EFFECTS OF PLANT DENSITY AND SOIL MOISTURE ON GROWTH INDICES OF TWO UPLAND RICE VARIETIES

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disparition du stress hydrique. La faible densité a été favorable à l'assimilation nette et au taux de croissance relative pendant tout le cycle alors qu'elle ne l'a été pour le taux de coissance pondérale qu'en fin de cycle.

Mots-clés : Riz pluvial, Analyse de croissance, Indice foliaire, Assimilation nette, Taux de croissance, Surface foliaire massique, Densité de semis. Humidité du sol, Potentiel hydrique du sol.

INTRODUCTION

Crop yield reduction due to water stress is very common in the intertropical zones (Shouse et al., 1981 ; Denmead and Show, 1960). There is, however, little information on the effect of water stress on the growth indices which should help to explain yield losses. Radford (1967) presented the growth analysis concept as a means of quantitative analysis of the plant growth which is often used by physiologists (Watson, 1952; 1958; Williams et al., 1965). The objective of this study was to analyze the effects of water stress on the development of upland rice by the use of growth indices under field conditions.

MATERIALS AND METHODS

The experimental site was located on the agronomy farm of the ORSTOM Center of Adiopodoumé (Southern Côte d'Ivoire) about 17 km west of Abidjan, 5 19' N, 4 14' W at 29 m of altitude on deep sandy soils. In general, the soils of Adiopodoumé are ferrallitic with a very low percentage of saturation, modal and developed from tertiary sand (Table 1). Total N content in the topsoil (25 cm) ranges from 0.71 to 0.72 meq/100g and soil pH ranges from 5.2 to 5.3.

Two upland rice varieties, V1 (IRAT 112) and V2 (IDSA 6) were hand sown on 14 and 15 March 1986 at two plant densities, D1 (12 plants/m2) and D2 (60 plants/m2). IRAT 112 was derived from a cross between IRAT 13 and Dourado in 1978 and it is a short-season (105 days) cultivar. Its height ranges from 90 to 105 cm and it can yield up to 4.0 tonnes/ha. IDSA 6 was derived from a cross between Colombia and M 312 A in 1982. IDSA 6 which is also called IRAT 216, is a mid-season (125 days) cultivar and can be used as either a rainfed or a flooded cultivar. IDSA 6 is 110 cm high and can yield up to 5.2 tonnes/ha (Poisson and Doumbia, 1987). The experimental design was a 2 x 2 factorial with five replications for a total of 20 plots. Each plot covered 62.5 m^2 (12.5 m x 5 m) in area and consisted of 16 sowing rows with 33 cm between rows. Two seeds were sown per hill at a distance of 25 cm for D1 and 5 cm for D2. The crop was hand-thinned to one plant per hill to obtain plant populations of 12 and 60 plants/m^2 for D1 and D2 respectively. Missing plants were replaced during the thinning period from 18 to 21 days after sowing (DAS).

Table 1 : Physical and chemical properties of the soils at the experimental site (After Goué et al. 1986).

Soil depth	Clay	Silt	Sand	Ca++	Mg++	K+	Total OM
(cm)	----- (%) -----			------ (meq/100g) ------			
0-15	6.1	4.6	87.5	0.48	0.01	0.06	1.5
15-35	6.5	4.8	88.5	0.22	0.07	0.03	1.0
35-50	8.5	4.8	85.9	0.10	0.05	0.02	0.7
50-70	12.1	5.1	82.8	0.24	0.07	0.03	0.6
70-90	16.5	6.0	76.9	0.18	0.05	0.02	0.8
90-100	22.8	4.9	72.4	0.22	0.03	0.03	0.8

OM = organic matter

Five hundred kg ha^{-1} of NPK (10-18-18) were added to the soil before plowing. Urea was put in the row at the beginning of tillering and stem elongation at a rate of 100 kg ha^{-1}. The field was irrigated on the 26th and 35th days after sowing bringing 14 and 24 mm of water respectively.

Soil moisture was monitored weekly by the gravimetrical method in the topsoil and by the neutron scattering method down to 100 cm. Soil water potential was also monitored from 20 to 100 cm depth using a series of tensiometers. Rainfall was recorded at the experimental site. Solar radiation was monitored with a Ballani pyranometer at a nearby weather station.

Beginning on day 21 after sowing, weekly samplings of 4 plants/plot were made to determine plant dry weight. From day 34 after sowing, the green leaf area of sampled plants was measured by using an area-meter (Type : Milliplan). Leaf area index (LAI) was calculated by considering leaf area per plant and plant density.

Crop Growth Rate (CGR), Relative Growth Rate (RGR), Leaf Area Index (LAI), Leaf Area Duration (LAD), Leaf Area Ratio (LAR) and Net Assimilation Rate (NAR) were calculated in order to analyze the development of upland rice under field conditions.

The following equations were used to calculate the different growth indices :

- Crop Growth Rate (CGR)

$$CGR = (1/S)\ dW/dt \qquad (1)$$

$$CGR = (1/S)\ (W_2-W_1)/(t_2-t_1) \qquad (2)$$

where W = above-ground plant dry weight

S = land area

t = time

- Relative Growth Rate

$$RGR = (1/W)\ dW/dt \qquad (3)$$

$$RGR = (\text{Log } W_2 - \text{Log } W_2)/(t_2-t_1) \qquad (4)$$

- Leaf Area Index (LAI), Leaf Area Duration (LAD), Leaf Area Ratio (LAR)

$$LAI = A/S \qquad (5)$$

$$LAD = \int_{t_1}^{t_2} LAI\ dt \qquad (6)$$

$$LAR = A/W \qquad (7)$$

$$LAR = (LAR_1 + LAR_2)/2 \qquad (8)$$

Where A = leaf area/plant

- Net Assimilation Rate (NAR)

$$NAR = (1/A)\ dW/dt \qquad (9)$$

$$NAR = (W_2-W_1)\ (\text{Log } A_2 - \text{Log } A_1)/(t_2-t_1)\ (A_2-A_1) \qquad (10)$$

Let us point out that RGR, LAR and NAR are related as shown in the following equation :

$$RGR = LAR \times NAR \qquad (11)$$

RESULTS

The analysis of soil water potential (Fig.1) indicates that most of the evapotranspired water came from the first 60 and 40 cm of soil for IRAT 112 and IDSA 6, respectively. This result suggests that IRAT 112 may have a deeper and more developed root system. The analysis of moisture data from the first 60 cm of soil over the growing season, reveals two drying cycles due to low amount of rainfall (Fig.2). The first one was short and started early in the growing season. The second, however, was long, starting between days 40 and 50 after sowing and ending around day 70. During this second drying cycle, soil moisture fell below the wilting point between days 60 and 70 after sowing, therefore, affecting the plant development. Solar radiation fluctuated throughout the growing period but is particularly lower at the end of the season

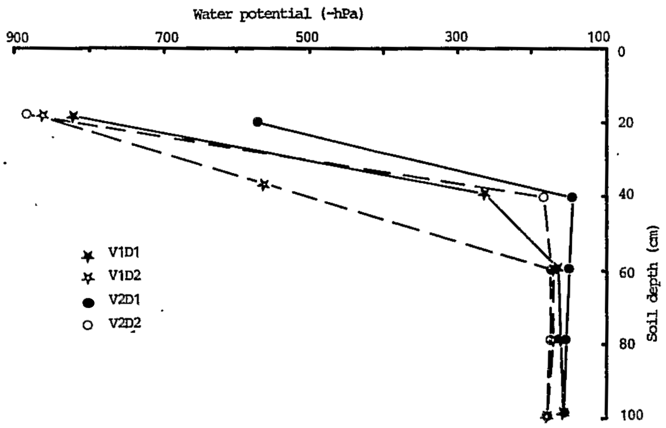

Figure 1 : Soil water potential profiles for May 12, 1986 under two rice varieties V1 (IRAT 112) and V2 (IDSA 6) and two plant densities D1 (12 plants/m2) and D2 (60 plants/m2).

because of the greater number of rainy days recorded during this period. (Fig.2)

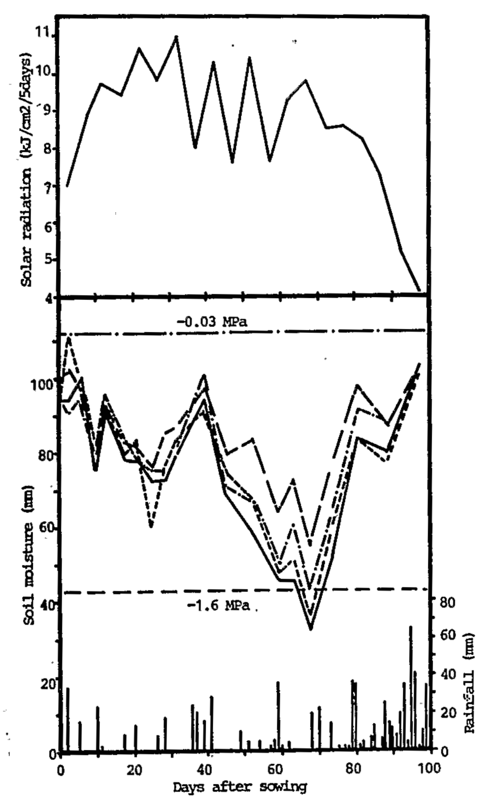

Figure 2 : Evolution of soil moisture in the first 60 cm and rainfall and solar radiationduring the growth season.

______ V1D1, ___ ___ V2D1, ___.___ V2D2,

_ _ _V1D2.

Figure 3 presents the evolution of dry matter accumulation per plant (g/plant) and per unit land area (g/m^2) (Remison and Lucas, 1982; Buttery, 1969a). These results show similarity in the growth of the two varieties suggesting that they react to environmental conditions in the same way. Thus, their dry matter accumulation rate was reduced accordingly by the dry period recorded between days 55 and 70 after sowing.

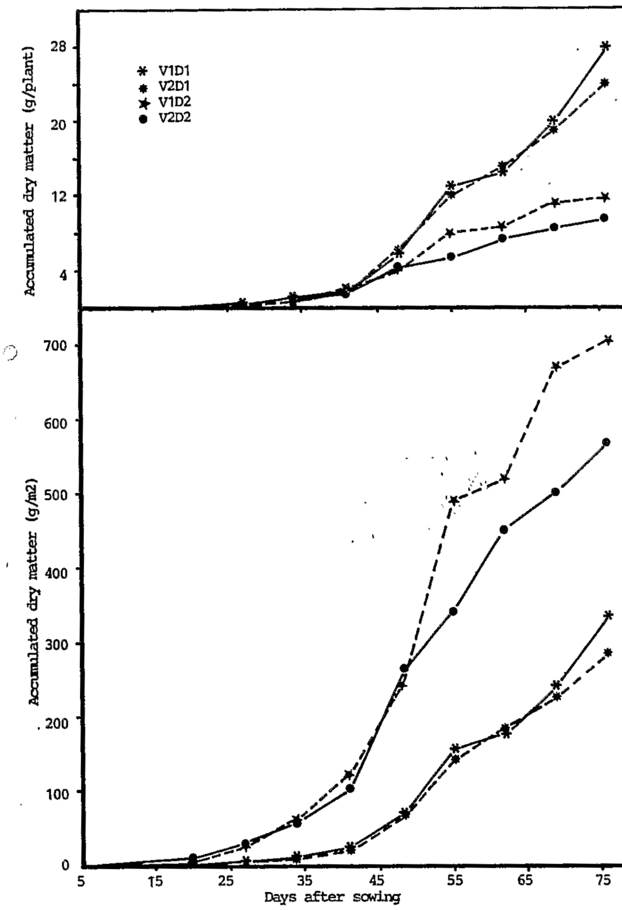

Figure 3 : Dry matter accumulation of two rice varieties V1 (IRAT 112) and V2 (IDSA 6) at two plant densities D1 (12 plants/m2) and D2 (60 plants/m2).

Figure 3 also shows that plant density had a significant effect on growth (g/plant) and yield (g/m^2). The high plant density led to reduced growth while the low density, despite the good plant growth resulted in a smaller crop yield. This indicates that 12 plants/m2 was below the optimum plant density. The better development of IRAT 112 as compared to IDSA 6 under high plant density suggests a differential root development as indicate the water potential data.

Figure 4 presents the evolution of CGR during the growing season. The high increase rate of CGR between days 35 and 50 after sowing occured at the beginning of stem extension when soil moisture content was high. During the second half of the stem extension period, CGR rapidly decreased following a dry period. The next increase in CGR occurring between days 60 and 70 after sowing (thus, during the dry season) was related to heading and early grain filling. Plant density had a positive effect on CGR only under good moisture conditions.

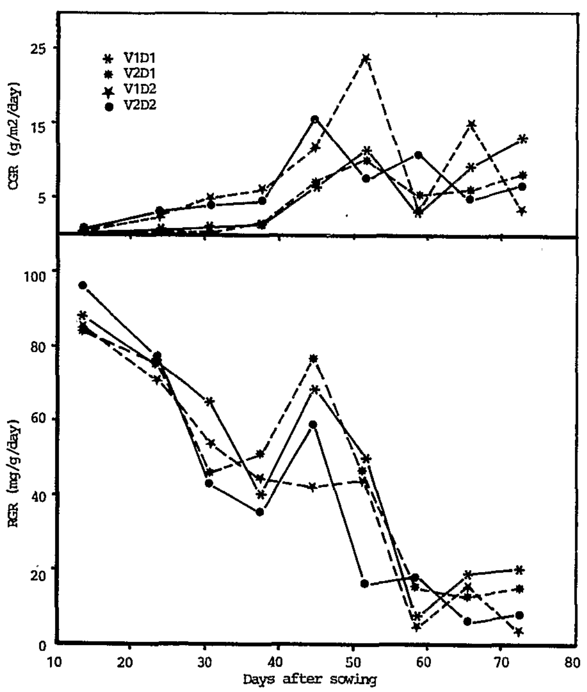

Figure 4 : Crop growth rate (CGR) and relative growth rate (RGR) of two rice varieties, V1 (IRAT 112) and V2 (IDSA 6) at two plant densities, D1 (12 plants/m2) and D2 (60 plants/ m2).

then rapidly decreased during the first drying cycle before rising again. This increase in RGR was associated with stem elongation and good rainy period. Starting about 50 days after sowing, RGR decreased very rapidly reaching a minimum value around day 60 before increasing slightly under the low plant density. At the beginning of the growing season, RGR was similar for all treatments but starting from day 35 after sowing, the low plant density treatments had higher RGR.

Leaf area index (LAI) of the high density treatments was significantly (5%) higher than that of the low density treatments until day 70 after sowing (Fig.5). However, LAI of the two varieties had a similar trend. From day 40 to day 50, the rapid increase in LAI was associated with stem elongation.
During the dry period (55 to 65 days after sowing) LAI increase rate was negligible (Cutler et al., 1980) but the important leaf wilting during that period led to leaf senescence between days 65 and 75 after sowing resulting in lower LAI especially under high plant density. Under low plant density conditions, maximum LAI was 1.0 while under high density conditions maximum LAI was 2.2 (Fig.5).

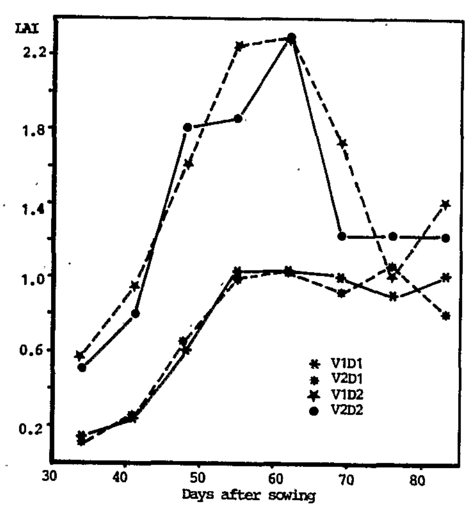

Figure 5 : Leaf area index (LAI) of two rice

Leaf area duration (LAD) between days 34 and 83 after sowing was 40.6, 42.3, 76.5 and 82.7 days for V2D1, V1D1, V2D2 and V1D2 respectively.

Leaf area ratio (LAR) was similar for all treatments but declined with time. It was observed, however, that the declining rate was slow between days 55 and 65 after sowing (Fig.6) only for the high density treatments. This result is due to the fact that leaf area remained the same while the relative growth rate was very minimum especially for the high density treatments (Fig.4 and 5).

and constant for all treatments except V1D2 after the dry period (Fig.6). Despite the important role that light intensity plays in photosynthesis, solar radiation recorded at the experimental site was not limiting as demonstrates Figure 7. The absence of a close linear relationship (NAR = 0.274 SR - 0.127, r = 0.449) between net assimilation rate and solar radiation was an evidence that other factors were limiting photosynthetic activity.

The effect of the water stress (days 50 to 70 after sowing) on the rice development was expressed by a reduction in the CGR rather than a decrease in the plant weight. Similar results were reported by Cutler et al. (1980) and Hsiao [redacted]

CONCLUSIONS

These results show that a severe water stress has a negative effect on [redacted]

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