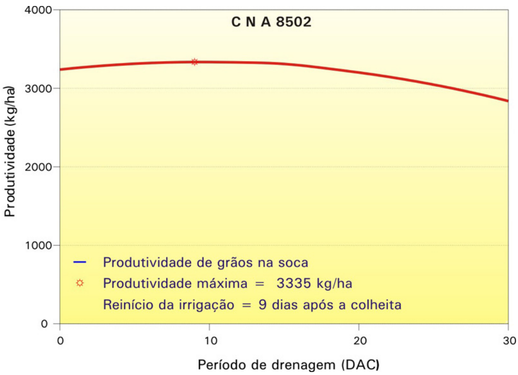


**Figure 6.** Irrigated ratoon rice response to flooding time.

## Plant treatments

Climatic conditions during ratoon crops are less favorable to the occurrence of diseases. Exceptionally, and depending on prevailing climate conditions, fungicides may be needed to obtain greater productivity and improved grain quality. Fungicides will result in a lower percentage of grain discoloration, caused by the fungus *Bipolaris oryzae*, which translates into a higher grain hulling yield. As far as insect pests are concerned, control may be necessary only if the field is attacked by the paddy bug (*Oebalus spp*.). Ratoon rice apparently is not a favorable environment for the development of *Oryzophagus oryzae* populations. Therefore, the need for controlling this pest remains quite remote.

# Drying, Storage and Processing

*Eduardo da Costa Eifert*

Rice grain quality is influenced by the drying method used, processing, storage conditions as well as by internal factors inherent to the cultivar, and by the prevailing climatic factors at the pre-harvest stage.

## Pre-cleaning

Pre-cleaning precedes the drying process. During this phase impurities that can slow the drying process, accelerate the appearance and development of microorganisms and facilitate the proliferation of insects are removed.

The choice of screens used for removing these impurities is critical. Additionally, the air flow generated by the fan is another important factor as it must be adjusted adequately, to prevent grain loss.

Generally speaking, at the end of this pre-cleaning stage, the resulting rice batches contain less than 2% impurities.

## Drying

The ideal moisture level for harvesting rice lies between 18-23%. These values are normally attained when grains reach the end of their formation stage. This range, however, is too high for storing grains.

When the grain is fully formed and ripe, delaying harvesting may result in loss of quality because moisture tends to oscillate upwards with dew at night and downwards with the heat of the sun, mainly in the hottest hours of the day. Moreover, while in the field, rice is subject to rains that may fall at the end of the ripening stage. These variations can cause cracks, which, may result in broken grains, during processing.

Therefore, to obtain high-quality rice with a good grain hulling yield, it must be dried until an adequate moisture content, around 13%, is reached. Before drying, which can be done naturally, leaving the rice exposed to the sun or with the use of a heat source, the grains must undergo a pre-cleaning process (BRAGANTINI, 2006).

## *Sun drying*

Sun drying is widely used by small and medium sized farmers who have no access to the infrastructure of industrial drying.

The newly-harvested grains are usually spread over a concrete slab, pavement or over a tarpaulin covered surface and are turned constantly to facilitate moisture exchange with the environment. When the moisture content of grains begins to fall, they should be arranged into a pile, at night, to prevent the re-absorption of moisture.

Although the climate in the state of Mato Grosso do Sul makes it possible to use this drying method, it is not a practical alternative when the farmer has large quantities of grain to dry or when weather conditions indicate that it might rain during the process.

## *Artificial drying*

In artificial drying, the newly-harvested, still moist grains, are placed in dryers that force air through them and transport moisture to the outside environment. Drying can be achieved by blowing natural or heated air on the rice pile (BRAGANTINI, 2006).

Artificial drying it is a highly sensitive process that, if not done properly, can result in losses during the processing stage, and produce high percentages of broken grains. To minimize these losses, natural or unheated air or even slightly heated air should be used at the beginning of the drying process, when grain moisture is still very high, because rice at this stage loses moisture very easily. When using hot air, thermal control becomes critical, to prevent any excessive increase in temperature, especially when using fossil fuels (firewood, bark, crop residues, etc.) to heat the air flowing through the grains (BRAGANTINI , 2006; VIEIRA; VIEIRA, 2001).

The temperature of the air flowing through the rice grain mass should not exceed 40° C during the drying process. Thermal shocks, in which the air stream temperature is raised or lowered very quickly should be prevented since they can result in a higher incidence of broken grains, which will cause the final product to become depreciated.

Among the various types of dryers available in the marketplace, the best ones for rice grain drying are the “intermittent” types. Regardless of the intended grain use – seeds or food, gradual drying is the preferred method, as it prevents water from being removed abruptly. The temperature should be raised gradually, as the moisture content decreases, so the rice will not suffer a thermal shock and you will not run the risk of overheating the grains.

Removing more than 2% moisture per hour/drying is not recommended.

## Storage

When consumed soon after harvest, the grains of some rice cultivars may become soggy. To have good cooking qualities, rice almost always requires a period in storage before being processed. Rice can be stored in bulk, in silos made of concrete, metal or other materials, or in jute or polyethylene bags.

Whenever possible, rice should be placed in silos that have already been cooled, to avoid the need to pump in unheated air. After the silos are loaded, the temperature of the grain mass needs to be monitored on a daily basis, at various points, to prevent heating.

The rice should be moved every 30-60 days to aerate the grain mass and reduce the effects of compression inside the silo (HARA, 2006).

When rice is to be stored in bags, make sure it is dried so that the moisture content must be at least a 1% less than if it were going to be stored in ventilated silos, because the possibility that the rice will absorb moisture from the atmosphere is greater when it is bagged. Make sure the space between piles is sufficient to ensure adequate ventilation that the bags are placed in

12-cm high wooden slats, at least. This will also allow the air to circulate under the piles. Pile height should not exceed 4.5 meters. Remember that grains need a clean environment, so good maintenance is critical.

Purges should be performed as required, in compliance with an agronomist's recommendation and under his supervision. When rice is stored in silos, the chemical agent used for purging is applied as the silo is filled with the rice, during bin transfers, or by means of probes. Bagged grains can be purged by using plastic sheets that allow each pile to be fumigated separately.

## Processing

Rice processing (traditional rice, which has not been parboiled) starts with the separation of hull from the rest of the grain to obtaining the white rice which is consumed. It consists of the following steps: cleaning, hulling, pneumatic separation in the straw chamber; separation of unhulled rice, known as *marinheiro*; polishing, homogenization, and grading.

### *Cleaning*

Having gone through the pre-cleaning and drying process, paddy rice must undergo cleaning to remove coarser impurities that may have been left with the rice such as plant stalks, straw, dirt, rocks, jute rags, and threads, among others.

### *Hulling*

During this stage, the hull or husk is removed from the grain by two rubber rollers that turn in opposite directions and at different speeds. As the grain passes through the small space between the rollers, it is made to twist and this movement allows the hulls to break open and fall off. During this stage, care should be taken to prevent grain breakage, a problem which can be caused by excessive grain moisture content.

Hulling is almost never done immediately after harvesting and drying because storage significant increases grain quality and the tendency to become soggy after cooking decreases as the grain increases its ability to absorb water.

### *Pneumatic Straw chamber*

This machine uses a pneumatic system to separate the whole grain from the immature or green rice and from the husk and other undesirable impurities. It is worthwhile mentioning that among all the by-products obtained in the process, the hull represents 22% of the final volume.

### *Separation of unhulled rice, or marinheiro*

This specific machine separates the hulled rice from unhulled grains, known as *marinheiros*, in Brazilian Portuguese, left over from the pneumatic straw chamber.

Among other advantages, these machines ensure that a substantially lower (close to zero) incidence of unhulled grains (*marinheiros*) is sent to the next processing stages and an extremely low incidence of hulled grains is mixed with the still unhulled grains which will cycle back to the huller. These advantages translate into higher yields and a better final product.

## Polishing

During this stage, the hulled rice, known as brown rice, is polished by a machine that has abrasive components that separate the rice bran from the white rice.

## Homogenization

Complementing the dry-friction polishing stage, this homogenization process removes the rice bran still left attached to the grain with a high-pressure fine water mist which is sprayed onto the moving grains. This process ensures that each grain is smooth and free of all loose bran and white rice flour and there residues are removed by an air exhaust system.

## Grading

At this stage rice is goes through machines that separate the grains with a higher commercial value from the ½ and ¾ grains with a lower commercial value. The grains are also separated from other by-products which will be used by the brewing and the animal feed industries.

One of the most important quality parameters in processing rice is related to its milling capacity which is measured mainly in terms of the amount of whole grains obtained at the end of process.

# Integrated Stored Rice Insect Pest Management

*Daniel de Brito Fragoso*

Integrated management of insects and pests in stored rice requires knowledge, experience and professionalism. Since the presence of insects is usually associated to pre-existing infestation, it is important to make sure that silos and warehouses must be thoroughly cleaned before rice is brought in for storage (BRAGANTINI, 2006). Several species of insects can attack rice grains, regardless of how they are being kept – with intact hulls or after processing, but two groups are considered especially important: a) *Coleoptera* - weevils and beetles and b) *Lepidoptera* - moths.

## Weevils and beetles

- *Sitophilus oryzae* Linn., 1763 (Coleoptera, Curculionidae)
- *Sitophilus zeamais* Mots., 1865 (Coleoptera, Curculionidae)
- *Rhyzopertha dominica* Fabr., 1792 (Coleoptera, Bostrichidae)
- *Tribolium castaneum* Herb., 1797 (Coleoptera, Tenebrionidae)

### *Importance and damage*

Although these insects have less than 1 cm, they have a high biotic potential. Each female lays over 300 eggs throughout its lifetime. The first two species are popularly known as weevils and are easily identified by their mouthparts, which resemble a cylindrical beak (rostrum) extending forward. They attack intact grains, so they are listed as primary pests. Both larval and adult forms feed on the grain mass causing the final product to lose in quality and quantity. The two other species of beetles have mouthparts for chewing, but they attack defective grains in which the hull did not close or grains that were damaged during harvest. They are normally associated to the appearance of primary pests (weevils).

## Moths

- *Sitrotroga cereallela* Oliv.1819 (Lepidoptera, Gelechiidae)
- *Plodia interpunctella* Hubn. 1813 (Lepidoptera, Pyralidae)

## *Importance and damage*

These primary pests attack cereal grains, either in the field, when the grains have already achieved physiological maturity or while they are drying. In silos or bulk carriers, the attack occurs in the superficial layers of grains, where larvae devour the grains, reducing grain weight, quality and nutritional value.

## *Control*

A preventive measure includes the elimination of existing infestations inside and outside the storage unit. The best way to clean these facilities is to spray them, before the grains are brought to storage, with registered products (Tables 1 and 2). Grain water content is another important factor that must be used as a control tactic and it should always be maintained below 12%. An aeration system should be used to as a means to control moisture and temperature in the grain mass (VIEIRA, VIEIRA, 2001). If rice is going to be stored for more than three months, it should treated, preventively, with liquid insecticides registered for the species mentioned above. Additionally, as needed, purges should be performed under the guidance, supervision and technical responsibility of an agronomist. When rice is stored in silos, the chemical agent used for purging is applied as the silo is filled with the rice, during bin transfers, or by means of probes. Bagged grains can be purged by using plastic sheets that allow each pile to be fumigated separately. Purging should last no less than 120 hours of exposure.

**Table 1.** Products registered for *Sitophilus oryzae.*

| *Product* | *Active principle* | *Formulation* | *Toxic. Class* |
|---|---|---|---|
| Actellic 500 EC | Pirimiphos-methyl | CE | III |
| Degesch Aluphos | Aluminium phosphide | FP | I |
| Detia GAS-EX-B | Aluminium phosphide | FG | I |
| Detia GAS-EX-T | Aluminium phosphide | FP | I |
| Fermag | Magnesium phosphide | FP | I |
| Fertox | Aluminium phosphide | FP | I |
| Insecto | Diatomaceous earth | PS | IV |
| Starion | Bifenthrin | CE | III |
| Sumigran 20 | Fenitrothion | PS | IV |
| Sumigranplus | esfenvalerate + Fenitrothion | CE | II |

CE - emulsifiable concentrate formulation, PS – Dry powder, FP – Tablet formulation, FG – Granular formulation.

**Table 2.** Products registered for *Rhyzopertha dominica.*

| *Product* | *Active principle* | *Formulation* | *Toxic. Class* |
|---|---|---|---|
| Degesch-Fumicel | Magnesium phosphide | TB | I |
| Gastoxin | Aluminium phosphide | FP | I |
| Gastoxin-B 57 | Aluminium phosphide | FP | I |
| Insecto | Diatomaceous earth | OS | IV |
| K-Obiol 25 CE | Deltamethrin | CE | III |
| Phostek | Aluminium phosphide | FP | I |
| Pounce 384 CE | Permethrin | CE | III |
| Prostore 25 CE | Bifenthrin | CE | III |
| Starion | Bifenthrin | CE | III |
| Sumigran 20 | Fenitrothion | PS | IV |
| Sumigranplus | esfenvalerate + Fenitrothion | CE | II |

TB – Tablets, CE - emulsifiable concentrate formulation, PS – Dry powder, FP – Tablet formulation.

# Techincal Coefficients, Costs and Profitability

*Osmira Fátima da Silva*

## Technical coefficients

The technical coefficients used in this document are based on technical recommendations for irrigated rice in the counties of Rio Brilhante, Miranda, Bodoquena and Bela Vista, in the state of Mato Grosso do Sul. These coefficients are compared with unit prices of production factors in the calculation matrix used by Embrapa Rice and Beans to establish the total production cost for one hectare.

## Production costs

Production costs refer to expenditures that are proportional to variations in production volumes in a given period of time. This analysis considered only the variable costs of inputs such as seeds, fertilizers, agrichemicals, electricity, diesel oil, and the use of leased machinery and contracted services. Average prices for March 2009 were used as the basis for this analysis. Additional financial costs incurred during post-harvest were also considered, such as land lease, estimated at 10% of the production value, technical assistance, estimated at 2%, and 8.75%/year interest on bank financing for the 8-month period, calculated on the basis of plantation costing up to the planting stage, respectively. Also included was a 2.2% cost over selling price for rice, which covers social security expenses.

## Cost Analysis

The cost for producing rice was based on the implementation and crop management phases. Component cost values are shown in Table 1, in Brazilian reals, along with their equivalent values in U.S. dollars. Production factors are given with their measurement units according to specifications.

**Table 1.** Technical coefficients and production cost for irrigated rice in Mato Grosso do Sul, in 2009.

| Input/Operation/Service | Spec. | Unit.* | Amount/ha | Unit. value (R$ ha-1) | Current cost (R$ ha-1) | Current cost (US$ ha-1) | % |
|---|---|---|---|---|---|---|---|
| SOIL MANAGEMENT | | | | | | | |
| Soil grading | Plaina NSI-12 | hm | 2.00 | 60.00 | 120.00 | 53.33 | 3.02 |
| Disc plow | 90 HP Tractor | hm | 1.00 | 98.00 | 98.00 | 43.56 | 2.46 |
| Disc harrow | 70 HP Tractor | hm | 2.00 | 60.00 | 120.00 | 53.33 | 3.02 |
| Building fences | 70 HP Tractor | hm | 1.00 | 60.00 | 60.00 | 26.67 | 1.51 |
| Cleaning irrigation canals | 90 HP Tractor | hm | 0.20 | 98.00 | 19.60 | 8.71 | 0,49 |
| Subtotal – soil management (1) | | | | | 417.60 | 185.60 | 10.50 |
| PLANTING | | | | | | | |
| Seed | Piracema | kg | 150 | 1.40 | 210.00 | 93.33 | 5.28 |
| Seed treatment | Standak | kg | 0.15 | 400.00 | 60.00 | 26.67 | 1.51 |
| Fertilizer | 5-20-20+0.4 Zn | kg | 300 | 1.250 | 375.00 | 166.67 | 9.43 |
| Mechanized planting | 70 HP Tractor | hm | 1.50 | 60.00 | 90.00 | 40.00 | 2.26 |
| Labor – planting | | dh | 0.10 | 30.00 | 3.00 | 1.33 | 0.08 |
| Internal transport | 70 HP Tractor | hm | 0.10 | 60.00 | 6.00 | 2.67 | 0.15 |
| Irrigation | | ha | 1.00 | 210.00 | 210.00 | 93.33 | 5.28 |
| Labor – irrigation | | dh | 6.00 | 30.00 | 180.00 | 80.00 | 4.53 |
| Subtotal – planting (1) | | | | | 1,134.00 | 504.00 | 28.52 |
| FIELD TREATMENTS | | | | | | | |
| Top dressing | Urea | hg | 300 | 1.100 | 330.00 | 146.67 | 8.30 |
| Top dressing application | Air spray | hA | 0.04 | 1,800.00 | 72.00 | 32.00 | 1.81 |
| Labor - fertilization | | dh | 0.50 | 30.00 | 15.00 | 6.67 | 0.38 |
| Weed control | | | | | | | |
| Herbicide – 1 | Glyphosate | L | 3.00 | 12.00 | 36.00 | 16.00 | 0.91 |
| Herbicide – 2 | Gamit | L | 1.00 | 40.00 | 40.00 | 17.78 | 1.01 |
| Herbicide – 3 | Nominee | L | 0.10 | 900.00 | 90.00 | 40.00 | 2.26 |
| Herbicide – 4 | Ally | g | 6.00 | 1.40 | 8.40 | 3.73 | 0.21 |
| Herbicide – 5 | Basagram | L | 2.00 | 40.00 | 80.00 | 35.56 | 2.01 |
| Mineral Oil | Assist | L | 0.50 | 7.00 | 3.50 | 1.56 | 0.09 |
| Post-emergence herbicide | Air spray | hA | 0.02 | 1,800.00 | 36.00 | 16.00 | 0.91 |
| Pest control | | | | | | | |
| Insecticide – 1 | Baytroid | L | 0.40 | 45.00 | 18.00 | 8.00 | 0.45 |
| Insecticide – 2 | Malathion | L | 3.00 | 22.00 | 66.00 | 29.33 | 1.66 |
| Disease control | | | | | | | |
| Fungicide – 1 | Bim | g | 300 | 0.12 | 36.00 | 16.00 | 0.91 |
| Fungicide – 2 | Folicur | L | 2.00 | 30.00 | 60.00 | 26.67 | 1.51 |
| Insecticide and Fungicide appl. | Air spray | hA | 0.08 | 1,800.00 | 144.00 | 64.00 | 3.62 |
| Subtotal – crop treatments (3) | | | | | 1,034.90 | 459.96 | 26.03 |
| HARVEST | | | | | | | |
| Mechanized harvesting | Combine | hm | 1.90 | 180.00 | 342.00 | 152.00 | 8.60 |
| Internal transport | | hm | 1.00 | 60.00 | 60.00 | 26.67 | 1.51 |
| Labor | | dh | 1.30 | 30.00 | 39.00 | 17.33 | 0.98 |
| Packaging (bags) | | un | 120 | 2,50 | 300.00 | 133.33 | 7.55 |
| Subtotal – harvesting (4) | | | | | 741.00 | 329.33 | 18.64 |
| POST-HARVEST (Others) | | | | | | | |
| Lease | | | | | 432.00 | 192.00 | 10.87 |
| Technical assistance | | | | | 31.03 | 13.79 | 0.78 |
| Interests | | | | | 90.46 | 40.20 | 2.28 |
| INSS (Social Security) | | | | | 95.04 | 42.24 | 2.39 |
| Subtotal – OTHERS (6) | | | | | 648.53 | 288.24 | 16.31 |
| TOTAL COST (1+2+3+4+5+6) | | | | | 3,976.03 | 1,767.12 | 100.00 |

* dh = man/day; hA = airplane/hour; hm = machine/hour; ha = hectare; un = unit.

For the purpose of this analysis, “conventional” soil management consisted of soil prepared with a NSI-12 grader, disc plows and disc harrows. It also included building fences and cleaning irrigation canals. The cost of flood irrigation was based on the cost of using electric and diesel engines to pump water.

The fertilization regime at the time of sowing included the application of 300 kg $ha^{-1}$ of a 5-20-20+0.4 Zn formula. To dressing was used to apply nitrogen, which consumed a total of 300 kg $ha^{-1}$ of urea.

Weed control was achieved with post-emergent herbicides, and insecticides and fungicides were applied by air. Among all the cost components, inputs are the most significant, and represent 48.36% of the final cost. They are followed by machine work, 29.37%, additional costs with post-harvest activities, 16.31%, and services, 5.96%. Among the most basic materials included in the production cost equation, fertilizers account for 17.73%, agrichemicals 12.52%, packaging 7.55%, seeds 5.28% and electric power or diesel oil, 5.28%.

## Profitability

The average profitability obtained by farmers with irrigated rice in the State of Mato Grosso do Sul was 7,200 kg $ha^{-1}$, that is, 120 60-kg bags $ha^{-1}$.

With this productivity level per hectare, the growers’ gross revenue will be R$4,320.00 while their net revenue will be R$343.97, since production costs represent R$3,976.03.

An analysis of economic indicators shows that the rice production system used in the state is economically viable and has a 1.09 cost/benefit ratio, i.e., growers earned a 9% profit on investments made in their crop (Table 2).

**Table 2.** Economic results from the production system used for irrigated rice in the State of Mato Grosso do Sul, in 2009.

| *Economic Indicator** | *Current situation* | | |
|---|---|---|---|
| | *R$ $ha^{-1}$* | | *US$ $ha^{-1}$* |
| Productivity (kg $ha^{-1}$) | | 7.200 | |
| Total cost | 3.976,03 | | 1.767,12 |
| Total revenue** | 4.320,00 | | 1.920,00 |
| Net revenue | 343,97 | | 152,88 |
| Cost/benefit ratio | | 1,09 | |

* Taking into consideration production factor prices in March 2009, when US$ 1.00 = R$ 2.25 on March 1st, 2009.
** Mean price for a 60-kg bag of rice in the counties of Rio Brilhante, Miranda and Bela Vista, in Mato Grosso do Sul = R$36.00, in March, 2009.

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