EFFECTS OF DIFFERENT DENSITIES OF ARTIFICALLY INFECTED WEEDY RICE ON YIELD AND YIELD COMPONENTS OF THE COMMON RICE VARIETY OM5451

Nguyen Van Tuan Anh[1], Dong Thanh Liem[1], Ho Le Thi[2], and Nguyen The Cuong[1,*]

[1]Center for Applied Biotechnology and High Technology in Agriculture, CuuLong Delta Rice Research Institute (CLRRI), Tan Thanh Commune, Thoi Lai District, Can Tho City, Vietnam;
[2]Faculty of Plant Protection, College of Agriculture, Can Tho University (CTU), Can Tho City, Vietnam.
[*]Correspondence: cuongnt.clrri@mard.gov.vn (N. T. Cuong).

ABSTRACT

Direct-seeded rice has gained popularity in the past few decades in the Mekong Delta due to its cost-effectiveness and labor efficiency. However, this method has led to an increase in the presence of weeds, especially weedy rice (Oryza sativa f. spontanea), which poses a serious threat to rice production. This study evaluated the impact of different densities (5, 10, 50, and 100 seedlings/m^2) of artificially infected weedy rice on the yield and yield components of the common rice variety OM5451 grown in the Mekong Delta. Results revealed a significant correlation between the density of weedy rice and the loss of yield and yield components of cultivated rice. At a density of 5 seedlings/m^2, the yield decreased by 22.6%, while the highest density treatment (100 seedlings/m^2) caused a loss of up to 60% of the cultivated rice yield. Our findings emphasize the need for effective management of weedy rice infestations to maintain rice yield and quality.

Keywords: Weedy rice, direct-seeded rice, yield loss.

INTRODUCTION

Rice is a crucial food source for over half of the world's population, with a total area of approximately 153 million hectares devoted to its cultivation. More than 90% of rice production is concentrated in Asia. Despite efforts to increase production in recent years, the growth rate remains relatively flat due to several challenges, including the impact of climate change, reduced irrigation water, scarcity of labor, rising input costs, and limited land available for rice farming. In response, rice farmers have gradually shifted from transplanted rice to direct-seeded rice, mainly because of the lower production costs, reduced labor requirements, and better water management. However, this transition has led to a significant increase in weed infestation, particularly weedy rice, which is closely related to direct-seeding cultivation methods. Weedy rice is a potential threat to rice production because it is closely related to cultivated rice. Weedy rice causes serious yield losses, quality degradation, and reduced economic profits in rice production (Chauhan et al. 2015). Despite extensive research on weedy rice in developed and some developing countries, in Vietnam, there have been few studies on the damaging and competitive ability of weedy rice, especially in the Mekong Delta, which is a significant rice-growing area. Therefore, this study was conducted to evaluate the impact of weedy rice on rice yield components at different levels of artificial weed rice infection. The findings of this study will contribute to a better understanding of the impact of weedy rice on rice production in Vietnam and provide a foundation for developing effective prevention and control strategies.

MATERIALS AND METHODS

Plant materials

This study evaluated the damage caused by different densities of weedy rice on a mixture of three weedy rice lines, namely WRKG4, WRCT20, and WRCT76 (collected from Kien Giang and Can Tho) to the popular rice variety OM5451 (certified seed provided by the CuuLong Delta Rice Research Institute). Detailed information on the weedy rice lines used in the experiment is presented in **Table 1**.

Table 1. Description of some key agronomic characteristics of weedy rice lines and cultivated rice varieties OM5451 used in the experiment.

No.	Name	Growth duration (day)	Awn length (mm)	Hull color	Pericarp color
1	WRKG4	84	0-46	Black	Brown
2	WRCT20	91	3.4-70	Yellowish brown	Red
3	WRCT76	84	0	Yellowish brown	Red
4	OM5451	101	0	Pale straw yellow color	White

Experimental design

The experiment was conducted at the CuuLong Delta Rice Institute net house from December 2021 to March 2022. The experimental design employed a completely randomized block design with five treatments, representing different densities of artificially infected weedy rice (0, 5, 10, 50, 100 germinated weedy rice seeds (hereinafter referred to as seedlings)/m²), and four replicates were included. Each treatment plot was 3.6m² in area and 0.4m apart to avoid light shade among treatment. All treatments were allocated in a cement tank with a total area of 24m^2, 4 cement tanks were used corresponding to 4 replications. The recommended fertilizer formulation for the OM5451 variety during the winter-spring crop, consisting of 100kg N-60kg P_2O_5-40kg K_2O, was used. The density of the OM5451 variety was maintained at 100kg/ha or approximately 300 rice seedlings/m². Prior to sowing, both rice and weedy rice seeds were soaked, germinated and evenly distributed in each plot after thorough soil mixing and cleaning to remove contaminated weed seeds and rice seeds. Pre-emergent herbicides were applied to eliminate any remaining weeds and weed seeds. All treatments and replicates received uniform management and care.

Observational parameters were recorded for the OM5451 cultivated rice variety, including yield components and the actual yield. For the weedy rice, the observation parameters included the number of tillers per plant, the total number of weedy rice grains and the ratio of weedy rice plants per total plants. Subsequently, all indicators were standardized to an area of 1m² for calculation and statistical analysis.

Data analysis

The collected data were analyzed using descriptive statistical methods such as calculating means to determine the agronomic and biological characteristics of weedy rice and cultivated rice. Analysis of variance (ANOVA) and the Duncan test were conducted to compare the mean differences between treatments. Excel and Statgraphics 15.0 software tools were employed for data analysis.

RESULTS AND DISCUSSION

Impact of various weedy rice densities on yield components OM5451

The findings presented in **Table 2** indicate that the density of weedy rice significantly impacts various yield components of the cultivated rice OM5451 variety. These components include the number of panicles/m^2, total number of grains per panicle, total number of filled grains per panicle, percentage of filled grains per panicle, and the 1000-grain weight (in grams). Notably, the number of panicles/m^2 emerged as a crucial yield component, exhibiting a statistically significant difference at a 5% significance level.

Among the treatments, the control group with zero weedy rice seedlings/m^2 displayed the highest number of panicles, recording 305 panicles/m^2. Conversely, the treatment with the highest weedy rice density (100 seedlings/m^2) exhibited the lowest number of panicles, with only 207 panicles/m^2. Statistical analysis revealed a significant decrease in the number of panicles/m^2 of OM5451 as the density of weedy rice increased, attaining a 5% significance level. This decline can be attributed to intense competition for resources such as nutrients, water, light, and others, between weedy rice and cultivated rice under similar cultivation conditions and management practices, as previously reported by Xu et al. (2018).

Moreover, the experimental use of the weedy rice lines WRCT20 and WRKG4 revealed their substantial plant height and tillering capabilities (data not shown). Consequently, at higher densities (i.e., treatments with 50 and 100 seedlings/m^2), these weedy rice lines tended to overgrow, further diminishing the tillering ability, photosynthesis, and water and nutrient absorption of the cultivated rice variety OM5451. This outcome aligns with previous studies conducted by Abdullah Al Mamun (2014) on the effects of weedy rice on cultivated rice yield and domestic research by Chin et al. 2008.

Overall, the results in **Table 2** highlight the significant impact of weedy rice densities on various yield components of the OM5451 variety, particularly the number of panicles/m^2. The findings underscore the importance of managing weedy rice populations to ensure optimal rice yield and minimize competition for vital resources.

The total number of grains per panicle of the OM5451 variety exhibited statistical significance among treatments at a 5% significance level. The treatment without weedy rice recorded the highest number of grains per panicle, with an average of 84.5 grains, while the treatment with a high weedy rice density (100 seedlings/m^2) had the lowest number of grains per panicle, with an average of 59.3 grains. The number of grains per panicle of OM5451 decreased progressively as the density of weedy rice increased. The severity of weedy rice infestation directly correlated with a decrease in the total number of grains per panicle of the cultivated rice.

Similarly, the average number of filled grains per panicle of OM5451 was 62.7 grains. The control treatment exhibited the highest average, with 75.3 filled grains per panicle, while the treatment with 100 weedy rice seedlings/m^2 had the lowest average, with 47.8 filled grains per panicle. As the density of weedy rice increased, the average number of filled grains per panicle of OM5451 decreased. This phenomenon can be attributed to the strong competition for water, nutrients, light, and living space between weedy rice and cultivated rice in the same agricultural system, as reported by Burgos et al. (2006), Chauhan and Singh (2016), and Xu et al. (2018). Weedy rice's detrimental effects on the photosynthetic efficiency of rice plants result in insufficient photosynthetic products for seed filling and hinder the transport of storage substances from the stem and leaves to the seeds. These factors ultimately affect the grain filling process and the percentage of filled grains. Zhang et al. (2014) have also reported significant reductions in rice yields when infected with weedy rice, further emphasizing these underlying causes.

The percentage of filled grains per panicle of OM5451 showed a statistically significant difference at a 5% significance level. The control treatment (0 weedy rice seedlings/m^2) recorded the highest percentage of filled grains per panicle, at 88.8%, while the treatment with 100 weedy rice seedlings/m^2 had the lowest, at 80.3%. Consequently, the percentage of filled grains per panicle gradually decreased as the density of weedy rice increased.

The infestation of weedy rice at different densities had varying effects on the 1000-grain weight of OM5451. Statistical analysis revealed significant differences in the 1000-grain weight of OM5451 between the treatments with 50 and 100 weedy rice seedlings/m^2 compared to the treatments with 0, 5, and 10 weedy rice seedlings/m^2. The control treatment without weedy rice recorded the highest weight of 1000 OM5451 grains, at 23.7g, while the treatment with 100 weedy rice seedlings/m^2 had the lowest weight, at 22.2g. The weight of 1000 OM5451 grains started to decrease when the density of weedy rice infection reached only 10 seedlings/m^2.

Table 2. The impact of different weedy rice densities on the yield components of the cultivated rice variety OM5451.

Treatment (weedy rice density, seedlings/m^2)	OM5451's yield components				
	Total number of panicles/m^2	Total number of grains / panicle	Number of filled grains/ panicle	Percentage of filled grain/ panicle (%)	1000-grain weight (g)
0	305[a]	84.5[a]	75.3[a]	88.8[a]	23.7[a]
5	288[b]	79.3[b]	68.5[b]	86.5[b]	23.3[ab]
10	270[c]	76.5[b]	65.0[b]	85.0[b]	22.8[bc]
50	239[d]	69.0[c]	57.0[c]	82.5[c]	22.5[cd]
100	207[e]	59.3[d]	47.8[d]	80.3[d]	22.2[d]
CV%	3.88	3.09	4.17	1.57	1.80

* The data presented are the mean values obtained from four replicates. Means in a column followed by the same letter are not significantly different at a 5% significance level ($P < 0.05$).

Impact of various weedy rice densities on the yield of OM5451

The difference in weedy rice density has a significant impact on the rice yield of OM5451, as measured by the total seed dry weight/m^2 (at 14% moisture content). Based on the statistical analysis results in **Table 3**, the highest total weight of OM5451/m^2 was recorded in the control treatment without any weedy rice interference (314.4g). When the rice plots were heavily infested with weedy rice, the crop yield decreased significantly. The actual yield of OM5451/m^2 was observed to decrease by about 2.5 times in the treatment with a weed rice infestation rate of 100 weed seeds/m^2 compared to the control treatment (0 weedy rice seedlings/m^2), and it decreased by 1.9 times in the treatment with a weedy rice infestation rate of 50 weedy rice seedlings/m^2.

Therefore, different artificially induced weedy rice densities have an impact on the yield components and overall yield of the rice crop, OM5451. The yield components of the rice crop were observed to decrease gradually as the artificially induced weedy rice density increased (**Table 2**). Similarly, the yield of OM5451 rice also decreased proportionally with the level of weedy rice infestation, competition, and interference. The percentage of yield loss increased correspondingly with the weedy rice density. At a density of 5 weedy rice seedlings/m^2, the yield decreased by 22.6%, while at the highest density of 100 weedy rice seedlings/m^2, the yield loss reached nearly 60%.

Table 3. The impact of various weedy rice densities on the yield of the cultivated rice variety OM5451.

Treatment (weedy rice density, seedlings/m^2)	Yield of OM5451 (g/m^2)	Percentage yield loss of the OM5451 variety (%)
0	314.4[a]	-
5	243.5[b]	22.6
10	206.4[c]	34.4
50	183.6[d]	41.6
100	126.4[e]	59.8
CV%	5.19	-

* Means in a column followed by the same letter are not significantly different at a 5% significance level ($P < 0.05$).

Figure 1 illustrates the close correlation between weedy rice densities (seedlings/m^2) and the yield loss of the OM5451 rice variety, with a correlation coefficient of $R^2 = 0.77$. These results are consistent with previous studies by Burgos et al. (2011) and Zhang et al. (2014) when assessing the yield losses caused by weed interference at different weed infestation densities.

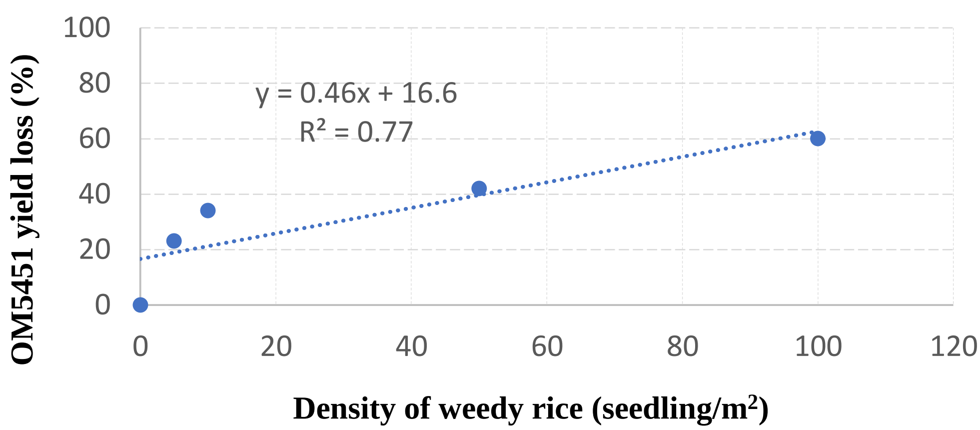

Figure 1. Illustration of the correlation between weedy rice density and the rate of yield loss of the cultivated rice variety OM5451.

The statistical analysis presented in **Table 4** highlights the variations in the average number of weedy rice tillers per plant, the number of weedy rice seeds/m^2, and the percentage of weedy rice infestation (weedy rice plants per total plants) at different densities of weedy rice. These characteristics play a crucial role in the reproductive and infestation capacity of weedy rice. The number of tillers per weedy rice plant is relatively low, averaging at 1.6 tillers per plant. However, the treatments with 50 and 100 weedy rice seedlings exhibit higher numbers of tillers per plant, with 2.4 and 2.2 tillers respectively, compared to the treatments with 5 and 10 weedy rice seedlings/m^2. From the tillering stage onwards, the presence of weedy rice significantly impacts the growth of cultivated rice plants (Chauhan 2013). Various growth parameters of cultivated rice, including plant height, leaf area index, leaf number, and dry shoot weight, can be influenced by the abundance of weedy rice as opposed to intra-specific competition, where weedy rice acts as a superior competitive opponent (Ottis et al. 2005)

Table 4. Several important biological indicators of weedy rice at different artificially induced infestation densities in the experiment.

Treatments (weedy rice density, seedlings/m^2)	Number of weedy rice tillers/plant	Total number of weedy rice seeds/m^2	Ratio of weedy rice plants in the plot (%)
0	0.0^{d}	0^{e}	0.0^{e}
5	1.5^{c}	667^{d}	6.0^{d}
10	2.0^{bc}	1182^{c}	11.0^{c}
50	2.4^{a}	2589^{b}	23.8^{b}
100	2.2^{ab}	4589^{a}	45.0^{a}
CV%	36.49	4.26	5.88

* Means in a column followed by the same letter are not significantly different at a 5% significance level ($P < 0.05$).

The highest seed count is observed in the treatment with 100 weed rice seedlings/m^2, reaching approximately 4589 seeds, while the lowest count is in the control treatment without weed rice. The percentage of weed rice infestation in the experimental plots varies significantly among different weedy rice densities, showing statistically significant differences at a 5% level. The treatment with the highest weedy rice infestation rate (occupying approximately 45% of the plot area) is the one with 100 weed rice seedlings/m^2 (**Figure 2**).

Figure 2. OM5451 plants and weedy rice plants at different densities of weedy rice during the reproductive stage (note: number of seeds/m^2 in the figures referred to as seedlings).

CONCLUSIONS

Different densities of artificially infested rice have varying effects on the yield and yield components of cultivated rice. The yield components of cultivated rice show a gradual decrease as the density of weedy rice infection increases. The yield of cultivated rice OM5451/m^2 at a density of 50 weedy rice seedlings/m^2 is reduced by 1.7 times, and at a density of 100 seedlings, it is reduced by 2.5 times compared to the control treatment without weedy rice infection and damage. There is a strong correlation between the density of weedy rice and the yield loss caused by weedy rice, with a density of 100 seedlings/m^2 resulting in a yield loss of up to 60% for cultivated rice.

CONFLICT OF INTEREST

The authors declare they have no conflicts of interest, either financial or otherwise.

AUTHORS' CONTRIBUTIONS

Nguyen The Cuong and Ho Le Thi were responsible for experimental design and manuscript editing. Nguyen Van Tuan Anh and Dong Thanh Liem conducted the experiment, managed data collection, and performed data analysis.

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ẢNH HƯỞNG CỦA MẬT ĐỘ LÚA CỎ LÂY NHIỄM NHÂN TẠO KHÁC NHAU ĐẾN NĂNG SUẤT VÀ CÁC THÀNH PHẦN NĂNG SUẤT CỦA GIỐNG LÚA OM5451

Phương pháp canh tác lúa sạ thẳng đã trở nên rất phổ biến trong vài thập kỷ qua ở Đồng bằng sông Cửu Long do tính hiệu quả về chi phí sản xuất và tiết kiệm công lao động. Tuy nhiên, phương pháp này đã dẫn đến sự hiện diện của cỏ dại gia tăng qua các vụ canh tác, đặc biệt là lúa cỏ (Oryza sativa f. spontanea), gây ảnh hưởng lớn đến năng suất và sản lượng lúa gạo. Nghiên cứu này đánh giá ảnh hưởng của việc lây nhiễm lúa cỏ nhân tạo ở các mật độ khác nhau (5, 10, 50 và 100 cây lúa cỏ/m^2) đến năng suất và các thành phần năng suất của giống lúa trồng phổ biến ở ĐBSCL là OM5451, và khả năng sản sinh hạt của lúa cỏ. Kết quả nghiên cứu đã cho thấy mối tương quan đáng kể giữa mật độ lúa cỏ và sự thất thoát về năng suất và các thành phần năng suất của giống lúa OM5451. Cụ thể, ở mật độ 5 cây lúa cỏ/m^2, năng suất giảm 22,6%, trong khi ở mật độ lây nhiễm cao nhất (100 cây lúa cỏ/m^2) gây thất thu năng suất lúa trồng lên đến 60%. Đồng thời ở mật độ lúa cỏ càng cao, số lượng hạt lúa cỏ rơi rụng và tồn lưu trong đất tăng lên đáng kể. Qua kết quả nghiên cứu này cho thấy cần thiết và nhanh chóng có các giải pháp quản lý hiệu quả lúa cỏ để giảm thiểu thiệt hại do lúa cỏ gây ra.

Từ khóa: *Lúa cỏ, lúa sạ thẳng, thất thoát năng suất.*