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Optimization of Water Management and Organic Fertilizer in Intensive Rice System in the Sudano-Sahelian Conditions in West Africa

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***Abstract* – After decades of operation, the rice growers of large irrigated areas of the Sudano-Sahelian region of West Africa are now looking for methods enabling them to address recurring constraints of water shortages impeding the productivity. Thus we had introduced the system of rice intensification. However, the principles of the system of rice intensification cannot be extrapolated, as things stand, in this ecology, with regard to the principle of site specificity. The objective of this study was to test the water management recommendations and organic fertilizer proposed by the system of rice intensification compared to local practices. The test has been conducted spanning between the dry season and the wet season 2016, in the irrigated area of the Kou Valley. The experimental design was a split plot with six water management options as the main factor and three manure doses. Piezometers have been installed to explore the state of the groundwater. Statistical analyzes showed that from transplanting to 20 days after, the case of saturation of the soil up to a standing water of 2 cm "every 3 days", and the case of saturation "every2 or3 days according to the demand of the soil", have given the best tillers and vegetative growth in the presence of organic manure. After this period of 20 days, the last case was the best. It has obtained an extra productivity gain of 40% compared to the mean paddy yields of the perimeter. Finally, our study showed that the frequency of irrigation "every 2 or3 days according to the demand of the soil" in combination with a dose of 5 t.ha^{-1} gives the best yields of rice intensification system in this ecology.**

***Keywords* – Rice Intensive System, Water, Fertilization, Management, Productivity.**

I. Introduction

Rice is a staple food for over half of the world population, in 2013 [1], [2]. In West Africa, its consumption is constantly increasing and approximately 60% of the rice consumed is imported each year [3]. To boost production and reduce imports, several actions have been undertaken. For irrigated rice, poor water management is one of the root causes of observed yield losses [4], [5]. To overcome this constraint, the system of rice intensification has been introduced. This is an agro-ecological method based on principles. However, these principles, as per [6], are not static and need to be adapted to the agro-ecological conditions of the areas concerned. That is why this study has been undertaken to adapt those principles in terms of water management and fertilization in the Sudano-Sahelian conditions in West Africa. The objective of this study was to test the water management recommendations and organic fertilizer proposed by the system of rice intensification compared to local practices.

II. Material and Method

A. Study Site

The testshave been conducted in the irrigated area of the Kou Valley in the west of Burkina Faso; average altitude of 300 m, between 11.35 ° North latitude and 4.36 ° West longitude.

According to [7], the climate of the Kou Valley is of South-Sudanian type and is characterized by the alternation of a rainy season from May to October and a dry season from November to April. The average rainfall in the area is about 900 mm [8].

The soils of the rice-growing area of the Kou Valley are classified into two broad categories: soils of sandy clay loam texture cover 66% of the perimeter while the soils of heavy texture (clay or silty clay) occupy 34%.

B. An Experiment

The experimental design was a split plot with six water management options as the main factor and three doses of organic manure in three repetitions. The plant material used is the variety WAS 122-IDSA-1 WAS 6-1. Table 1 shows the different modalities of factors. Transplanting has intervened on the 12th day of the plant nursery; that means 13 days old seedlings. The application of irrigation frequencies intervened from the recovery of the plants, i.e. 7 days after transplanting.

Table 1: Treatments applied in primary and secondary plots

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Factor	Code	Designation
main factor	I1	permanent soil saturation
	I2	frequency of irrigation 3 days
	I3	frequency of irrigation 5 days
	I4	At the cracking of the soil up to 0.5 cm width
	I5	frequency of irrigation 7 days
	I6	frequency of irrigation 10 days
secondary factor	f_0	without organic manure
	f_1	5 t.ha^{-1} of manure
	f_2	10 t.ha^{-1}of manure recommendation from Rice Intensification System

C. Monitoring of Groundwater

Six piezometers, that means one piezometer per each option (periodicity) of irrigation has been installed. Piezometric statements are made following the irrigation timing immediately before the next intake of water.

D. Data Processing

The approach followed to assess the dose of irrigation has been based on the assessment of the volume of the standing water and the volume of the soil voids. Evapotranspiration has been calculated with the FAO ETo calculator tool, Version 3.2 September 2012. The lengths of the roots havebeen measured at the end of the vegetative phase. Paddy yields have been estimated at 14% moisture. SAS / STAT 2010 software has been used for data statistical analysis.

III. Results

A. Level of Groundwater just Before Irrigation

The levels of the groundwater measured in each of the six piezometers immediately before irrigation are summarized in Figure 1. The levels of thegroundwaterin piezometers 2, 3, 4 and 5 always remained below the ground level; the highest level of groundwater has been recorded in I4 followed respectively by I2 and I3. There was never any water in the piezometer I6, just before irrigation.Regardingthe I1 irrigation frequency, intermittentstanding water remained oscillating, approximately at ground level.

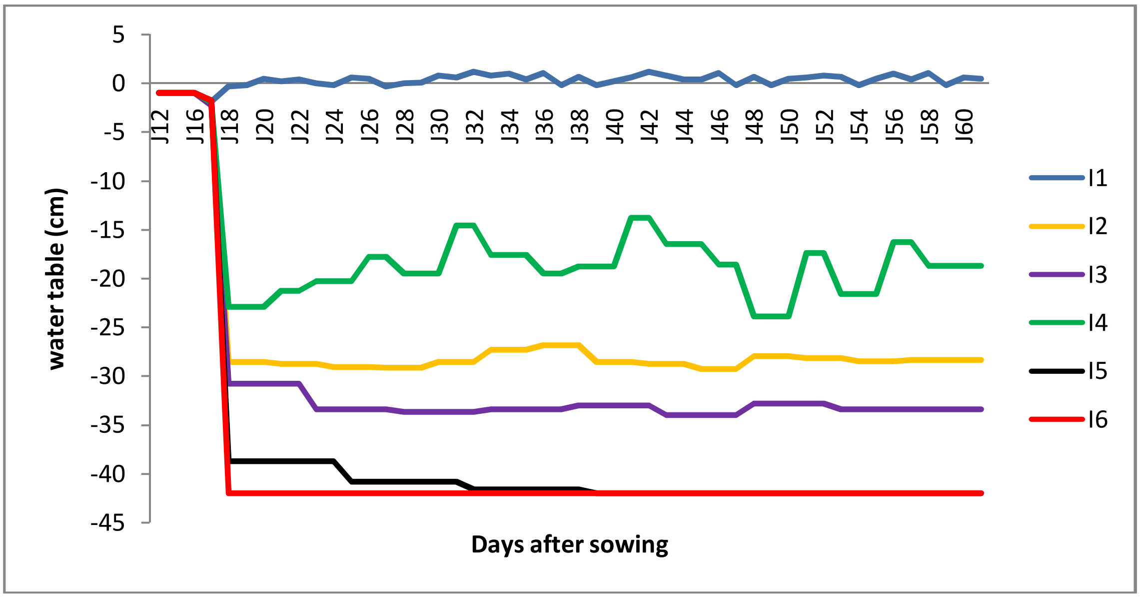

Fig. 1. Level of ground water in the piezometers just before irrigation.

B. Quantity of Water Supplied

Figure 2 shows that all the cumulative volumes of water, except that in I1, remained below maximum rice evapotranspiration (ETM riz) throughout the vegetative stage of rice. The curve I4 is the most approximate to the ETM. The curve I1 remained largely above the ETM and the curve I6 sufficiently below.

C. *Average Length of Roots*

Table 2 informs us that in the end vegetative phase, all the roots are in the top 30 cm of the soil. The longer roots (29 to 29.3 cm) have been developed by the plants of irrigation I5 and I6 in the absence of organic manure. They have also been produced by I4 combined with the dose of 10 $t.ha^{-1}$. Comparing to the levels of the groundwater, only the plants of irrigation I1 and I4 still have their roots reaching the water table at the moment of the next water supply. The roots in the case of I2 irrigation option (periodicity) were rarely reaching the water table. Regarding the other irrigations (I3, I5 and I6), the roots of the plants never had access to the water table, at the end of irrigation period.

D. Paddy Yield

Statistical analysis revealed a highly significant difference between the average paddy yields obtained under the effect of the interaction of irrigation dose and organic fertilizer.

The frequencies I1 and I4 combined with f2 doses or f1 give the best paddy yields no significant difference between these yields. The following group in terms of yields consists of I2f2, I2f1 and I3f2. The I6f0 and I5f0 combinations gave the lowest yields below 2 $t.ha^{-1}$ confer figure 3.

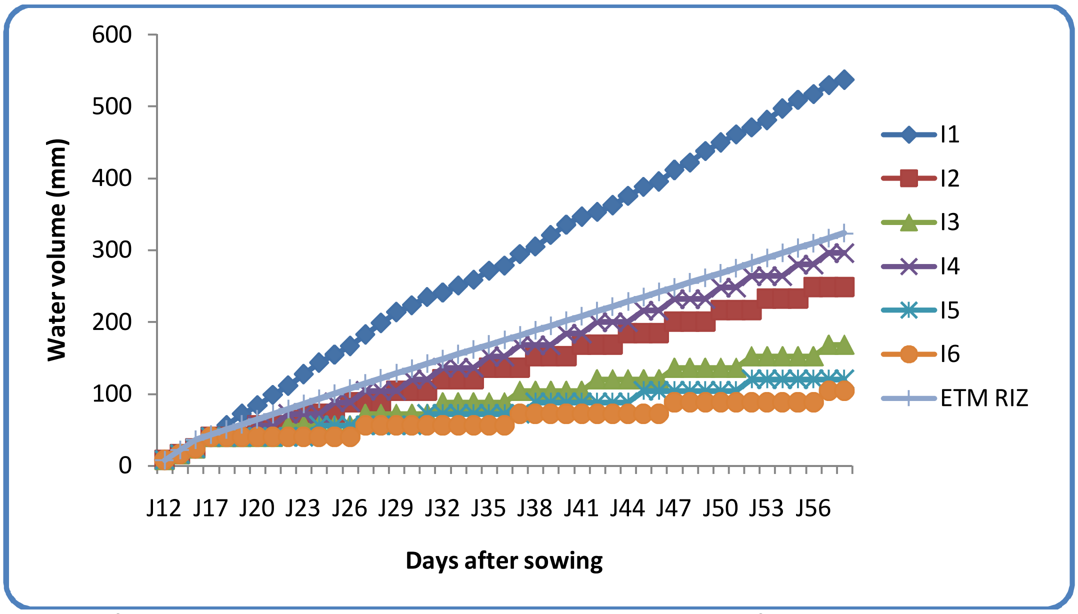

Fig. 2. Evolution of the rice ETM and water volume accumulated by irrigation frequency during the vegetative phase.

Table 2: Root Lengths at late vegetative stage (62 Days after sowing)

	I1	I2	I3	I4	I5	I6
f0	26.7	28.5	28.6	27.4	29	29.3
f1	27.9	27.8	27.4	28.9	28.1	28.6
f2	28.5	27.5	27.2	29.2	28	28.4

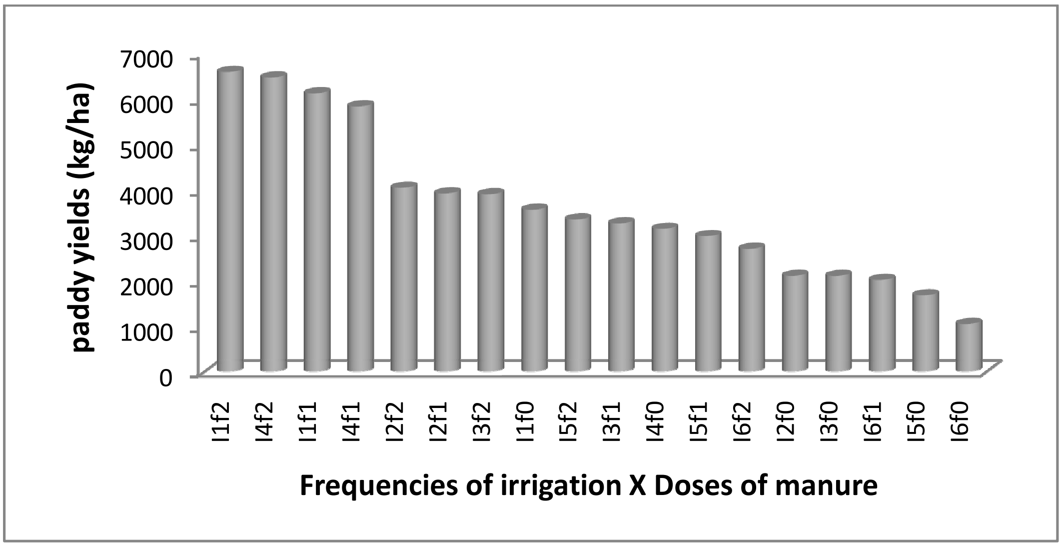

Fig. 3. Effect of irrigation interaction and organic manure on paddy yield

IV. Discussion

Inside all different irrigation frequencies applied in the experiment, the performance of the plants have increased with the increase of organic fertilizer dose. These results confirm all the comments already made by several authors [9], [10], [11]. The extension of irrigation periodicities led to the increase of the length of roots. This can be attributed to the search of water whose level is increasingly low in the ground, [12], [13] got similar findings that the roots become longer and more numerous with water stress. Moreover, soil residual moisture level in the periodicity of 5 days or more are smaller than 48% of saturation (I1). Seedlings of these treatments have suffered water stress which reduced performance. Indeed, [14] showed that when soil moisture goes down 70 to 80% of the saturation value, rice yields begin to decline.

V. Conclusion

The adaptation of the practice of the System of Rice Intensification in its water management principles and organic fertilization remains specific to agro-ecological conditions of each area. In the Sudano-Sahelian conditions, our study found that the system of rice intensification is not effective in the absence of organic manure applied regardless of the irrigation frequency. It is not efficient also for irrigation with periodicity longer than 3 days even with doses of 5 or 10 t.ha^{-1} of manure.

There is some opportunity, however, to apply the results of our work that increases the resilience of producers in relation to the late start of the rainy season.

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