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SHADING AS AN ENVIRONMENTAL FACTOR AFFECTING THE GROWTH OF *Ischaemum rugosum*[1]

Ricardo A. Marenco[2] and Andrea C.S. Reis[3]

Departamento de Fitotecnia e Fitossanidade (DFF/CCA), Universidade Estadual do Maranhão, C.P. 09, São Luís, MA, 65054-970, Brazil

ABSTRACT - Wrinkled grass *(I. rugosum* Salisb.) is one of the most important weeds in irrigated rice in Maranhão, with infested fields increasing each season. The experiment was conducted in pots to study the effects of shading (0, 50 and 70%) on wrinkled grass growth. Plants were harvested at seven days after emergence (DAE), and from 14 to 112 DAE at 14-day intervals. They were separated in culms, leaves and roots, dried, weighed, and leaf area measured. Dry matter (DM) accumulation of culms, leaves and roots was reduced by shading. In roots, dry matter accumulation diminished as levels of shading increased. A sharp decline in root dry matter accumulation was observed after the beginning of flowering in unshaded plants. Leaf area, however, was greater in plants grown at 50% shading than in those that were shaded at 0 or 70%. Relative growth rate (Rw) was greater in shaded than in unshaded plants. The contrary was true for net assimilation rate (Ea). At the end of the plant cycle, however, the net assimilation rate was greater in plants shaded at 70% than in those shaded at 0 or 50%. It was concluded that there was an effect of shading on sink preference. At full sunlight the roots were the preferred sink during the vegetative phase, whereas the culms appear to be the primary sinks during the reproductive period. In shaded environments the culms and leaves were the preferred sinks. Leaf thickness was lower in plants cultivated at high levels of shading than in sunniest plants receiveing more light.

Additional index terms: growth analysis, *I. rugosum*, Maranhão, rice.

SOMBREAMENTO COMO FATOR PARA O CRESCIMENTO DE *Ischaemum rugosum*

RESUMO – O *I. rugosum* é uma das plantas invasoras mais importantes do arroz irrigado no Maranhão, onde as áreas infestadas aumentam a cada safra. O experimento foi conduzido em vasos visando estudar o efeito do sombreamento (0, 50 e 70%) no crescimento dessa invasora. As plantas foram coletadas aos sete dias após a emergência (DAE) e a intervalos de duas semanas entre os 14 e 112 dias após a emergência, sendo separadas em colmos, folhas e raízes. Determinou-se a matéria seca (MS) e a área foliar. O acúmulo de matéria seca dos colmos, folhas e raízes foi reduzido pelo sombreamento. Nas raízes, a redução da matéria seca foi proporcional ao aumento do sombreamento, observando-se uma redução drástica após o início da floração nas plantas não sombreadas. A área foliar foi maior nas plantas sob 50% de sombra do que naquelas cultivadas a 0 ou 70%. A taxa de crescimento relativo (Rw) foi maior nas plantas sombreadas do que naquelas não sombreadas, o contrário observou-se para a taxa assimilatória liquida (Ea). No entanto, ao final do ciclo, os valores de taxa assimilatória líquida foram maiores nas plantas sombreadas 70% do que nos outros tratamentos. O sombreamento influenciou a preferencialidade dos drenos da planta. Sob alta irradiância as raízes foram os drenos preferenciais durante a fase vegetativa e os colmos na fase reprodutiva. Sob elevado sombreamento os colmos e as folhas foram os drenos preferidos. Folhas mais finas foram observadas nos tratamentos sombreados.

Termos adicionais para indexação: análise de crescimento, arroz, Maranhão.

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[2] Eng. Agron. Dr., Prof. Visitante, Bolsista da Fundação de Amparo à Pesquisa do Estado do Maranhão (FAPEMA).

[3] Acadêmica do Curso de Agronomia – UEMA, Bolsista do Programa Interinstitucional de Bolsas de Iniciação Científica, PIBIC/CNPq -UEMA

INTRODUCTION

Wrinkled grass (*I. rugosum*) is commonly found along rice fields and banks of canals. In rice fields it is an annual species. Although it is an important weed of irrigated rice it cannot emerge under water, but after emergence it easily grows in these environments. Its' seeds present long awns, which twinkles in such a way that short awns may be found under wet conditions, and 90° curved in dry conditions. High population of wrinkled grass may reduce yield by approximately 50 percent in rice (Itoh, 1991). *I. rugosum* is becoming one of the most important weeds of rice in the world. It has become increasingly important in irrigated rice of Maranhão, with infested fields increasing with each season, since practices that prevent infestation of new areas are not usually applied in the region.

In the field wrinkled grass germinates two or three weeks after seeding of rice, because of its characteristic seed dormancy, it grows under the canopy of rice. When it height reaches the same of the rice plants, and is exposed to full sunlight, seed production is initiated, ending its reproductive period at rice harvest time. This is especially important for wrinkled grass dissemination since this seeds species' mature at the same time as rice is harvested, resulting in contamination of the rice seeds, which may introduce the weed into new fields. Wrinkled grass is believed to have originated in Asia, and become an important weed in southeast Asia. It is a perennial grass, and once established difficult to control by either chemical or mechanical means. The objective of this work was to determine growth analysis parameters of wrinkled grass under reduced levels of solar radiation.

MATERIAL AND METHODS

The experiment was conducted at the Universidade Estadual do Maranhão experimental station (02° 35' S; 44° 10' W) at São Luís, MA. Average annual solar radiation was 4000 kcal.m^{-2}.day^{-1}, and mean temperature was 26°C. Substrate used for plant development was a red-yellow podsol (oxisol) collected from a 0-200 mm depth, with low natural fertility, sandy texture (25% coarse sand, 55% fine sand, 10% silt, and 10% clay), and 3.0 % organic matter. Fifteen days before planting, the soil was amended with 1.2 g of lime per kg of soil and fertilized with 0.1 g of N, 50 mg of P_2O_5, and 30 mg of K_2O per kg of soil. Just before sowing, wrinkled seeds were treated with a solution of sodium hypochlorite (2% v/v) during two hours for breaking dormancy (Marenco & Reis, 1997), then washed with tap water and planted, six seeds per plastic pot (3 kg), with holes in the bottom. Seven days after emergence, excess seedlings were thinned to two uniform plants per pot, a mean population of 12 plants/m^2. Additional N (0.2 g/pot) was applied 30 days after emergence. During the experiment the plants were watered with the same amount of tap water (900 ml/pot) to minimize moisture stress.

Just after emergence the plants were divided in three populations (about 30 pots per population). Each group of plants was grown under one of the following environments: 0, 50, and 70% shading.

The 0% shading treatment actually corresponded to plants cultivated under greenhouse condition (100 µm-transparent films). Further, the 50 and 70% shading treatments were provided by black nylon shade cloth woven as a screen (Sombrite^R) mounted on 4x4x3-m frames.

The experimental design was a randomized com-plete block with treatments in split-plot with four replicates. The main plots were the levels of shading and the subplots the dates of samplings (7, 14, 28, 42, 56, 70, 84, 98 and 112 days after emergence). At each sampling, plants were separated in culms, leaves and roots, and dried at 72°C in forced-air oven until constant mass, and weighed. Leaf area determinations were made by using a leaf area meter (Licor^R 3100).

The flowering time was defined when 50% of plants had produced visible spikelets.

Data derived from weighing were transformed to log(Y) before being subjected to analysis of variance. Mean values of leaf area and plant parts dry matter were fitted by a logistic model, $W_t=W_m/(1+Be^{-Ct})$, where Wm is the estimated value for the upper asymptote, *B* and *C* are fitting coefficients, and *t* is time in days after emergence. Crop growth rate (C_t) was obtained by differentiating Wt with respect to time (Radford, 1967). Instantaneous values of the relative growth rate (R_w), which represents the increase in dry matter, per unit time with respect to the initial dry matter, was obtained dividing C_t by W_t ($R_w = C_t/W_t$), and the net assimilation rate (E_a), which expresses the increase in dry matter for the total leaf area responsible for this increase, was obtained as C_t/A_f.

RESULTS AND DISCUSSION

Dry matter of culms, leaves and roots, and leaf area

Dry matter accumulation of culms was significantly ($P \leq 0.01$) reduced by the highest levels of shading (70%), with no difference between 0 and 50% shading treatments (Fig. 1). As observed for culms, leaf dry matter was lower in plants grown at 70 % shading than in those submitted to 0 or 50% shading during the whole plant cycle (Fig. 2). In addition, during the first 60 days after emergence unshaded plants accumulated a greater amount of leaf dry matter than plants shaded at 50%. Thereafter, however, plants grown at 50% shading accumulated greater amount of leaf dry matter than plants in full sun (Fig. 2).

Leaf area was greater in plants grown at 50% than in those grown at 70% shading during the whole plant cycle (Fig. 3). Plants shaded at 50% also produced greater amount of leaf area than those unshaded, from 50 to 112 days after emergence, which corresponded to the reproductive period. Further, it is important to note in Fig. 3 that, during the last five weeks of plant growth, unshaded plants produced the same amount of leaf area as those that were shaded at 70%. On the other hand, during the first 50 days after emergence there was no difference between 0 and 50% shading in the amount of

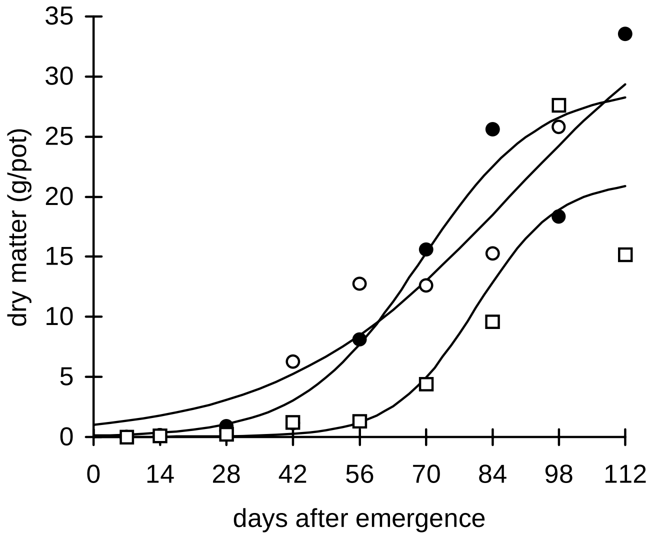

FIGURE 1 - Culm dry matter at three levels of shading: 0% (o), 50% (•) and 70% ( ). Y(o) = 40.00/ (1 + 38.13 $\boldsymbol{e}^{(-0.04156\,t)}$); $R^2 = 0.93$; Y(•) = 29.13/ (1 + 247.57 $\boldsymbol{e}^{(-0.0802\,t)}$); $R^2 = 0.91$; Y( ) = 21.46/ (1 + 10000 $\boldsymbol{e}^{(-0.11442\,t)}$); $R^2 = 0.83$; where ***e*** = natural log, and ***t*** = days after emergence.

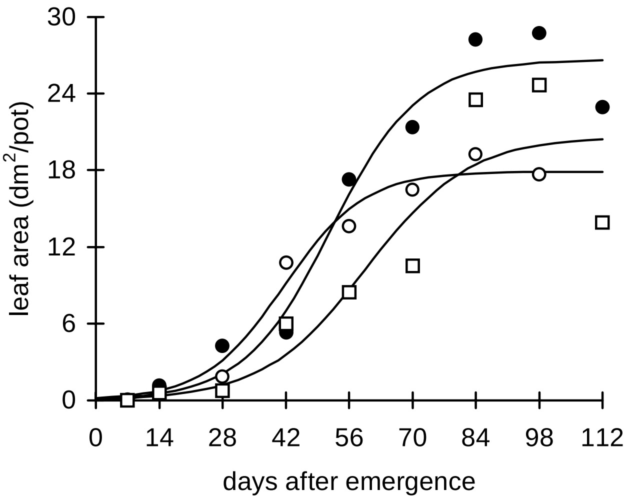

FIGURE 3 - Leaf area at three levels of shading: 0% (o), 50% (•), and 70% ( ). Y(o) = 17.90 / (1 + 112.53 $\boldsymbol{e}^{(-0.1135\,t)}$); $R^2 = 0.98$ Y(•) = 26.64/ (1 + 217.82 $\boldsymbol{e}^{(-0.1037\,t)}$); $R^2 = 0.97$ Y( ) = 20.65/ (1 + 192.09 $\boldsymbol{e}^{(-0.88\,t)}$); $R^2 = 0.84$; where ***e*** = natural log, and ***t*** = days after emergence.

leaf area produced. Taking into account that dry matter of shadiest plants was the lowest observed in the experiment, while leaf area was intermediate between the two other treatments (Fig. 2 and 3), it may be suggested that wrinkled grass may adapt its leaf thickness to input of solar radiation, producing the thinnest leaves under shadiest conditions, and the thicker ones under unshaded environments. Since plants cultivated under 70% shading produced about 80% of leaf dry matter, and as much leaf area as the sunniest plants it may be suggested that wrinkled grass can tolerate high levels of shading, which makes this weed highly competitive with rice, even when it germinates later in the rice crop cycle.

Root dry matter accumulation diminished as levels of shading increased during the whole plant cycle (Fig. 4). The highest values of root dry matter accumulation were observed at 70, 84 and 112 days after emergence for plants shaded at 0%, 50% and 70%, respectively, which suggests that under the sunniest conditions the roots

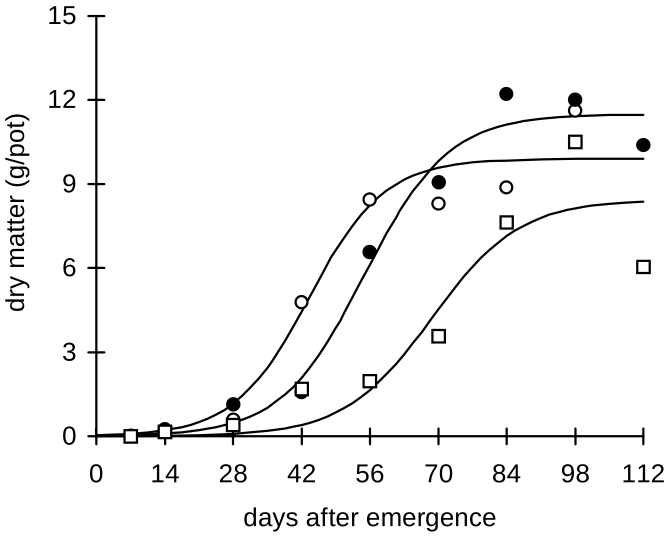

FIGURE 2 - Leaf dry matter at three levels of shading: 0% (o), 50% (•) and 70% ( ). Y(o) = 9.90/ (1 + 280.86 $\boldsymbol{e}^{(-0.1294\,t)}$) ; $R^2 = 0.95$; Y(•) = 11.49 / (1 + 615.87$\boldsymbol{e}^{(-0.1171\,t)}$); $R^2 = 0.98$; Y( ) = 8.44 /(1 + 2104.78 $\boldsymbol{e}^{(-0.1114\,t)}$); $R^2 = 0.88$; where ***e*** = natural log, and ***t*** = days after emergence.

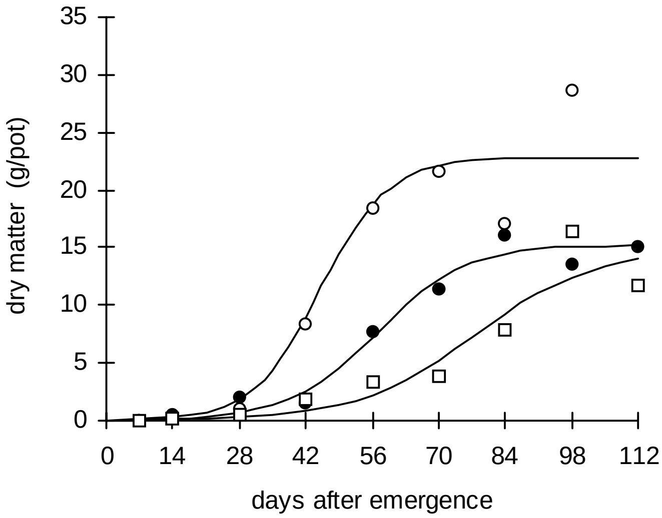

FIGURE 4 - Root dry matter at three levels of shading: 0% (o), 50% (•), and 70% ( ). Y (o) = 22.83 / (1 + 561.39 $\boldsymbol{e}^{(-0.1367\,t)}$); $R^2 = 0.92$ Y(•) = 15.22/ (1 + 500 $\boldsymbol{e}^{(-0.1091\,t)}$); $R^2 = 0.97$ Y( ) = 14.98/ (1 + 500 $\boldsymbol{e}^{(-0.0797\,t)}$); $R^2 = 0.90$; where ***e*** = natural log, and ***t*** = days after emergence.

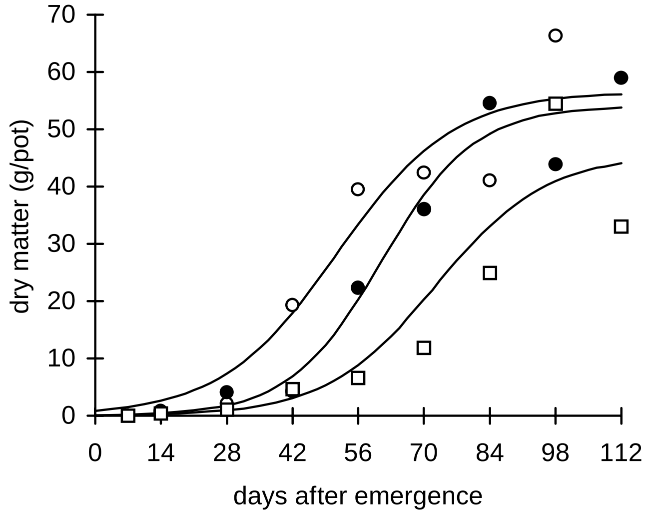

FIGURE 5 - Total dry matter at three levels of shading: 0% (o), 50% (•), and 70% ( ). Y (o) = 56.58/ (1 + 63.95 $e^{(-0.0808\,t)}$); R^2 = 0.92; Y (•) = 54.04 / (1 + 480.03 $e^{(-0.1012\,t)}$), R^2 = 0.97; Y( ) = 45.60/ (1 + 500 $e^{(-0.0856\,t)}$); R^2 = 0.86; where ***e*** = natural log, and ***t*** = days after emergence.

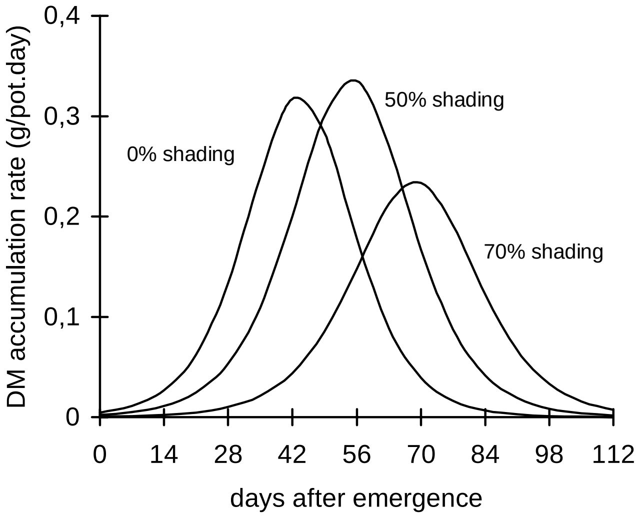

FIGURE 7- Leaf dry matter accumulation rate at 0, 50 and 70% shading. DM - dry matter.

were the preferred sinks during the first six weeks of plant development, whereas under the shadiest environments the roots were important sinks during almost the whole plant cycle, so that at the end of plant development, there was no difference in root biomass between 50% and 70% shading. This is likely to account for some delay in plant senescence in shadiest plants.

Total dry matter accumulation

Total plant dry matter accumulation was greater in unshaded plants than in those shaded at 50 and 70%

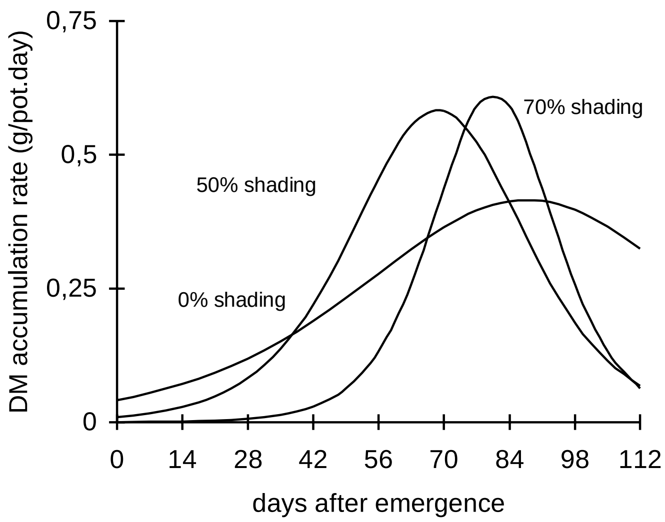

FIGURE 6- Culm dry matter accumulation rate at 0, 50 and 70% shading. DM - dry matter.

(Fig. 5). The three phases of growth, log, linear and senescence, were observed during plant development. In full sun plants, the log, linear and senescence phases were 0-35 days, 35-70 days and 7-112 days after emergence, respectively. In 70% shaded plants the phases of growth were observed from 0 to 50 days after emergence (log phase), 50 to 90 (linear phase), and after 90 days (senescence). For plants cultivated at 50% shading intermediary values between those observed for 0 and 70% shading were recorded.

Flowering of wrinkled grass was observed at 42, 56 and 70 days after emergence for plants grown at 0, 50, and 70% shading, respectively, which suggests that shading delays the reproductive period of this weed. There was no difference in seed production among treatments, which ranged from 80 to 550 (mean of 200) seeds per plant. Adaptation to shading and prolific seed production are important characteristics to be taken into account in properly-planned weed management strategies.

Rates of dry matter accumulation

Greater rates of culm dry matter accumulation were observed in plants shaded at 50% and 70% than in those unshaded. After 90 days, however, plants in full sun accumulated dry matter at higher rates (Fig. 6). These results indicate that culms were important sink for unshaded plants during the last phase of plant cycle, when production of leaves and roots was low. In 70% shaded plants culms were more important from 60 to 90 days after emergence period, whereas for plants cultivated at 50% shading greater rates of dry matter were accumulation observed during almost the whole crop cycle in comparison to unshaded and 70% shaded

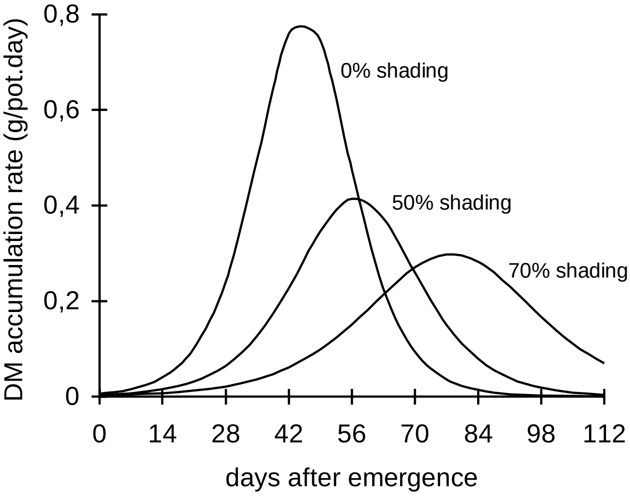

FIGURE 8- Root dry matter accumulation rate at 0, 50 and 70% shading. DM - dry matter.

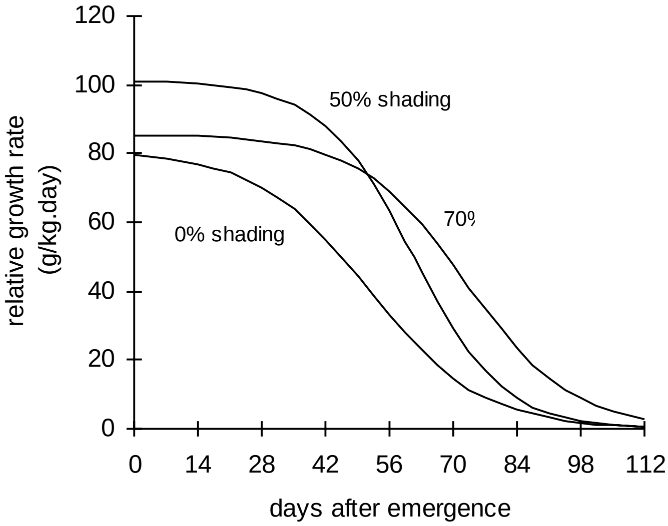

FIGURE 10- Relative growth rate at 0, 50 and 70% shading

plants, which emphasizes the importance of culms as the primary sinks under moderate levels of shading.

Leaf dry matter accumulation rates were greater in unshaded and 50% shaded plants than in those shaded at 70% (Fig. 7). The greatest values were observed at 40, 56 and 70 days after emergence for plants shaded at 0, 50, and 70%, respectively, which suggests that low levels of solar radiation delay the sink capacity of leaves.

There was a clear effect of shading on the rate of root dry matter accumulation (Fig. 8). In unshaded plants the highest rate of root dry matter accumulation (0.7 g/pot.day) was observed at the end of the vegetative period (40 DAE). Thereafter, there was a sharp decline in root dry matter accumulation. In plants cultivated at 50% and 70% shading the greatest root dry matter accumulation rates (0.3 to 0.4 g/pot.day) were observed at 56 and 80 days after emergence, respectively. Thus, it may be suggested that in wrinkled grass the importance of roots as the preferred sinks is delayed as the level of solar radiation is reduced. No assimilate appears to be allocated to roots in unshaded plants at the end of the growing period.

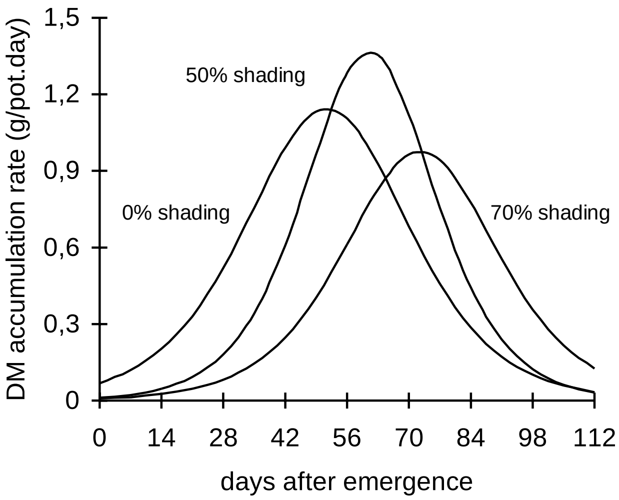

FIGURE 9- Crop growth rate at 0, 50 and 70% shading. DM - dry matter.

Crop growth rate (C_t)

Crop growth rate was greater in plants at 50% shading that in those at 0 or 70% shading (Fig. 9). The greatest crop growth rate values were observed at about 50, 60, and 70 days after emergence in plants shaded at 0, 50, and 70%, respectively. The peaks of crop growth rate in all treatments were consistent with those observed for dry matter accumulation in roots, which shows the great contribution of roots for the crop growth rate values, mainly in full sun plants.

Relative growth rate (R_w)

The relative growth rate was greater in shaded plants than in those that were unshaded (Fig.10), which suggests that shaded plants were more efficient than those unshaded in terms of biomass production per day. This was consistent with the greater amount of assimilate allocated to production of non-assimilatory tissue, mainly roots and culms, during the vegetative phase in full sun plants. Plants grown at the shadiest condition showed the highest relative growth rate values at the end of the plant cycle. This was probably due to a higher amount of

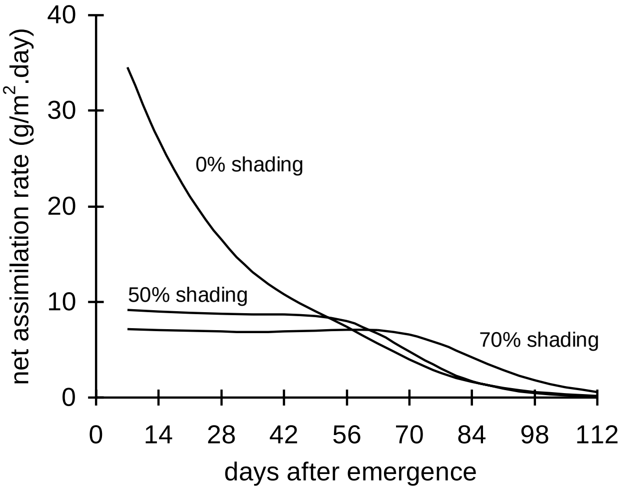

FIGURE 11- Net assimilation rate at 0, 50 and 70% shading

assimilate allocated to leaf production at the end of plant development.

Net assimilation rate (E_a)

During the first 42 days after emergence, net assimilation rate was greater in unshaded plants than in those shaded at 50 or 70% (Fig. 11). This may be attributed to the high sink capacity of roots in unshaded plants, which may increase the photosynthetic efficiency of plants, since there appears to be a relationship between sink capacity and assimilate production (Mondal *et al.*, 1978; Hendrix, 1995). At the end of plant development, plants at 70% shading showed the greatest net assimilation rates, probably due to delay in leaf senescence, and production of new leaves even at the end of plant cycle in shaded treatments.

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REFERENCES

HENDRIX, J.E. Assimilate transport and partitioning. In: PESSARAKLI, M. ed. **Handbook of plant physiology**. New York, Marcel Dekker. 1995. p.357-386.

ITOH, K. *Ischaemum rugosum*. In: ITOH, K. ed. **Life cycles of rice field weeds and their management in Malaysia**. Peang, Malasia. Tropical Agriculture Research Center, 1991. p.55-59..

MARENCO, R.A. & REIS, A.C.S. Crescimento e quebra de dormência de sementes em *Ischaemum rugosum* com hipoclorito de sódio. In: REUNIÃO ANUAL DA SBPC, 49, Belo Horizonte, 1997. **Anais**, comunicações. v. 2. Belo Horizonte, Sociedade Brasileira para o Progresso da Ciência, UFMG. 1997. p. 11.

MONDAL, M.H.; BRUN, W.A. & BRENNER, M.L. Effects of sink removal on photosynthesis and senescence in leaves of soybean (*Glycine max* L.) plants. **Plant Physiology**, 61:394-397, 1978.

RADFORD, P.I. Growth analysis formulae – Their use and abuse. **Crop Science**, 7:171-175, 1967.