MAJOR CONSTRAINTS ON RICE DOUBLE CROPPING IN TROPICAL AFRICA

DAT Van Tran*

ABSTRACT

In Africa, rice double cropping is commonly practiced where irrigation and drainage facilities are available. However, the yield performance of both rice crops, especially the second one is usually lower than the potential due to a large number of constraints. Above all, extreme temperatures, unreliable rainfall, low soil fertility and pest infestation as well as short interval between the two rice crops, poor farm management and low economic incentives have been reported. For the development of techniques to increase the productivity of rice double cropping the complexity and diversity of the continent's agro-ecosystems, farming conditions and socio-economic structures must be taken into account.

Introduction

In Africa, although rice production amounted to 8.6 million tons or 1.8% of the global rice production on 5 million ha or 3.4% of the world rice area in 1984 (Table 1) the importance of rice has increased rapidly in the last decade. Rice has become an essential component of the agricultural economy in many African countries. Indeed Africa has become one of the major net importing regions in the world. Its rice imports rose fourfold during the period from 1974 to 1984 while its rice production increased by 8% only (Table 2) since Africa's rice is grown predominantly under rainfed conditions and the consumer demand for rice has steadily increased due to the shift from conventional foods to rice. The emergence of the rice shortage has given a considerable impetus to many African governments to develop irrigation facilities for the cultivation of rice in their countries in order to increase rice production by the implementation of rice double or triple cropping and stabilize food production to check the drain on the scarce foreign exchange reserves. However, their efforts to expand irrigated areas for agricultural production in general and for rice-growing in particular have not been successful as irrigated rice farming is still new to many farmers and double cropping of rice has been associated with a large number of technical, socio-economic and management problems for the farmers who have had few opportunities to become exposed to agricultural innovations.

Irrigation and rice double cropping in Africa

In Africa, rice is cultivated under different ecological conditions including upland areas (40%), areas with hydromorphic soils, boliland, deep water areas, swamp lands and irrigated areas. The scope and potential for increasing rice production in the region are vast but limited by the lack of capital for development, skilled manpower, and effective implementation of programs. The use of swamp lands including flood flat plains would offer Africans long term and secure food production in the regions where the weather is uncertain as these lands can be put progressively under full water control. Irrigation, in fact, would facilitate the farmers' rapid adaptation to new technology and promote crop intensification, which would also allow for double or triple cropping. Due to the difficulties in large scale irrigation management, many African governments have been aware of the need for small scale irrigation development by

* Rice Agronomist, Food and Agriculture Organization of the United Nations, Rome, Italy.

Table 1　Rice area, production and yield in the African countries (1984)

Country	Area (ha) Irrigated[2]	%	Total[1]	Production[1] (tons)	Yield[1] (kg/ha)
Algeria	600	100	600	2,000	3333
Angola	–	–	20,000	22,000	1100
Benin	2,400	40	6,000	8,000	1204
Burkina Faso	6,000	20	30,000	40,000	1333
Burundi	2,000	100	2,000	9,000	4476
Cameroon	5,300	23	23,000	40,000	1739
Cent. Afr. Rep.	–	–	15,000	13,000	880
Chad	3,300	6	51,000	29,000	569
Comoros	–	–	13,000	15,000	1169
Congo	–	–	4,000	2,000	500
Egypt	420,000	100	420,000	2,230,000	5310
Gabon	–	–	550	1,000	1800
Gambia	2,700	14	20,000	22,000	1100
Ghana	2,000	4	57,000	66,000	1157
Guinea	9,100	2	400,000	400,000	1000
Guinea Bissau	4,200	3	145,000	105,000	724
Côte d'Ivoire	30,000	8	400,000	490,000	1225
Kenya	8,000	89	9,000	31,000	3489
Liberia	4,000	2	210,000	230,000	1095
Madagascar	460,000	38	1,200,000	2,132,000	1777
Malawi	2,675	6	42,000	33,000	786
Mali	38,100	29	130,000	125,000	962
Mauritania	2,700	54	5,000	14,000	2800
Mauritius	–	–	–	–	–
Morocco	2,000	100	2,000	10,000	5000
Mozambique	16,000	23	70,000	55,000	786
Niger	4,700	20	23,000	51,000	2217
Nigeria	265,000	44	600,000	1,100,000	1833
Rwanda	3,000	100	3,000	6,000	2000
Senegal	10,900	17	66,000	136,000	2055
Sierra Leone	100,000	25	400,000	450,000	1125
Somalia	1,000	100	1,000	3,000	3000
South Africa	1,000	100	1,000	3,000	3000
Sudan	4,000	100	4,000	7,000	1750
Swaziland	–	–	–	3,000	–
Tanzania	75,600	28	270,000	400,000	1481
Togo	1,500	12	13,000	10,000	790
Uganda	–	–	20,000	25,000	1250
Zaire	7,000	2	325,000	260,000	800
Zambia	–	–	8,000	5,000	585
Zimbabwe	–	–	1,000	500	500
Africa	1,494,775	30	5,008,000	8,582,000	1713

Source:　1)　FAO, 1984.
　　　　2)　Estimated.

Table 2 Rice production, gross exports and gross imports in the world

Country or region	Production		Gross exports		Gross imports	
	Average 1974–76	1984	Average 1974–76	1984	Average 1974–76	1984
	Million tons (paddy)		Million tons (milled)			
Africa	5.4	5.6	–	–	0.7	2.8
Far East	169.2	227.7	2.7	7.6	3.2	3.3
Latin America	13.9	17.0	0.4	0.7	0.5	0.7
Near East	4.6	4.8	0.2	0.1	0.8	2.1
90 developing countries	193.0	255.2	3.5	8.4	5.3	8.8
China	128.4	178.0	2.0	1.0	0.1	0.1
Developed countries	25.7	25.6	2.5	2.8	1.3	1.9
World	347.1	458.8	7.8	12.3	6.7	10.9

Source: ABERCROMBIE *et al.*, 1985.

Table 3 Contribution of irrigation to rice production in Africa

Region	Rice (paddy)		
	Total production (1000t)	Irrigation production (1000t)	% of total
Mediterranean and North Africa	2,406	2,406	100
Sudano-Sahelian Africa (1)	425	276	65
Humid and sub-humid West Africa (2)	2,749	263	10
Humid Central Africa (3)	320	35	11
Sub-humid and mountainous East Africa (4)	2,127	1,787	84
Sub-humid and semi-arid southern Africa	538	159	30
Total	8,565	4,926	58

(1) Excluding Cape Verde and Chad
(2) Excluding Guinea-Bissau
(3) Excluding Equatorial Guinea, Sao Tome and Principe
(4) Excluding Comoros and Seychelles
(5) Excluding Namibia

Source: FAO, 1986.

introducing simple irrigation and/or drainage methods to small farmers. Although this practice would decrease the investment, it entails structural changes in the traditional socio-economic organization for production, marketing and consumption.

At present, in Africa about 6.0 million ha of land are equipped with modern irrigation facilities and about 3.0 million ha depend on small scale, traditional flood, swamp surface and low lift forms of irrigation. This represents only 5% of the total cultivated area. Out of 9 million ha of irrigated lands, 6.23 million ha or about 70% are located in 4 countries, namely, Egypt, Sudan, Madagascar and Nigeria (FAO, 1986). In addition, at least 30 million ha of wetlands can be brought under either irrigation or simple water control for the production of rice and other food crops. The total irrigated rice area and production for Africa are not accurately known due to the lack of recent and reliable statistics. However, the irrigated rice areas are estimated at about 1.5 million ha, accounting for only 30% of the total rice area in Africa, while irrigated rice contributes 58% of the total rice production (Table 3). This explains the fact that rice production in this region has increased very slowly. With regard to the extent of rice double cropping, no accurate information is available for acreage and production. However, it is considered that a great part of the irrigated areas reserved for rice cultivation is grown with at least two rice crops a year and the rest is used for one crop of rice with other crops such as maize, tomatoes, food legumes, etc.

Limiting factors to the promotion of rice double cropping

The traditional system of rice cultivation in Africa is upland farming with bush-fallow methods, in which few or no inputs are being utilized. The grain yields vary from 0.5 to 1.5 t/ha depending upon the weather conditions. It is believed that as the population increases the farming practices are likely to become more intensive than they are at present. The pressure on the upland has caused soil erosion and decline in soil fertility due to over-cultivation, making it a necessity to turn to wetland cultivation. Rice farming in lowlands, especially in those with irrigation, is relatively new to many African farmers and many constraints are encountered in irrigation development schemes, in which rice double cropping is principally practiced.

Physical constraints

1 Temperature

The first limiting factor to the promotion of rice double cropping is the low temperature affecting rice plants from seeding until physiological maturity in the semi-arid and high altitude areas. The cool season occurs from late November to early March in the northern region of the equator (Fig. 1), from April to September in the southern region and from July-August and December-January in the equatorial high altitude region.

The low temperatures varying from 10 to 20°C can prolong the vegetative stage from 2 to 4 weeks or more and cause a high percentage of grain sterility depending upon the planting dates. If rice is grown early in the cool season the rice seedlings will spend two months in nurseries before they are ready for transplanting and if rice crops are planted late in the rainy season the flowering will coincide with the period of low temperature causing a high percentage of sterility. Hence the yield of the cool season crop (second crop) is usually lower than that of the humid season crop. (Tables 4, 5). There are no appreciable differences in solar radiation between both seasons in the semi-arid regions. The low yield of the cool season crop is not only due to low temperatures but also to long crop exposure to weeds and pests. The most effective methods to overcome the effects of low temperatures at the seedling and heading stages are to strictly respect the optimum seeding dates and use early-maturing varieties which would enable rice crops to escape the serious effects of low temperature periods. Another agronomic method,

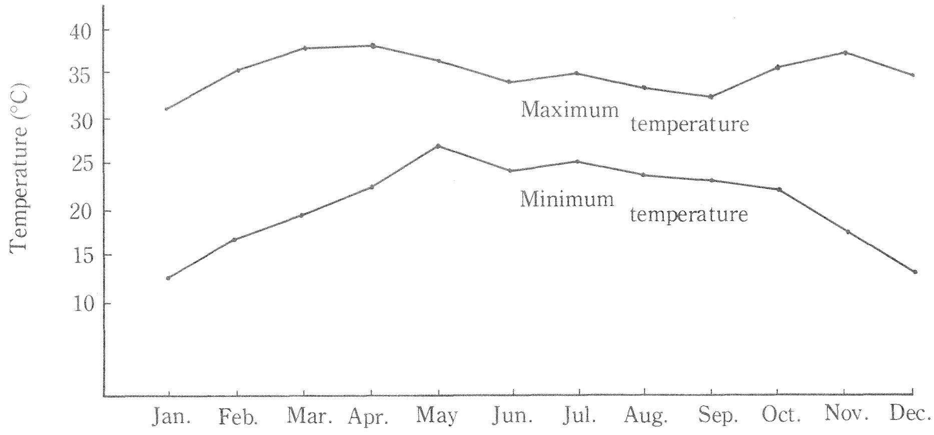

Fig. 1 Temperature variation in the Kou Valley, Burkina Faso (1983).

Source: TRAN, 1984.

Table 4 Yield and agronomic characteristics of IR 1529-680-3 for different planting dates in the Kou Valley, Burkina Faso (cool season 1982/83)

Planting date	Heading date	Days to heading (days)	Days to maturity (days)	Plant height (cm)	Panicles per m^2 (No)	Reproductive tillers (%)	Yield (kg/ha)
T_1 (27/12/82)	20/5	144	171	80	186	68	1,600
T_2 (3/1/83)	23/5	140	168	81	233	74	1,816
T_3 (10/1/83)	25/5	134	162	81	247	81	1,616
T_4 (17/1/83)	27/5	129	160	78	197	80	1,936
T_5 (24/1/83)	25/5	121	150	80	190	64	1,976
T_6 (31/1/83)	9/6	129	158	80	209	86	2,240
L.S.D.	5%					NS	616
	1%					NS	-

Source: TRAN, 1984.

is the use of straw or plastic-covered seedbed or modified dapog seedbed (with a thin soil layer on the bed) for raising the seedlings, which could reduce the nursery period from 6-8 weeks to 2-3 weeks and also enable to delay the transplanting dates until the temperature rises.

A layer of ash, straw, compost or manure can be used to cover the surface of the nursery to maintain heat in the soil. Similar effects can be achieved by keeping a static water level in seed beds during the day and water flowing in the night, if possible. Fertilization is also recommended for seed beds to stimulate the plant growth and permit seedlings to recover fast after transplanting.

Cold-tolerant varieties with early maturity must be introduced to farmers in high altitude regions as well as in semi-arid areas.

Not only low temperatures but higher temperatures also can affect rice production. Temperatures of more than 40°C combined with dry, hot wind (Harmattan season) occurring

Table 5 Yield, yield components and agronomic characteristics of IR 1529-680-3 for different planting dates in Kou Valley, Burkina Faso (humid season 1983)

Planting date	Agronomic characteristics: Days to heading (days)	Days to maturity (days)	Heading to maturity (days)	Yield components: Panicles per m² No.	Grains /pan. No.	Sterility percentage %	Grain weight G	Yield kg/ha
T_1 (4-7-83)	100	134	34	233	75,3	17,34	2,57	3,675
T_2 (15-7-83)	101	138	37	229	80,0	15,51	2,58	2,910
T_3 (25-7-83)	101	141	40	243	91,0	13,05	2,48	3,266
T_4 (4-8-83)	95	141	46	266	83,9	23,37	2,48	4,090
T_5 (15-8-83)	98	143	45	257	80,2	27,96	2,52	3,609
T_6 (25-8-83)	102	148	46	264	87,0	34,98	2,47	2,305
L.S.D. 5%				NS	NS	6,02	0,07	1,323
1%				NS	NS	8,33	0,09	1,830

Source: TRAN, 1984.

Table 6 Water requirement for rice in humid and cool-dry seasons in Kaedi and Guédé, Mauritania

A - Evapotranspiration per month in the humid season (mm)

	Kaédi				Guédé	
	Direct seeding		Transplanting		Direct seeding	
Year	1972	1973	1972	1973	1972	1973
June	-	136	-	-	353	189
July	285	453	129	227	481	238
August	364	355	384	377	376	358
September	365	148	401	414	96	128
October	205	-	314	-	-	-
Total	1,319	1,092	1,228	1,018	1,306	913

B - Evapotranspiration per month in the cool, dry season (mm)

	Kaédi				Guédé	
	Direct seeding		Transplanting		Direct seeding	
Year	1971/72	1972/73	1971/72	1972/73	1971/72	1972/73
November	175	-	115	-	155	200
December	199	363	196	-	236	123
January	272	240	232	238	186	253
February	302	342	280	303	315	388
March	419	437	414	417	375	397
April	312	475	346	415	401	360
May	-	-	46	239	228	-
Total	1,679	1,757	1,635	1,612	1,896	1,721

Source: FAO, 1976.

during May-June may burn rice leaf tips, and cause high evaporative demands of atmosphere (about 5 mm/day). In addition, high temperatures also cause hard-working conditions for man and oxen. Thus, in the cold and dry season, water requirement for rice cultivation is about 30-80% higher than that in the humid season (Table 6).

2 Rainfall

In Africa, the climate varies greatly from Sahelian to tropical regions. Erratic precipitation frequently occurs in East Africa and the semi-arid areas while abundant rainfall is found in

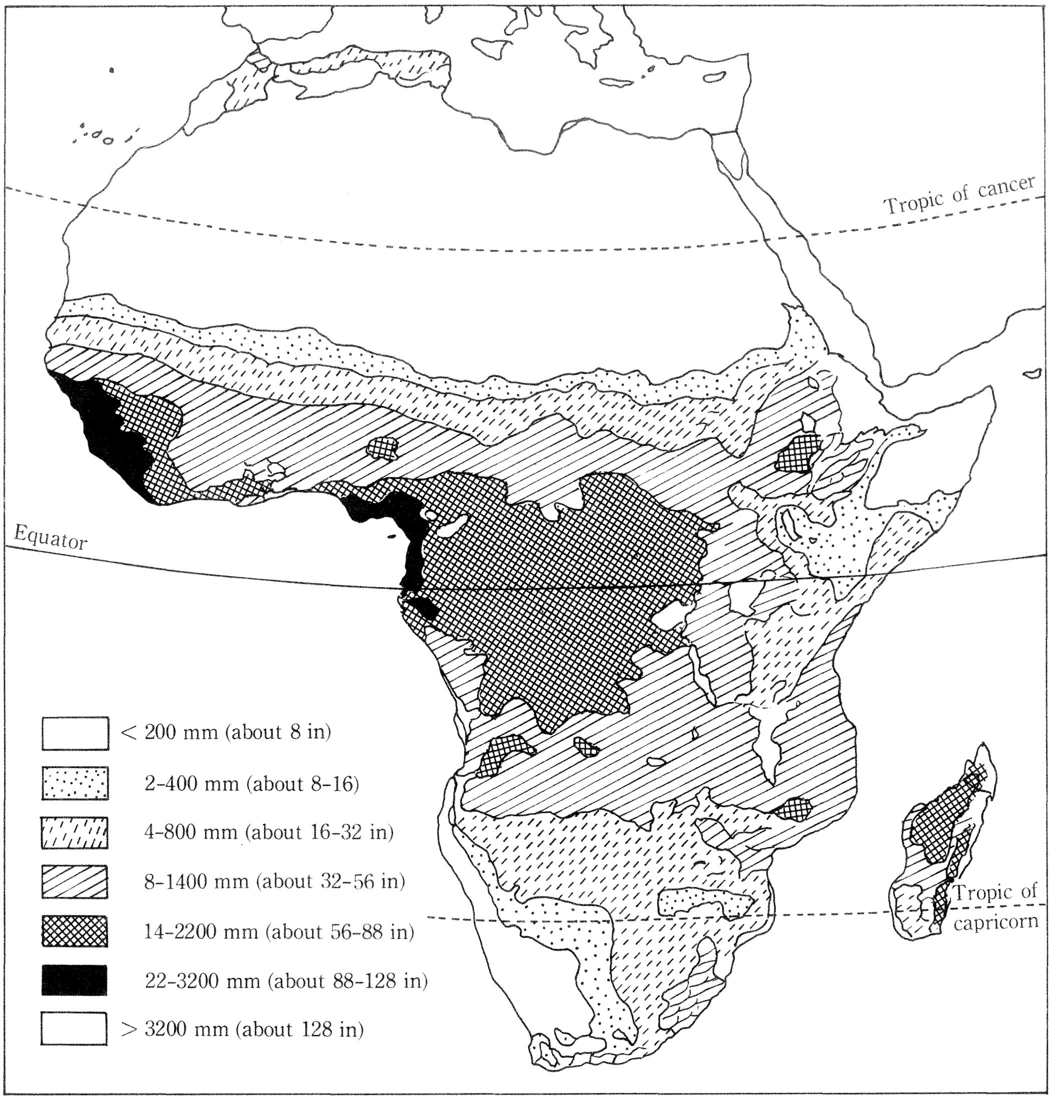

Fig. 2 Mean annual precipitation.
Source: After A.T. GROVE, 1978, IITA, 1982.

Central and West Africa (Fig. 2). In addition, different modes of rainfall distribution are also present: unimodal rainfall in the northern part of West Africa which is characterized by the irregularity in the onset and termination of rains, and bimodal rainfall in the southern part of West Africa with reduced precipitation in the middle (July–August) of the rainy season starting from March–April to October (LAWSON, 1979).

The drought which may occur at any time during the growing season becomes a menace to African farmers. It is a limiting factor to rice production in East Africa and the semi-arid regions including Burkina Faso, Niger, Mauritania, Mali, Mozambique, etc., even under irrigation conditions. The drought usually affects the second rice crop due to the shortage of irrigation water by increasing the irrigation period, thus exposing rice fields to weed invasion and nutrient losses. Moreover, late rains at the time of maturity are also another constraint for harvesting rice with combines. This applies to the irrigation schemes in Chokwe, Mozambique. Thus small hand tractor harvesters must be used as well as manual handling of the harvested rice for threshing must be applied (MACAPUGAY, 1985). However, this tends to reduce the interval between the two crops.

3 Soil-related problems

Rice is generally grown on all soil orders. According to MOORMANN and VOLDKAMP (1978) usually upland rice is grown on freely-drained Alfisols and Ultisols in West Africa while lowland rice and hydromorphic rice are mainly grown on wet suborders of Entisols and Inceptisols and Vertisols and Aridisols in the second place (in drier Sahel areas). In the Sudan and Sahel regions, soils of lowlands are suitable for irrigated rice as they have a finer texture, are less leached and have a higher cation retention capacity. However, in the humid and sub-humid areas, soils in valleys or coastal plains are highly weathered, highly leached, more acid and frequently sandy (for example in Sierra Leone). Thus the second crop suffers from moisture stress if the precipitation is lower in the main season.

On heavy soils (Vertisols), i.e. some valleys in the Senegal delta river, Rwanda rice can grow well, but land preparation with manual labor or animal draught is difficult when soils are dry. Better equipment and higher tractor power (60–80 C W) can be used more efficiently on such hard soils (FINASSI, 1984). Under certain circumstances land preparation for the second crop becomes more difficult due to the excessive moisture left from the first crops.

Moreover, sea water intrusion and groundwater salinity or alkalinity and a lack of fresh water have impeded double cropping practices in the coastal plains. Poor drainage and land levelling also lead to iron toxicity. Under intensive farming, symptoms of nitrogen, phosphorus and zinc deficiencies have been reported. The localized problem of organic acid associated with the short interval and low temperature was observed in Rwanda (TRAN *et al.,* 1983). It is necessary to study the evolution of nutrient reserves in soils in order to adjust the fertilizer use.

The improvement in water and soil management and the supply of organic matter, lime along with the use of suitable varieties and better cultural practices would alleviate the above soil problems.

Biological constraints

1 Rice varieties

Most of the varieties grown under irrigation conditions were introduced successfully from Asia into Africa. This proves that the technology transfer from Asia to Africa has not encountered major problems in irrigated rice. The modern varieties, such as IR 8, IR 20, IR 1529-680-3 were found in Burkina Faso, I Kong Pao, Jaya, Kwang She Shen in Senegal, IR 1561 in Mauritania, BG 90-2 in Ivory Coast, Ghana, etc., IR 46 in Cameroon, Yunan 3 in Burundi, Kengdiao 3, IR 5 in Rwanda, IR 1561-288-3, BG 90-2 in Kenya, Chianan 8 in Madagascar, etc.

Many of these varieties have a medium growth duration, ranging from 130 to 150 days if planted in humid and warm seasons and from 150 to 180 days if grown in dry and cold seasons (Tables 4, 5). This causes problems for rice double cropping in terms of the interval between the two crops. The use of early-maturing varieties with tolerance to low temperature and resistance to some major pests and appropriate planting dates would facilitate double cropping of rice and maximize rice production.

2 Insect pests

The pest pressure on rice production in Africa has not reached epidemic levels yet particularly in dry areas as intensive cultivation of rice crops has not been practiced over large areas as seen in Asia or elsewhere, except for Madagascar. In addition, the low level of pest control i.e. small amounts or absence of insecticides used by the farmers results in the preservation of the biological equilibrium in rice fields. Nevertheless, localized pest incidence has been found to be more common in the areas with rice double cropping than in those with traditional single cropping (Table 7).

Table 7 The relative occurrence of insect pests in different ecosystems

Insect	Upland	Lowland	Irrigated
Maliarpha separatella	++	+++	+++
Chilo spp.	++	++	++
Sesamia spp.	++	+	+
Diopsis spp.	+	++	+++
Orseolia oryzivora	–	++	++
Nymphula stagnalis	–	+	++
Grain suckers	++	+	++
Termite	++	+	–
Epilachna similis	++	+	+
Army worm	++	+	+
Aphid	+	–	–
Mole cricket	++	+	+
Whorl maggot	–	++	++
White fly	–	+	+
Black beetle	+	+	–
Leaf folder	+	+	+
Hispa	+	++	+

+++ = widely abundant, ++ = abundant, + = present but not abundant, – = not present

Source: ALAM, *et al.*, 1985.

Major indigenous species of insects which have been reported on rice in Africa are as follows: stem borers (*Maliarpha separatella, Chilo zacconius, Sesamia* spp.) stalk-eyed fly (*Diopsis thoracica, D. acrophthalma*), army worm (*Spodoptera* spp.), gall midge (*Orseolia oryzivora*). The most practical and inexpensive method of insect control for rice in Africa is the cultivation of resistant varieties. Also the integrated pest management approach is recommended.

3 Diseases

Disease problems vary from region to region since rice is grown under diverse conditions, including Sahelian, humid tropical to high altitude areas. A common and widespread disease is neck and leaf blast (*Pyricularia oryzae*) throughout Africa, however, the blast infestation is less important in the Sahelian and semiarid areas than in the humid tropics and in upland and drought-prone areas. Brown spot (*Helminthosporium oryzae*) is also common in many areas with poor soil management.

Sheath rot (*Sarocladium oryzae*) is becoming important in the lowlands and in irrigated rice subject to low temperature during flowering. The infection sets in shortly after heading and glume discoloration appears about one week after heading. The intensity and severity of infection increases with the progress towards maturity. When drought conditions prevail glume discoloration can be observed in the intermittently irrigated areas. The disease caused by *Pseudomonas fuscovaginalis* which is easily confused with sheath rot is a seed-borne disease. It has been reported first in Burundi and Rwanda. The severity increases with the altitude and seems to be pronounced on the very peaty swamps.

Leaf scald (*Rhyncosporium oryzae*) is also found in irrigated rice, but the infection is less serious.

Bacterial leaf blight has been reported in Cameroon, Madagascar, Niger (KAUNG ZAN *et al.*, 1984), Mali and Burkina Faso. At this time since the disease has been observed only at the late stage of grain filling it has not caused serious damage to rice production in Africa yet. Rice yellow mottle virus disease is an African disease which is easily transmitted by mechanical means and is becoming important in Africa. It has been reported in many countries including Burkina Faso, Niger, Nigeria.

Although numerous resistant varieties have been introduced from IRRI and elsewhere and developed by IITA, no variety is resistant to a wide range of major diseases. Fortunately, disease pressure on irrigated rice crops in the region is still localized.

4 Weeds

The most common weeds in the irrigation areas are grasses (*Echinochloa colona, Eleusine indica*) followed by broad-leaved weeds (*Ipomoea aquatica, Convolvulus, Stylanthes* spp., *Commelina* spp.) and sedges (*Cyperus* spp.). Yield reduction associated with weed infestation is estimated to range from 35 to 70% for lowland rice. Hand weeding is the most common practice to control weeds. However farmers usually remove weeds from their rice fields later than recommended. Herbicides are scarce and expensive and farmers rarely use them for the control of weeds. Hand rotary weeders introduced by the Chinese Missions in the 1960s and 1970s are available in many irrigation schemes but not widely used yet by farmers.

5 Wild rice

The infection of wild rice such as *Oryza longistaminata, O. breviligulata, O. fatua* has been reported in the irrigation schemes where direct seeding has been practiced and weed management ineffective. In the M'Pourié (Mauritania) irrigation area, wild rice mainly *O. breviligulata* accounts for 10 to 30% of some rice fields (FINASSI, 1984). Pure seed rice, row seeding, rogueing, good land preparation, crop rotation and proper herbicide application are effective methods to control wild rice in direct-seeded fields. Furthermore, transplanting method can avoid this problem easily.

6 Birds and rodents

The second rice crop (or off-season rice crop, which is grown with water supplied from irrigation during the dry season can suffer from attacks by birds (*Quelea quelea*) and rats since these crops are the only ones which are present in the field and they become food grain sources for hungry birds and rats. Bird boys and bird-scaring devices afford the best methods of bird control. No breakthrough has been made in this field so far. Baits and traps are used by farmers to eradicate rats.

Hope for ratooning crops in the irrigation area of Banzon, Burkina Faso disappeared because birds caused enormous damage to the ratooning crop which could yield 3–4 t/ha additionally for only 2 months (variety SC 27).

Management

There is a tendency for rice yields to decrease in the irrigation schemes after they are brought under production. This is the case for almost all the irrigated rice areas developed by the Chinese Missions in the 1960s and 1970s in Africa. Apparently the actual yields are the expression of interaction between genotypes and poor management in these schemes.

1 Interval between the crops

Farm management is a critical element in determining the yield of the second rice crop. The use of medium-late-maturing varieties, labor shortage for land preparation, harvesting and post-harvest operations and low temperature reduce the interval between the first and second rice crops. As a result the restoration of soil fertility and insect cycle's interruption after the first rice crop cannot be achieved. In Rwanda, a high altitude country, the growth duration of Keng Diao 3, a popular high-yielding variety is 150 days in normal seasons and 180 days in cool seasons leaving less than a month for the preparation of the next crop. In Burkina Faso, a Sahelian country, farmers grow IR 1529-680-3 mostly in irrigated areas. The growth duration of this variety is 140 days in the rainy season and 165 days in the dry cool season leaving an interval of two months or less between the two rice crops. Frequently the interval between the first crop and the second crop is about one month which affects the conditions of some important operations such as land preparation, seedbed preparation and planting dates which partly determine the crop's success in the future.

The reduced interval promotes farmers to practice minimum and low tillage and delay planting dates, and it also provides insects with a favorable environment for their survival resulting in yield losses. Thus, the minimum interval which would be allowed for the second rice crop under various ecological conditions (Sahel, Sudan, Guinea, coastal areas and high altitude) without sacrificing yields of this crop has to be determined. And appropriate technology should be developed to solve the problems of labor, low temperature, medium-late-maturing varieties, etc.

2 Farm machinery

Farm machinery which is an alternative to labor shortage allows for longer intervals between the croppings. For this purpose, in many irrigation schemes including the Chinese rice development projects tractors and hand power tillers were introduced to the farmers; however, after a few years of operation, most of these machines were out of work due to the lack of skilled personnel, spare parts, fuel and improper maintenance. Thus farmers tend to utilize manual labor and animal draught (in the semi-arid regions only). This situation prevails in the Kou Valley in Burkina Faso, Asutsuare in Ghana, in Togo, etc. Besides, small farmers cannot afford to buy farm machines even hand tillers.

In order to overcome these constraints, farm machinery introduced to Africa should be adapted to the local conditions and training programs should be available for the operators, small farmers and technicians. Farmers should be encouraged to become involved in cooperative activities and farmers' organizations, in order to utilize machinery in farm operations so as to save labor and time.

3 Fertilizers

Fertilizer use is still very low in many African countries because of the high cost and scarcity. According to ENZMANN, *et al.* (1983) Africa is using 3.3 million tons of chemical fertilizer accounting for 2.8% of the world consumption. Of these, 2.4 million tons are used in Egypt, Morocco, Algeria, Zimbabwe and South Africa, while the remainder 0.9 million tons are shared by 40 countries. The problem is aggravated in the land-locked countries, such as Chad, Mali, Burundi, Rwanda. In Rwanda farmers use little or no fertilizer for about 3,000 ha of irrigated rice which is grown with two crops per year. Fortunately, rice is planted in valley swamps which receive nutrients from surrounding upper areas adjacent to swamps. In practice, one third of the swamp areas is left fallow each year in order to restore the soil fertility. Nevertheless, yields are declining gradually from 4 t/ha to 2-2.5 t/ha. The Government of Rwanda is attempting to introduce legume crops, such as soja, peanut, cowpea and azolla into these swamps. Soil fertility is decreasing where rice double cropping is practiced and either the amount of fertilizer used is insufficient or an adequate amount of fertilizer is misused. Green manure crops (legumes, azolla, *Sesbania rostrata,* etc.), organic matters and suitable cropping systems should be introduced into these areas. Also, reduced rates or so-called "economic rates" of fertilizer that have been used in irrigation areas have to be evaluated in relation to the changes in soil fertility on a long term basis since the economic rates in many cases, particularly for nitrogen element, are far below the critical rates which enable to maintain the necessary equilibrium of soil fertility in the land exploited.

4 Water management

As mentioned earlier, due to the frequent occurrence of drought in many parts of Africa, the water supply is insufficient for the whole dry season crop. In the rainy season, flash floods take place any time where there is poor drainage. The most common problem is water distribution among farmers, from upper fields to lower fields.

In many large scale irrigation schemes in Senegal, Nigeria, Mali, Sierra Leone, Tanzania, Rwanda, the efficiency of irrigation is declining due to lack of maintenance, spare parts and the lack of farmer cooperation in water management. This affects the successful adoption of double cropping and economic rice production.

Socio-economic constraints

Most of the requirements for rice double cropping are in sharp contrast to those of traditional single cropping even on lowlands or uplands. The farmers who are not accustomed to the new cultivation techniques required for irrigated and double cropping of rice usually do not respect strictly the cultural calendar, and the technical recommendations made by the extension staff. In Rwanda, all the agricultural operations from land preparation to harvesting could be observed in a particular irrigated are at a time (TRAN *et al.,* 1983).

Due to economic incentives, young Africans tend to migrate to urban areas and to petroleum-producing (Negeria, Gabon, etc.), mining and cash crop regions (Sierra Leone). Therefore, the agricultural sector is seriously short of labor. In Burkina Faso, Chad, Sierra Leone, planting of wet season irrigated rice had been delayed until labor was released from work in rainfed areas in other places resulting in the reduction of potential rice yields. The productivity situation tends to deteriorate as the input supply is irregular and its utilization improper.

Furthermore, the rice price policy in several countries has discouraged farmers to improve and intensify rice production. Sometimes, the price of imported rice is lower than that of local rice. As a matter of fact, world rice prices have been decreasing since the last few years. In 1985, following a record crop in the previous year, world rice prices fell 13% below the values recorded in 1984 and 30% below the 1981-83 average (ESN, 1986).

Conclusions

Major attempts to increase rice production through crop intensification with irrigation in many African countries have been hampered by several limiting factors. Rice research and development aimed at developing a suitable technology and giving economic incentives to the small farmers should be promoted both at the national level and by the international organizations.

In order to optimize the output of rice double cropping, the techniques should include the use of improved early-maturing varieties with desirable agronomic characteristics that are adapted to strict cropping schedules and local environments, and appropriate farming systems. This would maximize the yield from the second rice crop by reducing pest infestation, promoting the restoration of soil fertility after the first crop, alleviating the labor shortage for certain labor-intensive operations and reducing the dependence on imported inputs.

In addition, simple low-cost irrigation methods along with an improved scheme design and equipment would allow irrigated rice to be accepted by the small African farmers. Also increased credit access to the farmers, timely input supply, effective marketing and price policies would promote the use of modern techniques in double cropping of rice.

Acknowledgements

The author is thankful to Drs. Trinh Ton That and A. Kandiah for reviewing the manuscript and making valuable suggestions.

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