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Density Dependent Competitive Interactions between Weedy Rice (*Oryza Sativa F. Spontanea*) and Cultivated Rice in Sri Lanka

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Abstract

Weedy rice (*Oryza sativa f. spontanea*) is a major threat in many rice-growing areas in tropical Asia including Sri Lanka since 1990s. Even though numerous scientific investigations on origin, diversity, distribution and controlling technique of weedy rice is available, there is a need in research pertaining to interactions of weedy rice with cultivated rice varieties under local situations. A green-house experiment was conducted at The Open University of Sri Lanka using an improved-cultivated rice variety (Bg379-2) with varying ratios of cultivated: a black-hulled weedy rice bio-type (0, 20, 40, 60 80 100/pot). Influence of weedy rice on growth and yield of Bg379-2 was assessed through 2, 4, 6 and 8 weekly measurements of plant height and number of tillers. Dry shoot-and root- biomass were determined through oven-dried uprooted plants at 8 weeks after sowing (8WAS). Yield components of Bg379-2 including 100 grain weight/plant, number of panicles/plant, number of grains/panicle and yield weight/plant were calculated. Data were statistically analyzed using SAS Ver. 9.0. Significant interactions between weedy rice bio-type and Bg379-2 were apparent after 6 weeks after sowing (WAS). A yield loss of 30% was observed even when at a percentage of 20 of weedy rice at 20/pot. At 80% plants/pot, weedy rice resulted in 90% loss of yield of variety Bg379-2. Further research is recommended to determine weedy rice density on growth and yield components of different new improved rice varieties.

Keywords: Competition; *Oryza Sativa F. Spontanea;* Yield loss; Sri lanka; Weedy rice

Introduction

Weedy rice (Oryza sativa f. spontanea) has become a major threat in many rice-growing areas. This weed is widely distributed in rice growing areas in the world, particularly in South and South-East Asia, South and North America, and Southern Europe [1-3] and leads to high production costs as well as considerable yield reduction [4]. In general, weedy rice (WR) populations diminish farmer's income both quantitatively and qualitatively [5]. At present, WR has reached to a competitive level of infestation to threaten the sustainability of rice cultivation especially in Asian countries.

The flower morphology and brief period of pollen viability of cultivated rice is an adaptation to being a predominantly self-pollinating crop. The wild rice, on the other hand, differ from cultivated rice by having a greater ability for out-crossing having longer styles, stigmas, filaments and anthers, and pollen viability as twice as cultivated rice [1]. Weedy rice, although systematically classified under the same species as cultivated rice, is strongly characterized by its very high seed shattering property and seed dormancy, which apparently enhance the distribution of this species and continuous enrichment of soil seed bank with WR seeds [6].

In Sri Lanka, WR has become a major problem since late 1990 affecting growth and yield of cultivated rice amounting to 30-40% yield loss (about 1,600-2,000kg/ha) despite farmers investing Sri Lankan Rs. 5000-8000/ha for herbicides [7,8]. The growth and competitive ability of WR vary considerably among populations due to differences in plant height, leaf area, or biomass [3]. According to [9], one to three plants/m2 of WR is the threshold infestation level that is required to prevent yield losses in rice, whereas the corresponding density for barnyard grass (*E. crusgalli*) is estimated as 5-10 plants/m2.

As labor and or water costs rises in many Asian countries, transplanting of rice seedlings, the well adapted crop establishment method, has being replaced by direct seeding (DS) where the emergence of WR assumed to have initiated [10]. Direct seeded rice ecosystems provide environments conducive for the emergence and propagation of WR as compared to transplanted rice having standing water that suppress the emergence of WR at the early stages of the crop [11]. Furthermore, selective herbicides to control WR are yet to be identified. Thus, managing WR is a challenging problem for farmers because of its morphological and physiological similarities to cultivated rice. Weedy rice can cause severe yield losses to cultivated rice in relation to the density, type of weedy plants and cultivated varieties [12]. In Malaysia WR caused rice yield loss of 60% to 80% under moderate (15-20 weedy rice panicles/m^2) to high (21-30 panicles/m^2) infestations [4]. Short varieties are usually more susceptible to WR competition than tall ones [13]. Some studies have been conducted to assess the effects of different weed densities. [14] reported that density of 11 weedy rice plants m-2 led to considerable yield loss of 43%. Although a number of scientific investigations on WR origin, diversity, distribution and technique for control are available, researches pertaining to interactions of WR with new improved rice varieties under local conditions are inadequate. In spite of the importance of WR rice as a noxious weed, there is a scarcity of information is available in Asia on the magnitude of the yield and other growth parameters of cultivated rice and WR rice.

An expansion in the area under direct-seeded rice systems in the near future in Asia is expected due to labor and water deficiency [15,16]. In these systems, WR infestation will increase because of the absence of the suppressive effect of standing water during crop emergence. Therefore, it is important to study the effect of the degree of WR infestation on the growth and yield of cultivated rice. The proper understanding of the density dependent competitive interaction between cultivated and WR rice is essential in providing baseline information for farmer-awareness programs and strengthening farmer capabilities of WR management in rice fields in particular, for the preparation of guidance and justification of the costs of WR prevention and control measures. The present study was carried out with the objective to quantify the competitive performance between WR and a new improved rice variety as a function of rice yield and selected growth parameters.

Methodology

Experiments were conducted at The Open University of Sri Lanka. The improved-cultivated rice variety Bg379-2 and a black hulled WR bio-type collected from Matara District in Southern Province of Sri Lanka served as experimental materials. The rice variety Bg379-2 was chosen for the reason that it has been widely cultivated in the District of Matara. The soils were collected from the areas from the rice field where weedy rice bio-type was collected. Collected soils were passed through a 2mm sieve and placed in cement pots of 30x30x30cm. There were no holes in the pots. The weedy rice and cultivated rice (cv. Bg379-2 and a commonly grown variety in Matara District and black hulled WR bio-type) were grown in a replacement series design at proportions (cultivated rice: weedy rice) (%) of 0:100, 20:60, 40:60, 60:40, and 80:20 plants in a pot. The population was grown in 100% proportion considered as no completion and the rest represent the different degrees of completions (Figure 1).

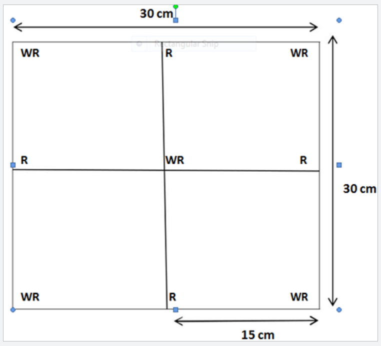

Figure1: A pot representing the placement of weedy rice plants and Bg379-2 rice plants (R-Bg379-2, WR- Weedy rice bio-type).

The plants were fertilized with urea at a rate of 100kg/ha at 14, 28, and 60 days after sowing and pots were maintained at field capacity by irrigating regularly. After crop emergence, 2cm depth of water was maintained until crop maturity. Insect or disease problems were not observed during the experimental period and, therefore no control measures were undertaken.

The influence of WR plants on growth and development of Bg379-2 was assessed through 2, 4, 6 and 8 weekly measurements of important agro-morphological characters, plant height and number of tillers. The dry shoot- and root- biomass were determined through oven drying at 70b °C for 72h of uprooted randomly selected plants at 8WAS. At harvesting stage, the yield components of both Bg379-2 and WR bio-type, including 100 grain weight/plant, number of panicles/plant, number of grains/panicle and yield weight/plant were estimated(data were not given for WR bio-type). Collected data were statistically analyzed using [17]. One way analysis of variance (ANOVA) carried out comparing the treatment means were compared using of Tukey's studenize test (HSD) and difference at $p \leq 0.05$ was considered as statistically significant.

Results and Discussion

Table 1: Plant height of Bg379-2 grown under different densities of weedy rice at different weeks after sowing (WAS). (Means (+SE) within a column followed by the same letter(s) are not significantly different at $p \leq 0.05$).

Plant Height (cm)				
Weedy Rice: Cultivated Rice Ration (%)	2WAS	4WAS	6WAS	8WAS
0	27.0 (0.31)c	46.4 (0.12)a	68.7 (0.32)a	81.9 (0.23)a
20	28.4 (0.15)a	45.8 (0.21)ab	65.1 (0.29)b	77.1 (0.25)b

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40	28.0 (0.47)ab	45.1 (0.21)c	63.9 (0.31)c	76.8 (0.23)b
60	27.4 (0.15)bc	41.2 (0.12)d	58.6 (0.15)d	70.9 (0.29)c
80	27.3 (0.15)c	45.5 (0.26)bc	56.8 (0.31)e	64.9 (0.40)d
Critical value	0.7169	0.9841	0.7648	0.7342

The effect of WR density on Bg379-2 was evidenced by the significant differences observed in plant height and tiller number from 6 WAS onwards (Table1). Comparatively, there was a considerable decrease in plant height at 8 WAS (from 81.9cm in the control to 64.9cm at the highest WR density: 80 WR plant/pot) and number of tillers/plant (from 35 in the control to 22.1 at the highest WR percentage; 80% WR plant/pot). Even at the lowest WR density tested (1WR plants/ pot), the effect is apparent in both parameters (Table 1).

In the present study, the varying densities of WR indicated a considerable reduction in growth parameters and yield components of improved-cultivated rice variety Bg379-2 under the green-house conditions. The plant height and number of tillers of rice plants seem to be less affected at 2 and 4 WAS at different percentages of WR/pot. However, the effect of varying percentages of WR on root and shoot biomass indicated decreasing trends for Bg379-2. This finding agreed with [17] who suggested that the decreasing trends are due to the shading effect of WR, and observed that different sunlight regimes and shoot biomass (stem and leaf biomass) of cultivated rice declined by 57% and 72% when grown in 50% and 75% of shade, respectively. On this basis, it could be suggested that the decrease of dry matter accumulation in cultivated rice variety Bg379-2 is attributed to competition of WR over cultivated rice for capturing the light. The effect of WR percentage on Bg379-2 was obvious on root biomass (65% reduction) than shoot biomass (60% reduction) at 8WAS under the density at 4 plants/pot (Table 2) (Figure 2).

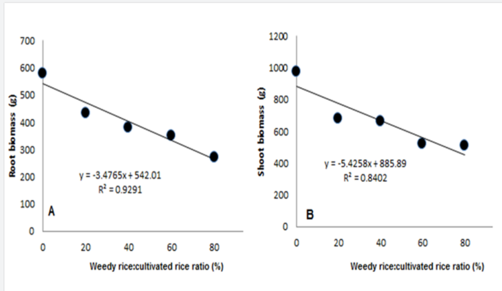

Figure 2: Relationship between the weedy rice: cultivated rice ratio. A. Root biomass and B. Shoot biomass.

Table 2: Root and shoot biomass of Bg 379-2 grown under different densities of weedy rice at 8WAS. (Means (+SE) followed by the same letter(s) in a column are not significantly different at p≤0.05.

Weedy Rice: Cultivated Rice Ratio (as %)	Root Biomass (g/plant)	Shoot Biomass (g/plant)
0	57.81 (0.01)a	97.28 (0.04)a
20	43.41 (0.03)b	67.84(0.01)ab
40	37.96 (0.05)c	66.38 (0.02)ab
60	35.09 (0.03)d	51.96 (0.05)b
80	27.20 (0.02e	50.97 (0.04)b
Critical vale	0.8074	323.66

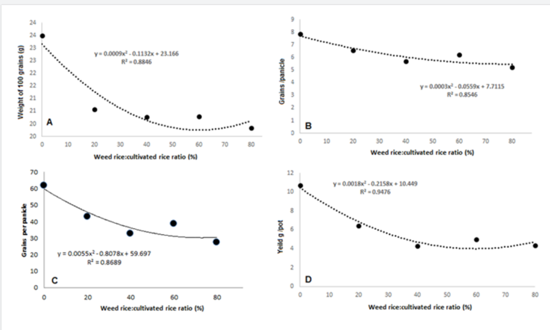

Figure 3: Relationship between the weedy rice: cultivated rice ratio and yield components. A. 100 grain weight/plant (g/plant), B. Number of grains/panicle, C. Number of panicles/plant, and D. yield (g/plant) of improved-cultivated rice variety, Bg379-2.

The effect of density of WR plants on Bg379-2 on the root biomass at 8WAS even under the density of one WR plant/pot suggests that WR roots may exert considerable competitive effect over the improved rice variety and interfere with the nutrient uptake. This finding is further supported by results of detailed comparative study with other weed species as well as with other improved rice varieties carried out by [18]. The overall effect of different WR densities on Bg379-2 was more apparent in the relationships observed for yield components; 100 grain weight/ plant (Figure 3A), grains/panicle (Figure 3B), panicle density (panicles/plant) (Figure 3C) and yield (Figure 3D) (Table 3). Even under lower values of WR densities (1WR plants/pot), there were substantial difference in 100 grain weight (ranged from 61.06 g/ plant to 87.55g/plant), grains/panicle (ranged from 33.0to42.0), panicle density (from 5/plant to 10/plant) and yield reducing from 47.76g/plant to 68.01g/plant. These results indicated that there was a substantial effect of the presence of WR plants on panicle formation and grain filling of the improved rice cultivar, Bg379-2. The relationship observed between the WR density and the yield

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of Bg379-2 showed a yield loss of 90% ((calculated from data available in (Table 3)) at weedy rice density of 4 WR plants/pot. Comparatively higher (90%) yield loss of the cultivated rice even at the weedy rice density at 1WR plants/pot could be attributed to the presence of weedy rice (Figure 3D) (Table 3) (Figure 3).

Table 3: Yield components of Bg379-2 grown under different densities of weedy rice. (Means (+SE) within a column followed by the same letter(s) are not significantly different at p=0.05).

Weedy rice: Cultivated Rice Ratio (as %)	100 Grain Weight (g/plant)	Grains/Panicle	Number of Panicles/Plant	Yield (g/plant)
0	87.55(0.01)a	42.0(0.01)a	10.0(0.01)a	68.01(0.01)a
20	61.06(0.00)b	33.0(0.02)ab	9.0(0.02)b	47.76(0.01)b
40	29.87(0.01)c	32.0(0.02)ab	6.0(0.02)d	21.04(0.02)e
60	15.59(0.02)d	28.0(0.03)b	8.0(0.03)c	18.52(0.03)d
80	6.97(0.01)e	27.0(0.05)b	5.0(0.00)e	6.27(0.05)c
Critical value	0.5131	1.7102	1.5	2.32

As present study revealed, the yield loss of the cultivated rice due to the presence of WR is comparatively higher even at WR density at 1WR plants/pot. Similarly [14] has made observations with 1 WR plants/pot and observed a yield loss of about 43%. These evidences suggest farmers to take controlling measures even at the lowest WR density. However, it is proposed to extend this study to other popular improved-cultivated rice varieties to facilitate the understanding of the differential interactions of WR and cultivated rice and to define action thresholds for WR. A study with two WR variants (WR1 and WR2) revealed that, WR1 reduced the grain yield of cultivated rice by 30% and 47% at densities of 4 and 8 WR plants/pot respectively. The values for WR2 were 66% and 81% respectively [17]. Weedy rice, with its deep root system and height found to interfere with the nutrition and light availability to the new improved rice. In addition, WR, as a newly invading plant to the rice soils may have developed tolerance and adaptability to limited resources for survival and to compete with other plants.

Several studies have shown that competition effects of rice and WR rice are also closely related to the interference duration [19]. Combining the effects of WR density and duration of competition, [12] observed a 50% yield reduction at 24 WR plants/m^2 competed with the crop during the first 40 days after emergence. With the same initial density, the yield loss reached 75% in the case of season-long competition. In a green-house experiment, significant effects on rice plant growth were reported only at the competition longer than 70 days, starting from the emergence [20,21]. In studies of competition using cultivar Mars, inter-varietal competition resulted as being important than intra varietal competition, with the WR acting as the dominant competitor [22]. Considering the yield components, the effect of plant density seems to be significant on the number of rice panicles/plant and florets/panicle, while the percent of filled florets and the grain weight do not seem to be influenced by this parameter [23,24] have observed that interference between rice and WR commenced three weeks after rice emergence, but was not affected by an increase of the nitrogen rate from 100to150kg/ha. According to their study a density of 40WR plants/m^2 resulted in a reduction of 46% and 58% in Ariete and Thaibonnet rice varieties, respectively.

Conclusion

The findings of the present study led to conclude that infestation of WR even at low density of 1WR plant/pot affected the growth of the new improved rice variety, Bg379-2 leading to a considerable loss in yield (30%). However, further research is needed to determine the impact of crop management on the competitiveness of WR under field conditions representing different climatic conditions [25,26].

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