Sprinkler-irrigated rice under Brazilian conditions

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In Brazil, 60 to 70 percent of the rice is produced upland, mostly in the *cerrado* region. Soils in this region are acidic and possess low natural fertility and water-holding capacity. The rice crop is cultivated during the rainy season, which is often interrupted by dry spells lasting from a few days to several weeks. As a result of the high atmospheric demand associated with low water-holding capacity during those dry periods, plants suffer water deficits, causing severe yield losses. Drought is one of the main factors responsible for the low yield of upland rice in Brazil – approximately 1.4 tonnes per hectare.

Supplemental irrigation by sprinkling is one way of increasing upland rice yields. This is a viable alternative for soils with high permeability and low water-holding capacity, such as those in the *cerrado* region. These soils require frequent watering but only small quantities at a time.

Such requirements are more easily satisfied through sprinkler than surface irrigation. Table 1 shows that upland rice yield was increased by about 145 percent with supplemental irrigation in relation to yields obtained under natural rainfall, and differences were maximized under conditions of severe water stress.

The use of supplemental irrigation minimizes the negative impact of drought; as a result the farmer is stimulated to adopt better technology to ensure adequate fertilization as well as effective disease and pest control. In addition, farmers can make better use of their land by cultivating another crop species during the dry season that will contribute to the amortization of the cost of the equipment.

It is estimated that the rice area covered by sprinkler irrigation in Brazil is about 50 000 ha. The goal of PRONI, the national irrigation programme, is to cover 840 000 ha by centre-pivot and 285 000 ha by autopropeller irrigation systems, reaching a target of 1 125 000 ha by 1990. Further, it is estimated that 50 percent of this projected area is to be cultivated with rice during the rainy season. Supplemental irrigation is expected to increase productivity from 1 400 kg/ha^{-1} to 3 000 kg/ha^{-1}, which will result in the production of an additional of 900 000 tonnes of rice. This amount represents 8 percent of rice production in Brrazil.

WATER MANAGEMENT

Irrigation frequency

It was recommended that rice plants be watered when 40 percent of the available water found up to 20 cm below the surface of the soil was depleted. In 1977 the highest yields were obtained by replenishing water when 30 percent of the available water was depleted. In 1979 it was observed that the relation ETa/ETp decreased by 1 and stomas closed when 67 percent of available water was depleted under *cerrado* conditions. It was recommended that a soil water potential above -0.03 MPa be maintained in a study of sprinkling for rice in 1986. In a study conducted in Goiânia, Goiás, in 1986, it was concluded that water should be applied when soil water potential at 15 cm soil depth reached -0.025 MPa. This value corresponds to 35 percent of available water in the soil under study. At Uberaba, Minas Gerais, yield increases of up to 70 percent were observed for sprinkler-irrigated rice in relation to non-irrigated control when water was applied at five-day intervals.

Water requirements

Total water needs for a rice crop varies from 600 to 700 mm. In an experiment with cultivars IAC 47 and CICA 4 in 1979 in Goiânia, a consumption of 600 mm was measured. In the same site in 1986, a total consumption of 676 mm for cultivar IAC 47 was observed, the daily consumption being 5.3 mm. The same cultivar in Uberaba consumed 715 mm. The daily consumption in this case was between 5 and 6 mm. Water requirement can be estimated using the formula $ETm = ECA \times Kp \times Kc$. ETm is the crop maximum evapotranspiration; ECA, the evaporation in Class A pan; Kp, the Class A pan coefficient; and Kc the crop coefficient. The following values of Kc were obtained for upland rice

TABLE 1 **Rice yield with and without supplemental irrigation by sprinkling at different technological levels**

Location	Year	Cultivar	Yield (*kg/ha*$^{-1}$)		Row spacing and sowing density	Observations
			Irrigated	Non-irrigated		
Viçosa, Minas Gerais	1973/74	IAC 1246 (U) IR 665-4-1 (L) IR 661-1-140-3 (L)	6 145 to 6 923 5 302 to 6 115 5 506 to 6 737-	- - -	0.50 m e 160 seeds/m² -	Yield variations were a result of different nitrogen levels
Viçosa, Minas Gerais	1974/75	IAC 1246 Batatais (U)	4 058 to 5 086- 2 920 to 4 788-	- -	- -	Yield variations were a result of different row spacing and sowing density
Goiânia, Goiás	1976/77	IAC 1246 IAC 47 (U) CICA 4 (L)	5 160 to 5 696 5 128 to 5 663 5 216 to 5 548	1 299 to 1 646 1 487 to 1 852 1 049 to 1 504	0.30 m e 100 seeds/m²	Non-irrigated yield was obtained in 1977/78. Yield variations were a result of different nitrogen levels
Goiânia, Goiás	1975/76	IAC 1246 CICA 4	1 620 to 4 200 1 410 to 3 410	860 to 3 020 1 130 to 1 700	0.50 m e 100 seeds/m²	Yield variations were a result of different technological levels
Goiânia, Goiás	1976/77	IAC 47 IR 665-4-4-5 (L)	1 594 to 4 817 593 to 1 749	680 to 2 105 402 to 574	0.50 m e 100 seeds/m²	Yield variations were a result of different technological levels
Goiânia, Goiás	1977/78	IAC 47	960 to 2 820	440 to 2 090	0.50 m e 100 seeds/m²	Yield variations were a result of different technological levels
Uberaba, Minas Gerais	1978/79	IAC 47	4 029 to 5 514	3 263	-	Yield variations were a result of different water amounts applied
Ponta Porã-MS Ponta Porã-MS	1981/82 1982/83	IAC 165 (U) IAC 165	2 066 to 3 360 2 290 to 3 151	- -	- -	Yield variations were a result of different row spacing, sowing density and insect control
Goiânia, Goiás	1978-83	IAC 47	4 050 3 010 4 000	2 020 120 2 500	0.50 m e 100 seeds/m²	- -

(U) - upland rice cultivar.
(L) - lowland rice cultivar.

cultivar IAC 47 during different growth stages:

Plant age in days	*Growth stage*	*Kc*
8–18	Seedling	0.70
18–40	Vegetative	0.90
40–110	Late vegetative-reproductive	1.24
110–130	Grain filling	0.90

Irrigation systems

The main sprinkler system adopted for rice irrigation is the centre-pivot, although some areas are irrigated by autopropellers. The centre-pivot system is used for areas above 40 ha and is utilized with low to medium pressure in the sprinklers. The autopropeller system is used for areas ranging from 12 to 80 ha and pressure is from 0.55 to 0.8 MPa.

CROP MANAGEMENT

The effects of the different yield factors and their interactions are not well known because of the little research done on sprinkler irrigation to this date.

Fertilization

If risk of water stress is minimized in the system, it is possible to use a higher level of fertilization than that of traditional upland culture. In the latter system, the usual recommendation is to apply 10 kg of nitrogen, 60 kg of P_2O_5 and 30 kg of K_2O per hectare in the row before seeding. These quantities are usually furnished through the application of 200 kg/ha^{-1} of a N-P-K formula type 5-30-15 or 4-30-16.

In 1988, the Comissão da Fertilidade do Solo de Goiás recommended an increase of 50 percent in phosphate and 30 percent in potassium for sprinkler-irrigated conditions. However, factors to be considered other than fertilization are plant type, row spacing and plant density, because of their effect on lodging and the consequent yield reduction.

Cultivars

Although plant type may not impose limitations on a moderate target yield, when growth is not luxurious and water and solar radiation not scarce, a factor to take into consideration is that traditional upland cultivars

TABLE 2 **Installation costs of two sprinkler systems**[1]

Specification	Autopropeller *(15.5 ha)*	Centre-pivot *(50 ha)*
Irrigation equipment	25 561	111 038
Electrical network plus substation	5 308	12 771
Hydraulic work	2 439	2 662
Engineering work	957	2 062
Total	34 265	128 533
Cost/ha-1	2 210.64	2 570.66

[1]Costs in US$.

TABLE 3 **Production costss of three rice cultivation systems**[1]

Specification	Sprinkler-irrigated rice *(3 000 kg/ha^{-1})*	Flooded rice *(5 100 kg/ha^{-1})*	Upland rice *(1 400 kg/ha^{-1})*
Inputs	256.13	272.41	90.75
Services			
Land preparation	75.19	86.36	52.49
Seeding	21.05	21.44	21.44
Cultural practices	27.75	23.59	13.68
Irrigation	100.10	26.82	-
Harvest	47.92	89.60	37.76
Others	42.75	47.40	20.50
Reception and drying	28.33	54.73	15.45
Total	**599.22**	**622.35**	**252.07**
Cost/kg-1	0.20	0.12	0.18

[1]Costs in US$/ha^{-1}.

lodge very easily under intensive crop management system. The recommendations for favourable conditions – fertilizer application and disease and pest control – may not prove profitable when a traditional upland cultivar is planted. Mutual shading and lodging accounted for potential yield reduction under these conditions, in which the leaf area index (LAI) may attain values as high as 8. In addition, those genotypes at high plant density present a high susceptibility to diseases, especially blast. On the other hand, lowland cultivars do not behave well under aerobic soils and show high susceptibility to diseases. The productivity of such plant types was lower than that of traditional upland types under sprinkler-irrigated conditions.

In 1982, the National Research Centre for Rice and Beans (CNPAF) initiated a breeding programme to create rice cultivars adapted to sprinkler-irrigated conditions and to favoured upland conditions *vis-à-vis* water availability. The plant type aimed at for those conditions is something between the traditional and the lowland plant types. The characteristics of such an ideal plant type are: average height (90 to 110 cm), average tillering ability (250 tillers per square metre), lodging resistance, medium growth cycle (120 to 130 days from seeding to maturity), moderate drought tolerance, high resistance to blast and grain spot diseases, and long, slender and translucent grains.

Row spacing and sowing density

Under sprinkler-irrigated conditions, the highest yield was obtained with a row spacing of 0.30 m and a sowing density of 58 or 118 seeds per square metre for cultivars IAC 1246 and Batatais, respectively. Using cultivar IAC 165, the highest yield was obtained with 0.50 m between rows and 200 seeds per square metre. Closer spacing promoted lodging.

Yields higher than 5 000 kg per hectare were obtained by using 0.50 m row spacing and 160 seeds per square metre and 0.30 m row spacing and 100 seeds per square metre.

These heterogeneous results can be accounted for by different soil and climatic conditions as well as disease and pest incidences. They were all generated with traditional upland plant types. Such cultivars attain a yield plateau at a LAI of 4.5. Small yield increments over this LAI are attributed to mutual shading as well as lodging. Altering the traditional plant type would thus allow an increase in LAI with a concomitant increase in yield. The American lowland cultivar Lebonnet, grown under sprinkler-irrigated conditions, attained the highest yield when rows were spaced at 0.20 m and sowing density was 50 to 100 kg per hectare, which corresponds roughly to 200 to 400 seeds per square metre. More research is needed in this field under local conditions.

COSTS

Irrigation system cost

Considering the equipment, involved, the electrical network (with substation) and hydraulic and engineering works involved, the establishment of an autopropeller system carries an estimated cost of approximately US$2 210 per hectare, while the centre-pivot system costs $2 570 per hectare (Table 2).

Crop production cost

On a per hectare basis, the production cost of sprinkler-irrigated rice is about 4 percent less than flooded rice and 138 percent higher than traditional upland rice (Table 3). Taking into consideration the actual average yield of the three systems – irrigation by sprinkling (3 000 kg/ha[1]), flooding (5 100 kg/ha[1]) and upland (1 400 kg/ha[1]) – the cost per kilogram of grain produced in the sprinkler-irrigated system is 67 percent higher than flooded irrigation and 11 percent higher than upland irrigation. However, the adoption of new cultivars and cultural practices would reduce the cost in the very near future because of yield increase per hectare. Another advantage offered by sprinkling is the possibility of planting two crops per year under *cerrado* conditions. Although low temperatures during the dry season would not allow a double rice crop, farmers may benefit from a second crop such as a legume.

One of the factors that contributes to the expense of sprinkling is the high cost of power; therefore, it is absolutely necessary to know in the event of a dry spell when it would be convenient to irrigate the rice crop.

Centre-pivot sprinkler irrigation system in operation