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WRINKLEDGRASS AND RICE INTRA AND INTERSPECIFIC COMPETITION[1]

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ABSTRACT – Wrinkledgrass (*Ischaemum rugosum* Salisb.) has been reported to infest rice (*Oryza sativa* L.) in many parts of the world; its populations have increased in irrigated rice of Maranhão State of Brazil in recent years. An experiment was conducted in pots to study the effects of competition on dry matter accumulation and yield of both rice and wrinkledgrass at 60% shading. Intraspecific competition was assessed in monocultures (one to five plants per pots) of rice and wrinkledgrass, whereas interspecific competition was evaluated by cultivating a mixture of both species (1+4, 2+3, 3+2,and 4+1 plants per pot, rice and wrinkledgrass, respectively), keeping the plant density in the experimental unit constant. Reductions in grain yield and biomass production were similar in both rice and wrinkledgrass owing to intraspecific competition. Phytomass production was decreased by 46% and grain yield by about 60%. Interspecific competition effects were more evident in rice than in wrinkledgrass. In rice, total biomass production was decreased by as much as 78%, leaf area by 75%, and grain yield by 60%; whereas in wrinkledgrass these reductions ranged from only 27% for total dry matter to less than 10% for spikelet yield. It was concluded that wrinkledgrass is a stronger competitor than rice, in the weed-crop mixture perhaps because the crop competition has a low effect on wrinkledgrass root biomass production, even when it was grown under a high level of shading.

Additional index terms: ecophysiology, *Ischaemum rugosum*, Maranhão, *Oryza sativa*, substitutive experiments, weeds.

COMPETIÇÃO INTRA-ESPECÍFICA E INTERESPECÍFICA ENTRE CAPIM MACHO E ARROZ

RESUMO – O capim macho (*Ischaemum rugosum* Salisb.) é uma planta invasora do arroz (*Oryza sativa* L.) em vários países. No Estado do Maranhão, as áreas arrozeiras infestadas com *I. rugosum* tem aumentado nos últimos anos. Um experimento foi conduzido em vasos visando estudar o efeito da competição na produção de biomassa e rendimento do arroz e do *I. rugosum*, sob 60% de sombreamento. A competição intra-específica avaliou-se em monoculturas (uma a cinco plantas por vaso), enquanto que a competição interespecífica estudou-se cultivando ambas espécies em misturas (1+4, 2+3, 3+2 e 4+1 plantas por vaso de arroz e *I. rugosum*, respectivamente), mantendo constante o número de plantas por vaso. A competição intra-específica teve um efeito similar em ambas as espécies. Assim, a produção de biomassa foi reduzida em 46% e o rendimento de sementes em aproximadamente 60%. A competição interespecífica teve efeitos mais expressivos no arroz do que no *I. rugosum*. No arroz, as reduções foram de 78% para a produção de fitomassa, 75% para a área foliar e de 60% para o rendimento de sementes. No entanto, essas reduções no *I. rugosum* oscilaram entre apenas 27% para a produção de biomassa até menos de 10% para o rendimento de sementes. Concluiu-se que na mistura arroz-*I. rugosum*, a invasora compete melhor do que o arroz, provavelmente por apresentar pouca redução na produção de raízes, ainda quando cultivada sob alto sombreamento.

Termos adicionais para indexação: ecofisiologia, experimentos substitutivos, *Ischaemum rugosum*, Maranhão, *Oryza sativa*, plantas invasoras.

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INTRODUCTION

Wrinkledgrass (*Ischaemum rugosum* Salisb.) has been reported to infest irrigated rice (*Oryza sativa* L.) in many parts of the world (Itoh, 1991; Lubigan & Moody, 1990; Moody, 1993). In the State of Maranhão, Brazil, fields infested with wrinkledgrass have increased in recent years, making wrinkledgrass one the major weeds affecting rice, partly because of its competition for water, light and nutrients. New fields are infested by wrinkledgrass mainly by seeds. This is favored because the life cycle of *I. rugosum* seems to adapt to changing environmental conditions (Marenco & Reis, 1998; Silva, 1998),with delays under shady conditions, and also because of the similarity in shape and size observed between wrinkledgrass seeds and rice seeds. Thus, wrinkledgrass viable seeds can be gathered at rice harvest time, despite some variation in the rice plant cycle. As a result, it is difficult to produce rice seeds free of weeds from wrinkledgrass infested fields. Therefore, it appears that wrinkledgrass has become a specialized rice weed, and highly adapted to irrigated rice fields. Its glumes induce seed dormancy (Marenco & Reis, 1997), which may delay by some weeks the germination of seeds. Therefore, its control by either pre-emergence or post-emergence applied herbicides is difficult. In addition, high crop rates have been observed under shady conditions (Marenco & Reis, 1998; Silva, 1998), indicating that the usual delay in germination does not appear to be a disadvantage for wrinkledgrass growth and its competition with rice.

Several methods have been developed to study plant competition in weed-crop systems; all of them involve the individual effect of one species on another. The different approaches include: (1) additive, (2) systematic, (3) neighborhood, and (4) substitutive experiments. The substitutive approach, also known as the replacement series, is especially recommended in research that aims to assess the relative effects of intra and interspecific competition, rather than the absolute effects of interference (Radosevich, 1987). A better understanding of the ecophysiology and life cycle of weeds, and their interaction with crops is important for defining sustainable management strategies. Therefore, the objectives of this study were to evaluate the effects of competition on yield and dry matter production of rice and wrinkledgrass.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Station of the State University of Maranhão in São Luís, MA (02°35'S; 44°10'W; 25 masl) between April and August 1998. Solar radiation (mean ± SE) under open sky was 16.8 ± 0.5 $MJm^{-2}\,d^{-1}$ (PY-23150/LI-1000 datalogger, Licor, Nebraska, U.S.A.). Air temperature ranged from 25°C at night to 38°C during the day and relative humidity oscillated from 60% to about 100%. The plants were cultivated under greenhouse conditions, at 60% shading provided by black nylon shade cloth woven as a screen. They were grown in polystyrene pots containing 20 kg of soil. The soil was fertilized with 12.5 mg of N; 25 mg of P; and 12 mg of K per kilogram of soil applied as urea, phosphoric oxide, and potassium chloride, respectively, and amended with lime (1.25 g/kg of soil). To make root separation by species at harvest time possible, the substrate was vertically halved with a polystyrene sheet, 5 mm in thickness and containing six 3-mm holes per square decimeter to permit exchange of water and dissolved substances between both sides of the pot.

Before planting, dormancy of wrinkledgrass seeds was removed (Marenco & Reis, 1998). Thereafter, the seeds were washed with tap water, germinated in 40-ml vessels with the amended soil, and one week later transplanted to the final environment. Rice and wrinkledgrass monocultures were cultivated at populations of one to five plants per pot. In addition, plants of both species were grown in mixtures at the following densities (plants/pot): one plus four, two plus three, three plus two, and four plus one, rice and wrinkledgrass, respectively. In this way, the relative proportions of the components of the mixtures were varied, but total density was kept constant (Kropff & Lotz, 1993). To minimize moisture stress the plants were irrigated daily at 6-h intervals with an automatic sprinkler system, which kept the soil near field capacity during the experiment. The design used in the experiment was a randomized complete block with three replications.

At harvest time, plant parts were separated in culms, leaves and roots, and dried at 72°C in a forced-air oven until constant mass, and weighed. Leaf area was measured with a leaf area meter (LI - 3100, Licor, Nebraska, U.S.A.). To conserve the viability of seeds, they were dried at 40°C for 48 h. At the highest density (five plants per pot), the relative intraspecific competition (I_1) was estimated as follows:

$$I_1 = (((A_1 \cdot K) - B_5)/(A_1 \cdot K)) \cdot 100 \qquad \text{(Equation 1)}$$

where, A_1 is the biomass production of one plant cultivated alone; B_5 is the total biomass of five plants in monoculture, and K is the constant that represents the number of plants at the highest density (K=5). Thus, $A_1 \cdot K$ is the expected growth of five plants without competition. Furthermore, the relative interspecific competition (I_2) of the species X against Y was calculated by the formula:

$$I_2 = ((A_1 - C_1)/A_1) \cdot 100 \qquad \text{(Equation 2)}$$

Where A_1 is the biomass production of one plant in monoculture (e.g., species X at 1 plant/pot), and C_1 is its biological yield when it is grown in mixture at the same density of monoculture (e.g., species X and Y at one and four plants per pot, respectively).

RESULTS AND DISCUSSION

Roots

Root biomass production was reduced more in rice (52%) than in wrinkledgrass (12%), because of the

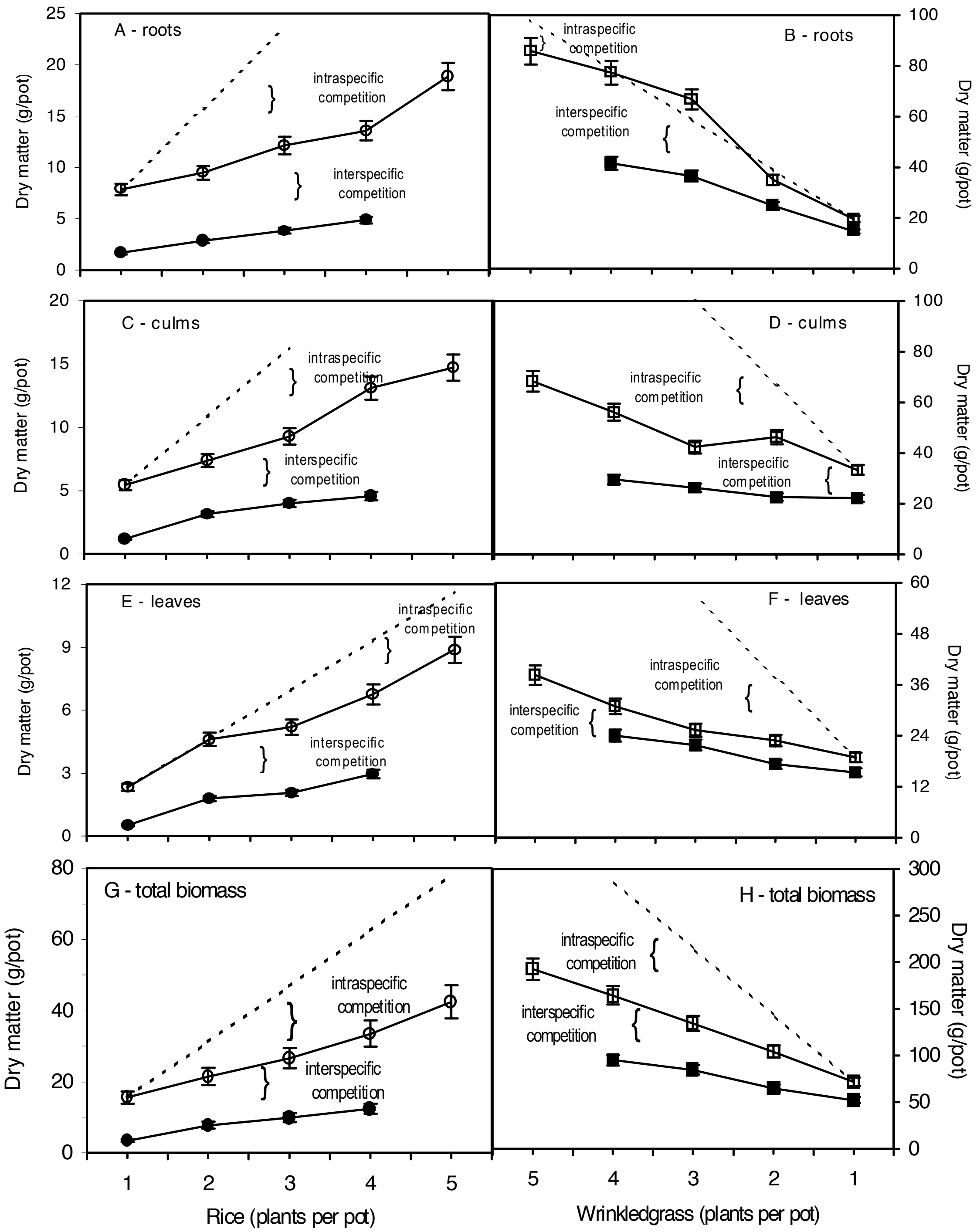

FIGURE 1- Dry matter of roots (A, B), culms (C, D), leaves (E, F), and total biomass (G, H) of rice (❍,●)and wrinkledgrass (☐, ■) in monoculture (open symbols) and mixture (solid symbols). The dotted lines represent the expected biomass (Y) without competition. The equations of the lines are: Y(A) = 7.9P; Y(B) =19.6P; Y(C)=5.4P; Y(D)=33.3P; Y(E)=2.3P; Y(F)=18.9P; Y(G)=15.6P; Y(H)=71.9P; where *P* is the density of plants.

intraspecific competition (Table 1; Fig. 1A,B). The interspecific competition also produced a lower effect on wrinkledgrass (25%) than on rice (79%). Since the weed interference on rice was about three times greater, it is probable that, at least partly, the effect of wrinkledgrass on rice root production was also caused by organic compounds released from the root, and not only by competition for growth factors, and light competition in the shoot. It has been reported that considerable amounts of exudates may be secreted into the

TABLE 1- Effect of intraspecific and interspecific competition on the relative biomass reduction of rice and wrinkledgrass plant parts.

Plant parts	Intraspecific competition[1]		Interspecific competition[2]	
	Rice (%)	Wrinkled grass (%)	Rice (%)	Wrinkled grass (%)
Roots	52aB	12cD	79aA	25bC
Culms	46aC	59aB	78aA	33aD
Leaves	23bC	59aB	78aA	18cC
Total biomass	46aB	46bB	78aA	27bC

[1] Calculated by Equation 1 as: $(((A_1 \cdot K) - B_5)/(A_1 \cdot K)) \cdot 100$; where, A_1 and B_5 represent the biomass of one and five plants cultivated in monoculture, respectively; K is the number of plants at the highest density (K=5).
[2] Calculated by Equation 2 as: $((A_1 - C_1)/A_1) \cdot 100$; where A_1 and C_1 represent the biomass of one plant in monoculture and mixture, respectively.
Within columns means followed by the same lowercase letter or within rows means followed by the same capital letter do not differ (P = 0.05) according to Duncan's multiple range test.

rhizosphere, mainly under stress factors in the environment (Marschner, 1991). Root exudates may either influence the acquisition of nutrients or contribute towards allelopathy, as most of the identified allelochemicals have been isolated from root exudates (Devi *et al.*, 1997; Marschner, 1991).

Culms

Culm biomass showed a greater reduction in wrinkledgrass (59%) than in rice (46%) on account of intraspecific competition. Nevertheless, culm dry matter was much less decreased in wrinkledgrass (33%) than in rice (78%) owing to the interspecific interference (Table 1; Fig. 1C,D), which is consistent with reports that the height of wrinkledgrass increases with plant density in the mixture with rice (Lubigan & Moddy, 1990). The interspecific effect on rice culm production may be important under field conditions because smaller plants are weaker competitors for light.

Leaves

Competition in monoculture caused less effect on leaf biomass of rice than on leaf dry matter of wrinkledgrass, the reductions being 23 and 59%, in rice and wrinkledgrass, respectively (Table 1). Moreover, intraspecific competition among rice plants was only observed at their highest density (Fig. 1E). The effect of competition on wrinkledgrass was attributed to the relatively greater amount of assimilates allocated for root production, which probably reduced the availability of carbon to the shoots. In the mixtures, however, weed competition lowered sharply the relative leaf dry matter of rice (78%) in comparison to wrinkledgrass (18%). Leaf area was reduced in a similar pattern by intraspecific competition in both species. The reductions were 51% in rice and 55% in wrinkledgrass (Table 2). Notwithstanding, leaf area was substantially more decreased in rice (75%) than in wrinkledgrass (17%), in the mixture cropping (Table 2). These values were similar to those observed for reductions in leaf biomass because of interspecific competition, indicating that the specific leaf area was kept constant in the weed-crop system.

Total biomass and yield

On average, the total biomass per plant was about four times greater in wrinkledgrass (72 g) than in rice (16 g). Both in rice and wrinkledgrass a phytomass reduction of 46% was recorded owing to intraspecific competition (Table 1; Fig. G,H). As observed for plant

TABLE 2- Leaf area (mean ± SE) of rice and wrinkledgrass grown in monoculture and mixture as affected by intraspecific and interspecific competition.

Density (plants/pot)		Rice		Wrinkledgrass	
		Monoculture	Mixture	Monoculture	Mixture
Mono- culture	Mixture[1]	$(m^2/pot) \times 10^{-2}$	$(m^2/pot) \times 10^{-2}$	$(m^2/pot) \times 10^{-2}$	$(m^2/pot) \times 10^{-2}$
1	1+4	4.5 ± 0.5	1.1 ± 0.1	40.7 ± 1.5	61.4 ± 2.1
2	2+3	7.1 ± 0.6	3.2 ± 0.1	47.8 ± 1.6	51.0 ± 4.0
3	3+2	8.0 ± 0.3	3.6 ± 0.1	57.1 ± 4.0	40.1 ± 3.1
4	4+1	9.2 ± 0.1	3.1 ± 0.1	73.8 ± 3.2	33.5 ± 5.1
5	-	11.0 ± 0.6	-	91.2 ± 5.2	-
F test		*	*	*	*
Reduction (%)		51.1[2]	75.5[3]	55.2	17.2

*Significant at $P \leq 0.05$.
[1] Rice plus wrinkledgrass.
[2]Calculated by Equation 1 as: (((4.5 x 5) – 11.0)/(4.5 x 5)) x 100.
[3]Calculated by Equation 2 as: ((4.5 - 1.1)/4.5) x 100.

TABLE 3- Yield (mean ± SE) of rice and wrinkledgrass gown in monoculture and mixture as affected by intraspecific and interspecific competition.

Density		Rice		Wrinkledgrass	
(plants/pot)		monoculture	mixture	monoculture	mixture
Mono- culture	Mixture[1]	Seed yield (g/pot)	Seed yield (g/pot)	Spikelet yield (g/pot)	Spikelet yield (g/pot)
1	1+4	5.7 ± 0.7	2.3 ± 0.4	3.2 ± 0.1	6.6 ± 0.4
2	2+3	7.3 ± 1.1	4.4 ± 0.6	4.3 ± 0.1	4.8 ± 0.3
3	3+2	7.5 ± 0.2	6.6 ± 0.7	6.3 ± 0.2	4.0 ± 0.4
4	4+1	8.1 ± 0.1	7.6 ± 0.3	8.0 ± 0.2	2.9 ± 0.3
5	-	10.0 ± 0.6	-	10.6 ± 0.4	-
F test		*	*	*	*
Reductions (%)		64.9[2]	59.6[3]	56.0	8.1

*Significant at $P \leq 0.05$.
[1]Rice plus wrinkledgrass.
[2]Calculated Equation 1 as: (((5.7 x 5) – 10.0)/(5.7 x 5)) x 100.
[3]Calculated Equation 2 as: ((5.7 - 2.3)/5.7) x 100.

parts, weed-crop competition decreased dry matter more drastically in rice (78%) than in wrinkledgrass (27%). Moreover, in rice all the plant parts were greatly affected to the same extent (about 78%) by interspecific competition, but in wrinkledgrass, none of them was drastically influenced by rice competition, with the culms and leaves the parts most (33%) and least (18%) affected, respectively. Intraspecific competition influenced similarly the grain yield in both species. The yield of rice was reduced by about 60% as a result of interspecific competition, which confirms the importance given to this weed at the farm level. On the other hand, rice competition had a small effect on the spikelet yield of wrinkledgrass, less than 10% (Table 3). The comparative advantage of wrinkledgrass over rice may be ascribed at least partly to its extensive root system, which represented about 45% of the whole plant biomass (Fig. 1 B,H), and also to its C_4 photosynthetic pathway for carbon assimilation (Watson & Dallwitz, 1992). Because the relative effect of wrinkledgrass upon rice growth was about three times greater than the reciprocal effect, the possible role of allelopathy in the rice-wrinkledgrass interaction should not be ruled out. It was concluded that: (1) root biomass production of wrinkledgrass is little affected by both intraspecific and interspecific competition and (2) wrinkledgrass is a stronger competitor than rice. Further research is needed to determine if the interference of wrinkledgrass on rice involves any allelopathic effect in addition to competition for light and other factors essential for growth.

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