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CONSTRAINTS AND OPPORTUNITIES FOR THE SUSTAINABLE DEVELOPMENT OF RICE-BASED PRODUCTION SYSTEMS IN EUROPE

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CONSTRAINTS AND OPPORTUNITIES FOR THE SUSTAINABLE DEVELOPMENT OF RICE-BASED PRODUCTION SYSTEMS IN EUROPE[1]

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I. INTRODUCTION

Rice is not a major food crop in Europe. However, rice consumption has slowly but steadily increased during the period from 1992 to 2001. The total quantity of rice consumed as food in Europe increased from about 4.15 million tons of paddy equivalent in 1992 to about 4.77 million tons in 2001. The quantity of rice consumed in the Russian Federation in 2001 was 0.96 million tons, followed by Spain (0.52 million tons), Italy (0.48 million tons), Germany (0.46 million tons), France (0.44 million tons), and Portugal (0.27 million tons) (FAOSTAT, 2003).

Rice production was introduced into Europe during the 15th Century and despite the low rate of rice consumption of the population and a number of unfavorable economic and social factors production has continued. The production costs in Europe are relatively high; therefore the continent has a very hard time competing with imported rice. Also, there is increasing concern in the population regarding the possible negative effects of rice production on the environment and bio-diversity.

However, the existing rice-based production systems have a number of opportunities for sustainable development. This paper attempts to briefly describe the rice production systems in Europe and discuss the agronomic constraints and opportunities of sustainable development of rice-based systems.

II. THE EVOLUTION OF RICE PRODUCTION

During the period from 1992 to 2002, the rice harvested area in Western Europe increased slightly from 350,000 ha in 1992 to about 420,000 ha in 1996, after which it decreased slightly in 1998 and then remained unchanged at about 400,000 ha until 2002 (Figure 1). Within Europe, the changes in the harvested area were pronounced in Greece and Spain. The rice harvested area in Greece increased rapidly from 1992 to 1997 and then experienced a rapid decline, while in Spain the rice harvested area decreased (from 1992 to 1995), increased in 1996, and then remained unchanged.

The rice harvested area in Eastern Europe declined rapidly from about 330,000 ha in 1992 to about 200,000 ha in 1996 and then remained stable for the rest of the 1992-2002 period (Figure 1)

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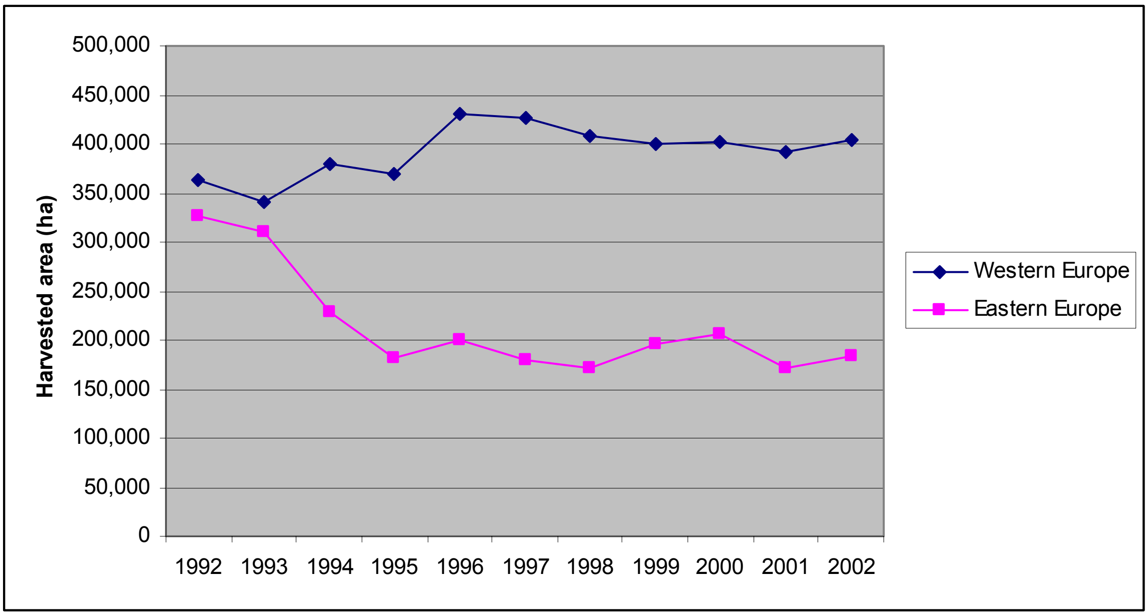

Figure 1: Evolution of rice harvested area in Europe from 1992 to 2002 period (Source of data: FAOSTAT 2003)

Table 1 shows the rice harvested area, yield and production in select countries in Europe in 2002, during which Western Europe (WE) produced 2.60 million and Eastern Europe (EE) produced only 0.59 million tons. However, the three top rice producers were Italy (WE), Spain (WE) and the Russian Federation (EE). Together they contributed about 83% of the total rice production in Europe in 2002.

Table 1: Rice harvested area, yield and production in Europe in 2002 (FAOSTAT, 2003)

	Harvested area (ha)	**Yield (kg/ha)**	**Production (tons)**
		Western Europe	
Italy	223,000	6,148	1,371,000
Spain	112,900	7,225	815,700
France	19,000	5,526	105,000
Greece	22,413	7,451	167,000
Portugal	24,000	6,041	145,000
		Eastern Europe	
Russian Federation	154,000	3,136	483,000
Ukraine	18,300	4,371	80,000
Hungary	2,104	3,327	7,000
Bulgaria	2,791	3,403	9,500
Romania	1,600	937	1,500
Macedonia	1,870	4,738	8,860
Europe	**581,978**	**5,487**	**3,193,560**

The data in Table 1 shows that, in general, rice yields in Western Europe were much higher than that in Eastern Europe. Within Western Europe, rice yield was highest in Greece and Spain. In Eastern Europe, yield was highest in Macedonia, which may be due to a more favorable climate. Data in Figure 2 shows the evolution of rice yields in the 2 regions of Europe during the 1992-2002 period. The rice yield in Western Europe increased steadily from 6 tons/ha at the beginning of the period to about 6.5 tons/ha at the end of the period. In Eastern Europe, rice yield remained stagnant at around 3 tons/ha during the period from 1992 to 1999, finally increasing to about 3.5 tons/ha in 2000.

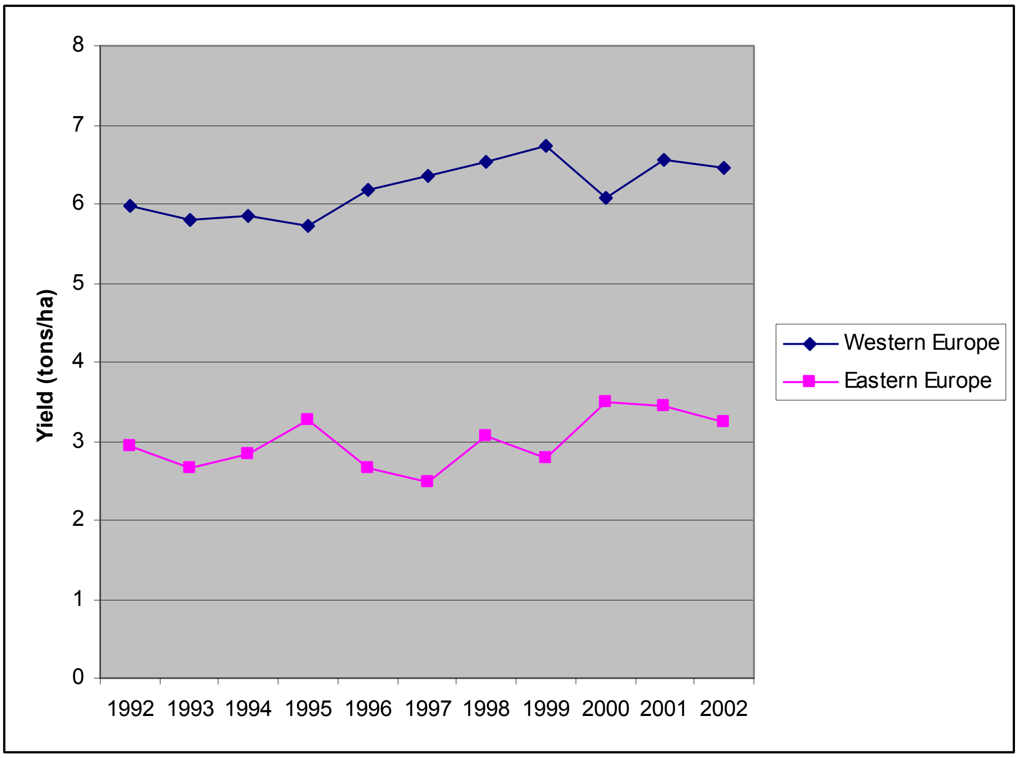

Figure 2: Evolution of rice yield in Europe from 1992 to 2002
(Source of data: FAOSTAT 2003)

III. RICE PRODUCTION SYSTEMS IN EUROPE

According to FAO classification (1996), the primary climate in Western Europe is Sub-tropical with a dry summer (Mediterranean climate), while the primary climate of rice production in most of Eastern Europe is Temperate Continental. In most of Western Europe, the main rainfall occurs during the first stages of growth (April-June) and during the harvesting period. Average temperatures range from 10 to 12°C during rice germination and from 20-25 ° C during crop flowering. Throughout most of Eastern Europe, the rice-growing season is much shorter than that of Western Europe, due to the low temperature regimes. The Mediterranean climate is characterized by warm, dry, clear days, and a long growing season. This climate is favourable for high photosynthetic rates and high rice yields, while its low relative humidity throughout the growing season reduces the development, severity, and importance of rice diseases.

About 80% of the rice area is cultivated with *japonica* varieties. The remainder is cultivated with *indica* varieties (mainly "Thaibonnet" and "Gladio"). Rice is planted from mid-April to the end of May and harvested from mid-September to the end of October. Rice is usually grown on fine-textured, poorly drained soils with impervious hardpans or claypans. These soils are primarily in three textural classes: clay, clay with silt, and loam with clay and silt; each ranging from 8% to 55% clay. A few of the soils are loam in the surface horizon, but are underlain with hardpans. The pH is between 4 and 8, with organic matter between 0.5% and 10% (this last value only on a limited surface area). These soils are well suited for rice production. The low water permeability enhances water-use efficiency. In some regions (the Camargue in France, Ebro delta in Spain, etc.) soils are saline or very saline. Most of the irrigation water for European rice comes from rivers (the Po in Italy, Ebro in Spain, Rhone in France, Tejo in Portugal, etc.) and lakes. It is estimated that less than 5% of rice irrigation water is pumped from wells (areas where surface water is not available or where supplement water is required). The quality of surface water and most groundwater is excellent for rice irrigation.

In all European countries rice is cultivated with permanent flooding. Seedbeds are commonly prepared by ploughing in autumn right after the harvest of the previous rice crop or in springtime in the following year at a depth of 20 cm to incorporate the residues from the previous crop into the soil. The soil is sometimes prepared by adopting minimum tillage practices to favour weed germination in order to control them better. Precision land grading, obtained with laser-directed equipment, is an agronomic practice that has greatly contributed to better water management, and consequently to increase crop stand establishment and improved weed control. Since the beginning of the 1960s, rice has been seeded mechanically.

In general, rice seeds are mechanically broadcasted in flooded fields. However, in about 40,000 ha, mostly in Italy, seeds are drilled to dry soil in rows. In the wet-seeded rice systems, soil is dried for short periods of time after the emergence of rice seedlings to promote rice rooting and to faciliate weed control treatments. However, the rice that was planted in dry soil is generally managed as a dry crop until the it reaches the 3-4 leaf stage. After this period, the rice is flooded continually, as in the conventional system. In these conditions, rice has no competitive growth advantage over weeds, which can compete with the crop from the beginning of stand establishment.

The conventional irrigation system for rice production is known as a "flow-through" system. Water is usually supplied and regulated through a series of floodgates from the top-most to the bottom-most basin. Throughout the rice cultivation period, water is commonly kept at a depth of 4-8 cm, and drained away 2-3 times during the season to improve crop rooting, to reduce algae growth and to allow application of herbicides. Rice fields are commonly drained toward the end of August to allow harvesting.

Fertilisation of the soil is mostly aimed at restoring the main plant nutrients removed by crops. Due to the flood conditions, nitrogen is primarily absorbed in its ammonium form. This nutrient is commonly supplied at 80-120 kg/ha, 50% in pre-planting and 50% in post-planting, using urea or other ammonium-based fertilisers. Phosphorous and potassium are supplied in the pre-planting stage at 50-70 and 100-150 kg/ha, respectively.

IV. THE EUROPEAN RICE MARKET

The European rice market consists of long-grain *indica* rice and round to medium-grain *japonica* rice. Traditionally Europeans consumed mostly *japonica* rice, but the consumption of *indica* rice has increased in recent years. Demand in Northern European countries is almost entirely for *indica* type grains. Consumption of *indica* rice has surpassed *japonica* rice consumption since 1999/2000.

European rice consumption is divided between human consumption (85%), animal feed (7%), industry and seeds (3% each) and loss (5%). Human consumption has increased, while other uses are stable or decreasing (industry) (CEC, 2002). European Union consumption (industrial uses included) of milled rice equivalent reached 1.8 million tons for the 2000/01 marketing year (CEC, 2002). The trend in consumption of milled rice equivalent is up and reached about 5 kg/per capita in 2002.

Rice produced in southern Europe is processed by the local food industry in response to the demand of Mediterranean consumers, and demand for export to northern Europe. In addition to imports from southern Europe, the food processing industry in the north imports *indica* husked rice from the US, Thailand, India and Pakistan. Imports have increased since 1994/95 as a consequence of the Uruguay round, the subsequent reduction of the Basmati rice tariff and the implementation of preferential regimes. The quantity of imports from third countries, expressed in milled equivalent rose by 30% from 1995 to 2000. Over the same period exports fell by 11%. Since then however, total exports have stabilised, and food aid operations have at least partially replaced commercial exports (CEC, 2002). However, according to data collected between 1997/98 and 1999/2000, internal trade quantities were twice of those of external trade. Italy is the main provider (about 300,000 tons of milled rice equivalent), which was followed by Spain (about 150,000 tons of milled rice equivalent).

Market liberalisation for rice will be applied starting from 2009. Tariff reductions will be phased in with a 20% cut in 2006, 50% in 2007 and 80% in 2008. In the meantime a duty-free quota, based on previous exports to the EU, has been established, with an increase by 15% each year until 2009, when all tariffs and quotas will be removed. This liberalisation policy was agreed upon after the introduction of the European Commission agreement of February 2001. The agreement grants duty free access to the EU market for imports from the Least Developed Countries (LDCs) for everything but arms (EBA).

On June 26, 2003 EU Agriculture Ministers agreed on fundamental reforms to Common Agricultural Policy (CAP), a break in the link between subsidy and production and an allowance of preparation for full implementation of EBA from 2009. The primary aspects of CAP reform concerning rice are aimed at reducing the intervention price by 50%, and limiting the amount to 75,000 tons per year. These reductions are compensated by a subsidy devoted in part to environmental protection.

V. RICE PRODUCTION CONSTRAINTS

The most significant constraints to rice production in the Mediterranean climate areas include low temperature, water scarcity, biotic stresses, unsatisfactory grain quality, high production costs and population’s concern on the harmful effect of rice production on the enivronment.

Low Temperature

As rice plants originate from sub-tropical and tropical zones, they are easily damaged by low temperatures at any growth stage from germination to ripening (Ferrero and Tabacchi, 2002). Several experiments point out that a potential yield of 10t/ha requires a density of at least 250 seedlings/m2. The cool weather and strong winds during stand establishment in Mediterranean climate areas may cause partial stand loss and seedling drift, which lead to poor crop establishment. In many temperate areas, emergence rate quite often does not exceed 30-40% of the planted seeds.

Therefore, to achieve an acceptable crop stand, rice growers usually use about 200 kg/ha of seed.

This low rate of crop emergence is due primarily to the effect of anaerobic conditions on germination that occurs under low temperatures. To avoid low temperatures during crop establishment stage, therefore, some growers end up with delays in crop planting. However, a delay in crop establishment leads to the occurrence of reproductive stages of the crop during periods of low temperatures during the autumn that causes the death of pollen cells at meiosis stage and subsequent grain sterility. Damage to rice yield caused by spikelet sterility could be one of the most severe in some years.

Poor crop establishment under European conditions could be overcome by developing new high-yielding varieties with good tolerance to low temperatures during germination, better land levelling and water management.

Water Scarcity

Water is becoming more and more scarce throughout many regions of the world. Between 1700 and 2000, total worldwide water withdrawal increased more than 35-times the rate of population increase. Governments will be compelled to place severe limitations on the use of water resources, particularly in agriculture. Agriculture is by far the biggest consumer of water. Water consumption in agriculture represents about 40% of the total consumption in Europe, 50% in North and Central America and 85% in Asia. In the short-run the conflicting demand for water for industrial activities, sanitation and safe drinking water will most likely increase.

Many water problems are related to its uneven distribution. Other problems include pesticide pollution, soil erosion and deforestation, waterlogging in heavy soils, and increasing irrigation cost. All these constraints are forcing agronomists to develop management strategies to reduce water consumption and increase the efficiency of irrigation systems. As a result, agronomists are continually creating strategies that increase the rice yield per unit of water input. According to the estimates of the World Resources Institute 15% of the water losses due to evaporation, leaching or other inefficiency can be saved through more sensible use. Water problems can also be tackled by providing new rice varieties more suitable to the various conditions of water management.

Rice is more water consuming than many other crops: in continuous flooding cultivation it takes about 6 times the water required by wheat. New varieties suitable to a reduced use of water are needed in irrigated systems. The availability of short-cycle and high-yielding rice could successfully lower the amount of irrigation water used in continuously flooded cultivation. A more consistent reduction of water consumption could be obtained by developing profitable varieties suitable to discontinuous irrigation in all climate conditions. These conditions of water management will also contribute to the alleviation of methane emissions from rice. Non-flooded conditions, however, can lead to increased competition from weeds and increased soil salinity. The constraints on rice yield caused by weed growth and soil salinity must also be addressed as new varieties are developed.

Biotic Stresses

According to Oerke et al. (1994), rice loss caused by disease, pests and weeds, despite current crop protection, account for about 50% of the crop potential. The numerous experiments conducted each year in European rice paddies reveal that the failure to control weeds may potentially result in the complete loss of the rice yield. . The main rice noxious organisms are blast (*Pyricularia oyzae*) and stem rot (*Rhizoctonia oryza-sativae*) among other diseases, rice leafminer

(*Hydrellia griseaola*) and Tadpole shrimp (*Criops longicaudatus*) among the animal pests, and *Echinochloa* spp., *Bolboschoenus maritimus, Schoenoplectus mucronatus, Heteranthera* spp., *Alisma plantago-aquatica* and weedy rice forms, among the weeds. All these species are usually controlled with pesticides. The use of these products may, however, result in the appearance of resistant species, cause environmental pollution and risk disrupting the precarious balance of the natural enemies to pests (Ferrero et al., 2001 and Ferrero et al., 2002).

Weed resistance to herbicides has been reported in Italy, Spain, France and Greece. For example, a few years after the introduction of sulfonilurea herbicides, some species began to develop resistance to acetolactate synthase inhibitors. This phenomenon was first noticed in 1995 in *A. plantago aquatica* and *S. mucronatus* plants, which had been continuously treated for at least 3 years. The studies of Sattin et al (1999) on *S. mucronatus* have shown that there is a cross-resistance among several sulfonylureas (azimsulfuron, bensulfuron-methyl, cynosulfuron, ethoxysulfuron). Some of these resistant populations appeared to be sensitive to triazolopyrimidine herbicide (metosulam) at very high dosages (three times the recommended field dose). In Italy weed resistance has been reported on a rice surface of more than 15,000 ha (Ferrero et al., 2002).

A solution to these issues could be the development of rice cultivars that are resistant to pests and diseases, highly competitive against weeds, with allelopathic traits, tolerant to safe and wide spectrum herbicides ((Ferrero et al., 2001). The use of these varieties combined with prophylactic measures could be a sound strategy to prevent damage.

Grain Quality

The quality of rice is not always easy to define as it depends on a combination of many subjective and objective factors, largely related to the consumer and the intended end use of the grain. The demand by the consumer for better quality has notably increased in the more economically developed countries of Europe, giving rice producers the opportunity to increase the total economic value of rice. Quality traits are also related to the taste of the several ethnic groups that make up European society.

Grain quality is influenced either by characteristics of variety or the crop production environment, harvesting processing and milling techniques. Main key components of rice quality are listed in the table 2. Some of these have also been defined by EC regulations, which have recently come into force. The regulations relate to the common organisation of the rice market (No 1785).

Table 2: Main components of rice quality in Europe

Component of rice quality considered by the EC regulation 1785/2003
- Grain shape
- Colour of the grains (green, chalky, striated, spotted, stained, yellow, amber)
- Grain integrity (malformed and clipped or broken grains)
Other components of rice quality
- Milling quality
- Cooking and processing
- Grain fissuring
- Aroma

Many characteristics of grain quality are related to rice grain shape. Since rice is consumed in the grain form, the physical dimensions and weight are considered among the first criteria of rice quality that breeders consider when developing new varieties. Grain type categories are based upon three physical traits: length, width and weight. Only length and width and their ratio are formally considered according to EC regulations. In the USA however, grain weight is also taken into consideration (Table 3). Long slender grains usually have greater breakage than short grains and consequently result in a lower milling yield.

The demand for long grain varieties increased significantly in the most recent years as a result of food diversification and immigration (Tran, 1996). The European Communities further encouraged this demand through the allocation of subsidies to rice growers who planted indica type rice. Subsidies were originally given to compensate for lower paddy and milling yields. The variety was often recorded in comparison to *japonica* varieties. To meet this demand many long grain varieties have been introduced in European countries. All these varieties are suited to temperate climatic conditions even if they are sometimes damaged by the low night temperatures, which occur particularly during the flowering period (Ferrero et al., 2002).

Table 3: Range of grain size among typical European and US long, medium and short grain rice.

Type		**EC regulation**		**U.S.A. regulation**		
		Length (mm)	Length/Width Ratio	Length (mm)	Width (mm)	Weight/1000 (g)
Long	Long A	>6.0	>2.0 <3.0	7.0 - 7.5	2.0 - 2.1	16 – 20
	Long B	>6.0	≥3.0			
Medium		>5.2	<3.0	5.9 - 6.1	2.5 - 2.8	18 – 22
Short		<5.2	<2.0	5.4 - 5.5	2.8 - 3.0	22 – 24

Grain shape is usually associated with specific cooking characteristics. Cooked long grain rice is fluffy and firm, while medium and short grain rice is soft, moist and sticky in texture. The demand among consumers in Europe is higher for long grain rice.

Grain fissuring is often due to overexposure of mature paddy to fluctuating temperature and moisture conditions. Cracks in the kernel are the most common cause of rice breakage during milling. Milling degree is influenced by grain hardness, size and shape, depth of surface ridges, bran thickness and mill efficiency. Whole grain milling yield is the percentage of intact kernels to broken kernels after milling and separation. Producers are paid less for broken kernels than for whole.

Other specific quality traits are usually required for the production of processed rice such as parboiled, quick cooking or pre-cooked rice and rice flour. Rice parboiled for consumption as table rice, is generally a long grain variety. Medium grain rice is also parboiled, but it is more commonly ground into flour for use as an ingredient in food products (baked crackers, fried snacks).

Aroma is an important qualitative trait in specific varieties (Basmati-type). Rice of this type is generally long grain with a high grain quality. It has an aroma often described as being popcorn like. The grains become very long and thin and maintain a moderately firm texture after cooking. Demand for aromatic rice varieties has shown a significant increase since the early 1990s, primarily in UK and other European countries, but also with a significant presence in Asiatic communities, (Faure and Mazaud, 1996). It seems reasonable to expect a further increase in aromatic rice consumption in the years to come, throughout Europe, because of the increase in people migrating from far-east countries and the growing interest in ethnic cuisine. European consumption of Basmati rice is met entirely by imports from India and Pakistan. For this reason, specific research programmes need to be set up in order to develop aromatic varieties suited to European climatic conditions.

The European consumers are showing a growing interest in special rice varieties such as organic rice, waxy rice, Jasmine-type rice, wild rice, and coloured (red, black) pericap. At present, the demand for these products only accounts for a small share of the market, with the exception of organic rice. Organic rice has already found a place in market demand, and is demand is expected to increase at least in the short to medium-term. The yield obtained in organic rice systems is usually 25-30% lower than that obtained in ordinary cultivation, mainly because of the great difficulty in controlling weed infestations.

Lodging resistance has been a key target trait to raise yield potential. It is associated with traits such as plant height, stem strength, thickness, etc. Lodging-resistant rice cultivars usually show slow grain filling when nitrogen is applied in large amounts. Many other problems such as variable milling-yield, grain fissuring, grain-shedding and non-contemporaneous maturity are sometimes closely linked to the genetic features of the rice varieties, and are also related to other agronomic constraints, such as cold temperature and lodging.

High Production Cost

The cost of rice production in Western Europe is generally much higher than the production cost in most Asian countries, with the exception of Japan. The production cost/ton of paddy rice in Europe is also higher than those in the USA. The high production cost in Europe compared with the USA was largely due to the high expenses relating to operations including: fertilizer, seed, crop protection products, custom application, fuel and labor. The cost of production in the USA can range from 104 to 180 $US /ton (Salassi, 2002) while in Italy the cost is about 200 €/ton (AIDAF-VC/BI, 2003).

Population's Concern

The growth of mosquitos and concern for the spread of malaria was a major reason causing the restriction in rice production in the past. Recently, concern related to negative effect of rice production on the environment especially the emission of methane gases which cause global warming and the harmful effect of pesticide application on the agricultural bio-diversity in rice-based production systems has been increasing. This new concern may lead to further restriction in rice production in the continent. Integrated management systems for efficiency in input utilization, including the use of water, need to be promoted in rice production in the continent. Also, the promotion of agricultural biodiversity in rice-based production systems such as rice-livestock, rice-other crops are desirable.

VI. OPPORTUNITIES FOR SUSTAINABLE RICE PRODUCTION

One of the most effective means of addressing the issues in rice cultivation and raising the average yields at the farm level is through research and subsequent dissemination of the resulting data. Numerous research programmes at a national or European level have been set up throughout Europe. They cover the whole rice sector from agronomic practices and breeding aspects to quality and market problems. Much of the research done in Europe has been fostered by the Mediterranean research network (Medrice).

Advances in rice research

Rice science has made some considerable progress. In the area of rice varietal improvement, recent advances in hybrid rice and the new rice for Africa (NERICA) are just two examples of the successful contributions of science to the development of rice. Scientists at IRRI have continued working to increase the genetic yield potential of tropical rice through the concept of "New Plant Types" (NPT) with the stated goal of increasing the yield potential to 12-15 tonnes/ha (Fisher, 1996; Peng, *et al.*, 1994). The recent success in rice genome mapping has further increased the potential for the application of science. The increase in the yield potential of rice, the tolerance/resistance of rice to disease, weed and pest resistance, as well as tolerance to drought and salinity could be achieved without harming the environment (Khush and Brar, 2002). However, these opportunities have also created new imperatives for biosafety, field testing, and capacity building within nations to ensure that the new innovations benefit local people and do not incur long-term costs to the environment.

Most existing rice varieties have a potential yield that exceeds actual yield. Furthermore, there is considerable variation in the actual yield levels achieved even under similar production systems. The gap reflects numerous deficiencies due primarily to inadequate crop, nutrient and water management practices. During the 1990s, several systems were developed to allow a higher level of integrated crop management practices in rice production. The application of these rice integrated crop management (RICM) systems has increased rice yield and reduced cost and environmental degradation through more efficient application of inputs. From 1973 to 1985, rice yield in Australia remained stagnant at around 6/ha. The Rice Integrated Crop Management (RICM) system "RiceChecks" was developed and transferred in 1986 (Clampett et al., 2001). With the wide adoption of RiceChecks, the Australian national yield increased rapidly and steadily from about 6 t/ha in 1987 to 9.65 t/ha in 2000 (Fig. 5). Australian rice scientists considered that half of the observed yield increase since 1986 can be attributed to the adoption of new rice varieties and another half to the adoption of RICECHECK (Nguyen, 2002). The development and dissemination of RICM systems in Europe could help to lower production costs/ton of paddy and to minimize environmental degradation.

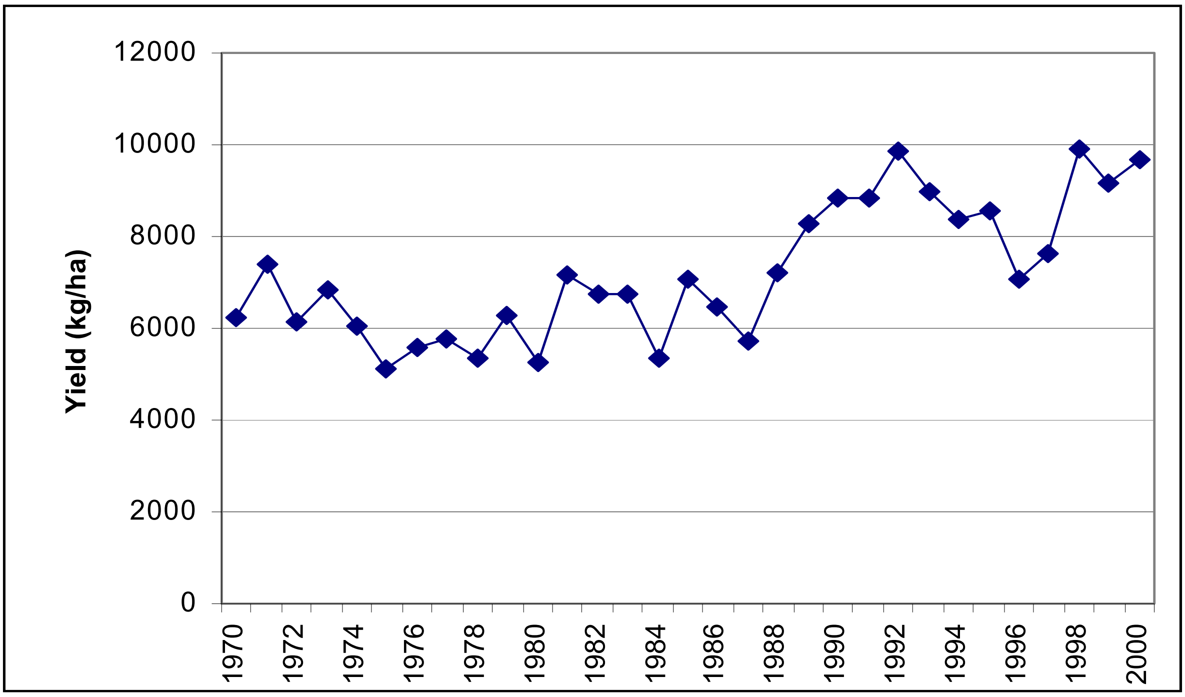

Figure 3: Australian rice yield, 1970 to 2000 (Source: FAOSTAT, 2001)

Medrice network

Rice cultivation in Mediterranean climate areas has had to face strong competition in the world market. In the local market demand for speciality and quality rice has become more and more common. To tackle these challenges institutions from Europe and the Middle East have improved scientific co-operation while trying to capitalize on the wide range of experience and potential in each country.

Relationships among rice scientists from many of the countries with a Mediterranean climate are strengthened through scientific gatherings sponsored by the FAO Inter-regional Cooperative Research Network on Rice in the Mediterranean Climate Areas. The Network, which is named Medrice, began as a response to the need for collaboration and coordination in research on rice in view of its increasing cultivation and consumption in Europe. Some of the issues dealt with include:

- The quality and competition of European rice
- Resistance to blast, water shortage, stem borers and disease
- Control of red rice
- Cataloging of rice genetic resources in the region
- A databank of knowledge on all aspects of rice cultivation for the purpose of improved management and rice yields

These issues are all being addressed through cooperative research programs between member institutions of the Network. Sixteen countries participate in Medrice: Bulgaria, Egypt, France, Greece, Hungary, Iran, Italy, Morocco, Portugal, Romania, Russia, Spain, Turkey, the United Kingdom, Ukraine and Uzbekistan. Activities of Med-Rice include scientific meetings, cooperative research programs, and publications ranging from reports and proceedings to a newsletter (Medoryzae). The web site for the Network can be found at (http://medrice.agraria.unito.it)

VII. CONCLUSIONS

Rice is not among the major food crops of Europe. However, rice consumption as food on the continent has slowly but steadily continued to increase. Rice production in Europe has remained from the time of its introduction despite the low rate of rice consumption and a number of unfavorable economic and social conditions. The cost of rice production in Europe remains relatively high making competition with imported rice difficult. In addition, concern over the negative effects of rice production on the environment and bio-diversity has continued to increase. However, the rice-based production systems in Europe have a number of opportunities for sustainable development.

A sustainable increase in rice production in Europe and North Africa requires strategies that must focus on the following:

- The collaboration among rice research institutions towards the adoption of modern plant breeding technology to develop new generations of high yielding varieties with better grain quality and with better resistance/tolerance to biotic and abiotic stresses.
- The promotion of development and rice integrated crop management (RICM) systems for improving productivity and reducing the production cost per unit of output.
- The promotion and adoption of production technologies and systems that aid the conservation of bio-diversity and the environment.

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