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Allelopathic effect of *Oryza sativa* L. (Rice) straw on *Echinochloa crus-galli* L. (Barnyard grass) and *Ludwigia octovalvis* (Primrose-willow)

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Abstract

This experimental research determined the allelopathic effects of *Oryza sativa* L. straw filtrate and fine cuttings on the seed germination, seedling emergence, growth, and dry weight of *Echinochloa crus-galli* L. and *Ludwigia octovalvis*. It compared the average percent inhibition of *Oryza sativa* L. (rice) straw fine cuttings treatments against the positive and negative treatments. It employed the Completely Randomized Design (CRD) using five different treatments for each of the two weeds and was conducted under laboratory conditions and improvised greenhouse. All data were analyzed using appropriate statistical tools. Findings of the study reveal that the *Oryza sativa* L. straw filtrate can inhibit the germination of *Echinochloa crus-galli* L. and *Ludwigia octovalvis* seeds. Similarly, the rice straw fine cutting soil mix reduced the seedling emergence, height, leaf number, leaf area, and dry weight of the two weeds. The seed germination and seedling emergence were found to be significantly associated with the treatments. The allelopathic effects of the treatments were significantly different along emergence, growth, and dry weight of the weeds. The highest concentration of *Oryza sativa* L. straw fine cuttings (30 g) indicated the greatest inhibitory effects. The study concluded that the rice straw filtrate and fine cuttings can potentially inhibit the germination and growth of *Echinochloa crus-galli* L. and *Ludwigia octovalvis* seeds. It was recommended to further establish evidences about the inhibitory effects of rice straw wastes using field trials. The use of rice straw wastes was recommended to be integrated as components of environment-friendly weed control and management practices.

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Introduction

Rice is the most important crop worldwide, with about more than 1.5 × 108 hm2 of land being cultivated for its production. Globally, rice provides approximately 20 percent of the caloric intake to more than 60 percent of the population in the world. Majority of Asian countries like Philippines and other rice-consuming regions of the world depend on rice as the main crop and staple food. Eighty percent of Filipinos has rice as their staple food and primary source of calories (Khanh *et al.*, 2015).

The Philippines is ranked eighth in the production of rice around the world. Rice is a crop that is grown in the different islands of the country. The main agricultural products of the Philippines are palay (rice), corn, sugar cane, coconut, bananas, pineapples, mangoes, coffee, abaca (a plant resembling a banana) and tobacco (Aquino, 2023). The Philippines per capita rice consumption rose from 93.2kg per year in 1995 to 123.3kg per year in 2009. Similarly, per capita caloric intake from rice rose from 917 kcal per day in 1995 to 1, 213 kcal per day in the same year (Hoang 2014). Although rice is cultivated at such a massive scale, its yield is prone to significant loss because of infestation by weeds, pests, and diseases. Out of these, yield loss because of weed infestation was reported to be more than the total loss caused by diseases and pests (Asaduzzaman *et al.*, 2011). The Philippine Statistics Authority (2019) reported that the country's total rice production over the last three years was down by an average of -1.2 percent annually.

Brown *et al.* (2018) reiterated the low agricultural productivity of the Philippines and identified possible reasons for it. One of which are pests and diseases which threaten the agricultural productivity in the Philippines. Weed infestation is a deep-seated problem in agriculture worldwide. Weeds cause reductions in yield and quality and remain one of the biggest problems in crop production. Even with the intensive use of synthetic herbicides, weeds cause 10 percent to 30 percent crop losses. There are numerous weed species in rice and they are important biotic constraints. They can severely affect rice production if not properly managed. Competition for light occurs throughout the growth of the plant. The light requirement varies with crop growth stage. Weeds compete with rice by growing faster and shading rice leaves with their large, horizontal leaves. The shading effect is most severe during the seedling stage. The period 30–45 days after planting is also critical for serious weed competition; from 45 to 60 days, rice plants are able to suppress later germinating weeds. Low light intensity after flowering decreases rice dry matter.

According to Heinrichs and Muniappan (2017), weeds reduce yield through competition for nutrients, soil moisture and sunlight, raise production and processing expenditures by increasing the cost of control, replacing nutrients and water loss, lower rice grain quality by causing admixtures of wild rice and other weed seeds that reduce the market value of rice, and reduce flow of water in irrigation and drainage channels resulting in seepage, flooding, and breaks in canal banks. Without weed control, crop losses reach as high as 45 percent to 95 percent, depending on the ecological and climatic conditions (Ampong-Nyarko *et al.*, 2010). Therefore, in order to reduce the yield loss of rice due to weed infestation, different herbicides are reported to be incorporated in rice fields (Ravi & Mohankumar, 2007).

Synthetic herbicides have been used to control weeds for many years, but their hazards against the environment and public health have raised questions about the farmer's reliance on such chemicals (Shibayama, 2010). In conventional agriculture, weed control using herbicides is not only an expensive practice; it is also harmful to the environment causing human exposures that could lead into serious and life-threatening health effects including acute and chronic neurotoxicity (insecticides, herbicides, fumigants), lung damage (paraquat), chemical burns (anhydrous ammonia), and infant methemoglobinemia (nitrate in groundwater). Since, extensive area is covered by rice cultivation, heavy pesticide (insecticides- 1.02 a.i/hm2 , herbicide-0.19 a.i/hm2, fungicides-0.51 a.i/hm2) load enters the environment and get accumulated via leaching and biomagnifications (Shende & Bagde, 2014).

The negative impact of commercial herbicides makes it desirable to search for other alternative weed management options (Nirmal Kumar *et al.*, 2010), and allelopathy seems to be one of the options (Tesio & Ferrero, 2010).

Baltazar (2017) identified two major rice weeds in the Philippines. These are *Sphenochlea zeylanica Gaertn.* and *Echinochloa crus-galli* L. *Beauv.* Baltazar (2017) found out that in the 1990s, *Echinochloa crus-galli* L. evolved resistance to butachlor and propanil in rice monocrop areas where both herbicides were used continuously for 7–9 years.

Some different types of cancers have been linked to exposure to various herbicides, particularly hematopoietic cancers. Immunologic abnormalities and adverse reproductive and developmental effects due to pesticides also have been reported (Melander *et al.*, 2014; Melander, 2012; Lotz *et al.*, 2010). Concern about herbicides polluting ground and surface water, human health risks from herbicide exposure or residues, effects on the flora and fauna, development of herbicide resistance and the lack of approved and effective herbicides for major field crops such as rice and vegetables are the major factors driving the present and increasing interest in non-synthetic chemical weed control (Melander *et al.*, 2014; Melander, 2012; Lotz *et al.*, 2010).

Allelopathy is a natural ecological phenomenon. It is an environment-friendly technique, which may prove useful as a unique tool for weed management (Molish, 2007; Rice, 2010). It involves direct or in direct (harmful or beneficial) effects of one plant upon another through the production of secondary chemical compounds called allelochemicals that technically escape into the environment in sufficient quantity and with enough persistence to cause the enrolled effects (Macias *et al.*, 2012; Zeng *et al.*, 2013).

Research showed that the use of crops with allelopathic properties in agriculture is currently being used, e.g., as components of crop rotations, for intercropping, as cover crops, or as green manure. The suitable application of allelopathy toward the improvement of crop productivity and environmental protection through environmental-friendly control of weeds, insect pests, crop diseases, conservation of nitrogen in crop lands, and the synthesis of novel agrochemicals based on allelochemicals has attracted much attention from scientists engaged in allelopathic research (Haider *et al.*, 2015; Khanh *et al.*, 2013; Reeves *et al.*, 2015; Cheema *et al.*, 2014; Farooq *et al.*, 2014; Silva *et al.*, 2014; Wezel *et al.*, 2014; Cheema & Khaliq, 2013; Mahmood *et al.*, 2013; Singh *et al.*, 2013; Wortman *et al.*, 2013; Yildirim & Guvenc, 2008; Iqbal *et al.*, 2007).

Rice residues (leaves, straw, hull) are known to have allelochemicals. Paddy weeds such as barnyard grass (*Echinochloa crus-galli* L.), oval-leafed pondweed (*Monochoria vaginalis*), redstem (*Erodium cicutarium*), and duck salad (*Heteranthera limosa*) can be suppressed by rice cultivars with high allelopathic property (Dilday *et al.*, 2009; Takeuchi *et al.*, 2011).

Utilization of rice residues in paddy fields has long been recognized as an important source to improve the status of organic matter of soil and was also reported to reduce the emergence of weeds (Narwal, 2010). However, the effect of rice straw extract in soil on the growth of *Echinochloa crus-galli* L. (barnyard grass) is not yet established. Through the survey of the literature, the researcher has not found evidence that used the methanol extract of rice straw as an alternative method to control the growth of barnyard grass in rice fields. Thus, the present study aimed to determine the allelopathic effect of rice straw extract on the growth of *Echinochloa crus-galli* L. (barnyard grass) and *Ludwigia octovalvis* (primrose-willow).

With the results of various relevant studies using rice cultivars as integral component of weed management systems, the current study aimed to provide evidences of the potential of filtrate and fine cuttings from *Oryza sativa* L. (rice) in controlling the growth of barnyard grass and primrose-willow weed.

This study aimed to propose an alternative method of improving rice production by offering an eco-friendly and a harmless procedure of weed management in most agricultural systems. Through the results of this research, the university can formulate a relevant extension program which can be offered to the farmers in the communities surrounding the university where they can be taught of managing weeds growth in their rice fields using natural, risk-free, and inexpensive method.

Materials and methods

This experimental study employed the completely randomized design (CRD) involving five treatments including the positive treatment and negative treatment for each of the weed varieties. For the *Oryza sativa* L. (rice) straw filtrate, treatments used were T_0 (negative treatment – distilled water), T_1 (positive treatment - 0.6% Machete® 5G (Butachlor)), T_2 (0.4% *Oryza sativa* L. (rice) filtrate), T_3 (0.6% *Oryza sativa* L. (rice) filtrate), and T_4 (0.8% *Oryza sativa* L. (rice) filtrate).

Each treatment was replicated three times. And for every replicate, five petri dishes which contained 20 seeds each were set up. For the *Oryza sativa* L. (rice) straw fine cutting soil mix, the treatments used were T_0 – distilled water + 1kg sterilized field soil + 20 seeds of *Echinochloa crus-galli* L. (barnyard grass)/ *Ludwigia octovalvis* (primrose- willow) weeds (negative treatment), T_1 – recommended rate (0.142 g) Machete® 5G (Butachlor) soil mix + 1kg sterilized field soil + 20 seeds of *E. crus-galli* L. (barnyard grass)/*Ludwigia octovalvis* (primrose-willow) weeds (positive treatment, commercial synthetic herbicide), T_2 – 20 g *Oryza sativa* L. (rice) fine cutting soil mix + 1kg sterilized field soil + 20 seeds of *Echinochloa crus-galli* L. (barnyard grass)/ *Ludwigia octovalvis* (primrose-willow) weeds, T_3 – 25 g *Oryza sativa* L. (rice) fine cutting soil mix + 1kg sterilized field soil + 20 seeds of *Echinochloa crus-galli* L. (barnyard grass)/*Ludwigia octovalvis* (primrose-willow) weeds, and T_4 – 30 g *Oryza sativa* L. (rice) fine cutting soil mix + 1kg sterilized field soil + 20 seeds of *Echinochloa crus-galli* L. (barnyard grass)/*Ludwigia octovalvis* (primrose-willow) weeds. Each treatment has three replicates and each replicate was sown with 20 seeds of each of the weed varieties.

The study was conducted from September to December 2019 at San Miguel, Agoo, La Union for the rice fine cutting soil mix while the 20-day laboratory experiment involving the rice straw filtrate was conducted at the Microbiology Laboratory of the College of Arts and Sciences at DMMMSU-SLUC, Agoo, La Union in November 2021. The experiment observed proper protocols and followed scientific procedures from the plant identification and seed collection until the counting of the number of seed germination, seedling emergence, and the measurement of growth parameters and dry weight of *Echinochloa crus-galli* L. (barnyard grass) and *Ludwigia octovalvis* (primrose-willow).

The data on the seed germination of *Echinochloa crus-galli* L. (barnyard grass) and *Ludwigia octovalvis* (primrose-willow) weeds were counted from all the replicates per treatment. For the treatments using *Oryza sativa* L. (rice) straw fine cuttings in soil, 20 samples of germinated seeds of *Echinochloa crus-galli* L. (barnyard grass) and *Ludwigia octovalvis* (primrose-willow) weeds from the three replicates per treatment were randomly selected for data gathering, particularly in plant parameters on height, leaf number, leaf area, and dry weight. The data gathered were analyzed using appropriate statistical tools through the SPSS Statistical Software v. 25.

Results and discussion

Allelopathic effects of Oryza sativa L. *(rice) straw filtrate on Echinochloa crus-galli* L. *(barnyard grass) weed*

This study looked into the effects of *Oryza sativa* L. (rice) straw filtrate on *E. crus- galli* L. (barnyard grass) and *Ludwigia octovalvis* (primrose-willow) weeds. Table 1 shows the seed germination of *Echinochloa crus-galli* L. (barnyard grass) doused with *Oryza sativa* L. (rice) straw filtrate using petri dishes. It can be seen from the table that *Echinochloa crus-galli* L. (barnyard grass) seeds started to germinate on the sixth and eight days only of the experiment for the negative treatment which used distilled water. However, no seed germination was further recorded on the succeeding days of the experiment. The positive treatment using 0.6 percent Machete®5G (Butachlor), a commercially available herbicide, did not indicate any seed germination for the entire duration of the experiment.

Table 1. Number of *Echinochloa crus-galli* L. (Barnyard grass) seeds that germinated.

	T0 distilled water (negative treatment)	T1 0.6% Machete® 5G (Butachlor) (positive treatment)	T2 0.4% *Oryza sativa* L. (rice) filtrate	T3 0.6% *Oryza sativa* L. (rice) filtrate	T4 0.8% *Oryza sativa* L. (rice) filtrate
Day 2	0	0	0	0	0
Day 4	0	0	0	0	0
Day 6	3	0	0	1	0
Day 8	3	0	0	1	4
Day 10	0	0	0	0	0
Day 12	0	0	0	0	0
Day 14	0	0	0	0	0
Day 16	0	0	0	0	0
Day 18	0	0	0	0	0
Day 20	0	0	1	1	0

In the case of the treatments involving the different concentrations of *Oryza sativa* L. (rice) filtrate, T2 recorded only one seed germination on the 20th day of the experiment. On the other hand, three seeds germinated under T3 which are recorded on the 6th, 8th, and 20th days of the experiment. From these data, it can be said that the *Echinochloa crus-galli* L. (barnyard grass) seeds may still germinate even after 20 days of being doused with 0.4 percent or 0.6 percent *Oryza sativa* L. (rice) filtrate which may consequently lead to a higher number of seed germination in T2 and T3.

Further observations of the result of the experiment lead to a different finding in T4. While T4 recorded the highest number of *Echinochloa crus-galli* L. (barnyard grass) seeds that germinated, no more seed germination was noted and observed in the treatment from the 10th day of the experiment and onwards.

Association between the E. crus-galli L. *(barnyard grass) Seed Germination and the Oryza sativa* L. *(rice) Filtrate*

A chi-square test of independence showed that there is a significant association between the seedling emergence of *Echinochloa crus-galli* L. (barnyard grass), $\chi2(4) = 10.431$, $p = 0.034 < 0.05$ and the various concentrations of *Oryza sativa* L. (Rice) straw filtrate. Also, there is a weak association between the treatments and whether the *Echinochloa crus-galli* L. (barnyard grass) seeds germinated or not.

Allelopathic effects of Oryza sativa L. *(Rice) straw filtrate on Ludwigia octovalvis (Primrose-willow) weeds*

The *Ludwigia octovalvis* (Primrose-willow) seeds were also subjected into a laboratory experiment with setup and treatments equivalent to that of the *Echinochloa crus-galli* L. (barnyard grass). As shown in Table 3, generally, there is no seed of *Ludwigia octovalvis* (primrose-willow) that germinated for all the treatments involved in the study. One factor that might have contributed to such result is the age of the seed used in this study.

Table 2. Pearson's chi-square test of independence between the *Echinochloa crus-galli* L. (Barnyard grass) seed germination and the *Oryza sativa* L. (Rice) filtrate.

Test Statistic	Coefficients	Remarks
Pearson's Chi-Square	10.431*	Significant
p-value	0.034	
Cramer's V	0.074	Moderate

*significant at 0.05 level of significance

Table 3. Number of *Ludwigia octovalvis* (primrose-willow) Seeds that Germinated.

	T_0 distilled water (negative treatment)	T_1 0.6% Machete® 5G(Butachlor) (positive treatment)	T_2 0.4% *Oryza sativa* L. (rice) filtrate	T_3 0.6% *Oryza sativa* L. (rice) filtrate	T_4 0.8% *Oryza sativa* L. (rice) filtrate
Day 2 - 20	0	0	0	0	0

As mentioned in the methodology, the *Ludwigia octovalvis* (primrose-willow) weed seeds used in this study were freshly picked and were air dried. According to the study of Oziegbe (2010, as cited by Sumudunie & Jayasuriya, 2019), seeds from the *Ludwigia* species germinate based on some conditions. They have reported that old seeds showed significantly higher germination percentage compared to that of freshly dispersed seeds.

Association between the Ludwigia octovalvis (Primrose-willow) seed germination and the Oryza sativa L. *(Rice) filtrate*

As a consequence of the zero-germination in all the treatments used in this study, it is not possible to determine statistically if each of the treatment is associated to whether the seeds of *Ludwigia octovalvis* (primrose-willow) germinated or not because of the entries equal to zero.

Allelopathic effects of Oryza sativa L. (Rice) straw fine cutting soil mix on Echinochloa crus-galli L. *(Barnyard grass) weed*

Table 4 presents the effects of *Oryza sativa* L. (rice) fine cutting soil mix on the number of seedlings that emerged and the growth of *Echinochloa crus-galli* L. (barnyard grass). Among the three treatments with rice fine cutting soil mix, the treatment with 30 g of rice straw fine cuttings has the least average number of seedlings that emerged. Treatment 4 (T_4) posted an average of 15 seedlings that emerged from all the replicates of the said treatment. In terms of the plant height, leaf number, leaf area, and dry weight of the *Echinochloa crus-galli* L. (barnyard grass), the negative and positive treatment recorded the highest and lowest observations, respectively.

Among the soil mixtures with *Oryza sativa* L. (rice) fine cuttings, T_4 posted the lowest average height while T_2 indicated the highest average height of the *Echinochloa crus-galli* L. (barnyard grass). Similarly, T_4 was found to posit the lowest means along the number of leaves present, leaf area, and dry weight of the *Echinochloa crus-galli* L. (barnyard grass). Among the three soil mixtures with *Oryza sativa* L. (rice) fine cuttings, the data obtained from T_4 can be said to be the closest to the observations noted in the positive treatment.

Table 4. Effect of *Oryza sativa* L. (Rice) fine cutting soil mix on the number of seedlings that emerged and growth of *Echinochloa crus-galli* L. (Barnyard grass) weed.

Treatments	Mean				
	Number of Seedling that Emerged	Plant height (cm)	Leaf number	Leaf Area (cm^2)	Dry Weight (g)
T_0 Negative treatment (distilled water)	18.33	38.95	5.60	13.14	2.36
T_1 Positive treatment (0.142 g Butachlor Machete® 5G)	13.00	23.45	2.45	8.56	1.11
T_2 20g *Oryza sativa* L. (rice) fine cutting soil mix	17.33	32.00	5.00	12.51	1.98
T_3 25g *Oryza sativa* L. (rice) fine cutting soil mix	16.33	28.80	4.40	9.89	1.71
T_4 30g *Oryza sativa* L. (rice) fine cutting soil mix	15.33	25.60	3.20	8.00	1.33

Allelopathic effects of Oryza sativa L. *(Rice) straw fine cutting soil mix on Ludwigia octovalvis (Primrose-willow) weed*

As can be observed in Table 5, the negative treatment consistently recorded the highest means in all the growth parameters of the *Ludwigia octovalvis* (primrose-willow). On the other hand, the positive treatment indicated the lowest average observations. The data obtained for the T_4 are equal or close to the observations that were recorded in the positive treatment. T_2 and T_4 posted equal numbers of average seedling emergence. The plant height of the *Ludwigia octovalvis* (primrose-willow) is taller in T_4 by an average of 2cm as compared to those in the T_2. The number of leaves of *Ludwigia octovalvis* (primrose-willow) observed in T_2 and T_4 are almost equivalent, with a difference of only 0.25. When the results are compared to T_2, the average measurements for leaf area and dry weight in T_4 are higher by 1.63cm² and 0.99g, respectively.

As the amount in grams of *Oryza sativa* L. (rice) fine cuttings increases, the number of seedling emergence that is recorded tends to decrease or become lower in number. Additionally, the height of *Ludwigia octovalvis* (primrose-willow) can also be affected, making their height shorter as compared to those *Ludwigia octovalvis* (primrose-willow) that have grown in a soil mix with a lower amount of *Oryza sativa* L. (rice) fine cuttings.

Table 5. Effect of *Oryza sativa* L. (Rice) fine cutting soil mix on the number of seedlings that emerged and growth of *Ludwigia octovalvis* (Primrose-willow) weed.

Treatments	Mean				
	Number of Seedlings	Plant height (cm)	Leaf number	Leaf Area (cm^2)	Dry Weight (g)
T_0 Negative treatment (0g *Oryza sativa* L.)	18.33	53.70	7.30	50.88	15.76
T_1 Positive treatment (0.142 g Butachlor Machete® 5G)	12.67	22.20	2.55	21.90	8.25
T_2 20g *Oryza sativa* L. fine cutting soil mix	14.33	46.60	6.00	45.87	13.06
T_3 25g *Oryza sativa* L. fine cutting soil mix	13.67	31.85	4.70	29.29	11.33
T_4 30g *Oryza sativa* L. fine cutting soil mix	12.67	24.20	2.80	20.27	9.26

Average percent inhibition (API) of the negative treatment and Oryza sativa L. *(rice) fine cutting soil mix on the field weeds*

Table 6 presents the summary of the average percent inhibition (API) of the *Oryza sativa* L. (rice) straw fine cutting soil mix on the seedling emergence, plant height, leaf number, leaf area, and seedling dry weight. Overall, the *Oryza sativa* L. (rice) straw fine cutting soil mix had inhibited the emergence and growth of *Ludwigia octovalvis* (primrose-willow) by an average of 33.39 percent, which is 10.6 percent higher than the average percent inhibition of *Oryza sativa* L. (rice) straw fine cutting soil mix on the growth of *Echinochloa crus-galli* L. (Barnyard grass).

Table 6. Average percent inhibition of *Oryza sativa* L. (Rice) straw fine cutting soil mix on *Echinochloa crus-galli* L. (Barnyard grass) and *Ludwigia octovalvis* (Primrose-willow) against the negative treatment and positive treatment.

Field Weeds	Number of Seedlings	Plant height	Leaf number	Leaf area	Dry Weight	API
Negative treatment *Echinochloa crus-galli* L. (barnyard grass) (*Oryza sativa* L. (rice) fine cutting soil mix)	10.91	26.06	25.00	22.87	29.09	22.79
Ludwigia octovalvis (primrose-willow) (*Oryza sativa* L. (rice) fine cutting soil mix)	26.04	36.27	38.36	37.48	28.83	33.39
Positive treatment						
Echinochloa crus-galli L. (barnyard grass) (*Oryza sativa* L. (rice) fine cutting soil mix)	-25.13	-22.81	-71.42	-18.34	-50.75	-37.69
Ludwigia octovalvis (primrose-willow) (*Oryza sativa* L. (rice) fine cutting soil mix)	-6.74	-54.16	-76.47	-45.25	-35.96	-43.72

As shown in the table, the average percent inhibitions of the treatments to the two weeds herein are of negative values which mean that the positive treatment, which is a commercially bought herbicide, indicates greater inhibitory effects.

When the average inhibitory effects of the *Oryza sativa* L. (rice) fine cutting soil mix on the two varieties of weeds were compared with respect to the positive treatment, the study found that *Oryza sativa* L. (rice) fine cutting soil mix posted higher inhibitory effects on the growth parameters of *Echinochloa crus-galli* L.(barnyard grass) as indicated in the average percent inhibition equivalent to -37.69 whereas the *Ludwigia octovalvis* (primrose-willow) has an average percent inhibition of -43.72. For the average percent inhibition, the negative values indicate that the data observed in the weed variety is closer to the values recorded in the positive treatment.

Such findings imply that the *Oryza sativa* L. (rice) fine cutting soil mix caused greater reduction rate on the seedling emergence, leaf number, leaf area, and dry weight of the *Echinochloa crus-galli* L. (barnyard grass) as compared to the effect it caused to the growth of *Ludwigia octovalvis* (primrose-willow). Additionally, the findings indicate that the *Oryza sativa* L. (rice) fine cutting soil mix had resulted to *Echinochloa crus-galli* L. (barnyard grass) with lesser number of seedlings, height that is shorter, leaves that are fewer and smaller, and plant biomass that is lesser.

Association between the Echinochloa crus-galli L. *(Barnyard grass) and Ludwigia octovalvis (Primrose-willow) seeds emergence and the Oryza sativa* L. *(Rice) fine cutting soil mix*

Pearson's Chi-square Tests of Independence were conducted independently to each weed variety to assess whether seedling emergence can be associated with the five treatments. For the *Echinochloa crus-galli* L. (barnyard grass), the test statistics shows that the different treatments have a statistically significant association between the seedling emergences of *Echinochloa crus-galli* L. (barnyard grass). In general, this means that whether the *Echinochloa crus-galli* L. (barnyard grass) seedling emerged or not can be related to the treatments applied to the seeds.

Table 7. Pearsons chi-square test of independence between the *Echinochloa crus-galli* L. (Barnyard grass) and *Ludwigia octovalvis* (Primrose-willow) seeds emergence and *Oryza sativa* L. (Rice) straw fine cutting soil mix.

Test Statistics	Coefficients	Remarks
Echinochloa crus-galli L. (barnyard grass)		
Pearson's Chi-Square	19.20*	Significant
p-value	<0.01	
Cramer's V	0.245	Strong
Ludwigia octovalvis (primrose-willow)		
Pearson's Chi-Square	24.36*	Significant
p-value	<0.01	
Cramer's V	0.253	Very Strong

*significant at 0.05 level of significance

Moreover, the Cramer's V equivalent to 0.245 indicates that there is a strong association between the treatments, which include the negative and positive treatments, and the different concentrations of *Oryza sativa* L. (rice) fine cutting soil mix) and whether the *Echinochloa crus-galli* L. (barnyard grass) seedlings emerged or not.

Consistently, as with the *Oryza sativa* L. (rice) filtrate, it was found that the 20 g, 25 g, and 30 g *Oryza sativa* L. (rice) straw fine cutting soil mix show no significant difference between their expected values and the observed data of which all the concentrations recorded absolute values of adjusted residuals to be less than 2 (Agresti, 2013; Agresti & Franklin, 2014).

These results indicate that the number of expected seedlings to emerge or not to emerge was likely to be more or less equal to the actual observation of the experiment.

For the *Ludwigia octovalvis* (primrose-willow), the results of the Pearsons' Chi-square test of independence indicated that there is a statistically significant association between the five treatments and whether the *Ludwigia octovalvis* (primrose-willow) seedlings emerged or not. In general, this means that the seedling emergence of *Ludwigia octovalvis* (primrose-willow) can be related to the treatments applied, in this study, the negative treatment using distilled water, the positive treatment using Butachlor, and the three different concentrations of *Oryza sativa* L. (rice) fine cutting soil mix.

Generally, the results of the Pearson's Chi-Square Tests of Independence suggest that the treatments, particularly those that applied with different concentrations of *Oryza sativa* L. (rice) straw fine cuttings have strong to very strong contribution in inhibiting the seedling emergence of the two weed varieties involved in this study, the *Echinochloa crus-galli* L. (barnyard grass) and *Ludwigia octovalvis* (primrose-willow). Compared to the *Oryza sativa* L. (rice) filtrate which indicated a weak association between the treatments and the seed germination of *Echinochloa crus-galli* L. (barnyard grass) and *Ludwigia octovalvis* (primrose-willow), the *Oryza sativa* L. (rice) straw fine cuttings is likely to have effected a higher inhibition or allelopathic effect on the two weed varieties.

Test of Significant Difference between Oryza sativa L. (rice) Fine Cutting Soil Mix and Echinochloa crus-galli L. *(Barnyard grass) Growth and Dry Weight*

Table 8 presents the results of the inferential statistical analyses performed to determine whether the data on plant height, leaf number, leaf area, and dry weight of the *Echinochloa crus-galli* L. (barnyard grass) seedling differ significantly with respect to the five different treatments. It can be inferred from the table that there is a statistically significant difference between the heights of *Echinochloa crus-galli* L.

(Barnyard grass) observed in the different soil mix treatments. The findings suggest that the average height of *Echinochloa crus-galli* L. (barnyard grass) varies significantly among the treatments.

On the other hand, a Welch-ANOVA was conducted to determine if leaf numbers of *Echinochloa crus-galli* L. (barnyard grass) were different for all the treatments. The results of the analysis reveal that leaf numbers were statistically significantly different between the various treatments.

Table 8. Summary of test of difference between *Oryza sativa* L. (Rice) fine cutting soil mix and *Echinochloa crus-galli* L. (Barnyard grass) growth and dry weight.

Parameters	Test		
	df	ANOVA or Welch ANOVA	p-value
Plant Height	(4, 95)	160.75**	< 0.01
Leaf number	(4, 45.63)	41.60**	<0.01
Leaf Area	(4, 46.64)	48.77**	<0.01
Dry Weight	(4, 44.96)	76.87**	<0.01

** Significant at 0.01 level of significance

Due to the violation of normality of the data gathered, Welch-ANOVA was also conducted to determine if leaf area of *Echinochloa crus-galli* L. (barnyard grass) was different for the five treatments. The table indicates that there is a statistically significant difference in the leaf area of the *Echinochloa crus-galli* L. (barnyard grass) among the various treatments.

For the dry weight of *Echinochloa crus-galli* L. (barnyard grass), the results of the Welch-ANOVA showed that there is a statistically significant difference in all the five treatments.

Consistently, the results suggest that the negative treatment and positive treatment indicated the highest and lowest observations, respectively, in all the plant growth parameters of *Echinochloa crus-galli* L. (barnyard grass). Among the treatments applied with *Oryza sativa* L. (rice) fine cuttings, T_2 and T_4 indicated the lowest and the highest, correspondingly. It can be said that a higher amount of *Oryza sativa* L. (rice) fine cuttings mixed in soil results to a higher reduction rate on the growth of *Echinochloa crus-galli* L. (barnyard grass).

Table 9 summarizes the pairwise comparisons between the treatments. The result for Tukey HSD post hoc analysis revealed that all pairwise comparisons were statistically significant (p<0.01). Additionally, Tukey HSD indicated that there is a notable difference between the average height of *Echinochloa crus-galli* L. (barnyard grass) between T_0 and T_4.

Table 9. Pairwise Comparisons between Treatments.

Pairs	Plant Height	Leaf Number	Leaf area	Dry Weight
$T_4 - T_1$	2.150*	0.750*	-0.564*	0.224
$T_4 - T_3$	-3.200*	-1.200*	-1.893*	-0.381
$T_4 - T_2$	-6.400*	-1.800*	-4.506*	-0.646*
$T_4 - T_0$	-13.350*	-2.400*	-5.145*	-1.023*
$T_1 - T_3$	-5.350*	-1.950*	-1.328*	-0.605*
$T_1 - T_2$	-8.550*	-2.550*	-3.942*	-0.870*
$T_1 - T_0$	-15.500*	-3.150*	-4.581*	-1.247*
$T_3 - T_2$	-3.200*	-0.600	-2.613*	-0.264*
$T_3 - T_0$	-10.150*	-1.200*	-3.252*	-0.642*
$T_2 - T_0$	-6.950*	-0.600	-0.639	-0.377*

Although further analysis of the results shows that the comparison between the average height of *Echinochloa crus-galli* L. (barnyard grass) in T_1 and T_4 are statistically significant, it can be said that among the three treatments with *Oryza sativa* L. (rice) fine cuttings, T_4 applied with 30 g indicated the greatest inhibitory effect on the height of *Echinochloa crus-galli* L. (barnyard grass) which recorded an average plant height of 15.33cm.

The Games-Howell post hoc analysis for leaf number revealed that all pairwise comparisons were statistically significant (p<0.01), except for T_0T_2 and T_3T_2. The findings suggest that the number of leaves present in T_2 with 20 g of *Oryza sativa* L. (rice) fine cuttings is comparable to the number of leaves counted in the negative treatment, T_0. Additionally, the data obtained for T_2 and T_3, with 20 g and 25 g of *Oryza sativa* L. (rice) fine cuttings, respectively, do not differ significantly in terms of the number of leaves. However, the leaf number for T_4 varies significantly to each of the T_2 and T_3. Although the difference between the positive treatments, T_1, is statistically significant, seemingly, T_4 with 30 g of

Oryza sativa L. (rice) fine cuttings posted the greatest inhibitory effects among the three treatments with *Oryza sativa* L. (rice) fine cuttings.

In terms of leaf area, the Games-Howell post hoc analysis revealed that all pairwise comparisons were statistically significant ($p<0.05$), except for the pairs T_2T_0. Seemingly, T_2, the treatment with *Oryza sativa* L. (rice) fine cuttings, indicated similar inhibitory effects as that of the negative treatment, T_0. Therefore, it is likely that the *Oryza sativa* L. (rice) fine cuttings can have an inhibitory effect on leaf area of *Echinochloa crus-galli* L. (barnyard grass). Probably the toxic influence of *Oryza sativa* L. (rice) fine cuttings in the leaf physiology of *Echinochloa crus-galli* L. (barnyard grass) hindered the leaf area development of the weed.

Along dry weight, the Games-Howell post hoc analysis also revealed that all pairwise comparisons were statistically significant ($p<0.05$), except for the pairs T_4T_1 and T_4T_3. From the results, the dry weight obtained in T_4 with 30 g of *Oryza sativa* L. (rice) fine cutting soil mix indicated an inhibitory effect comparable to the positive treatment T_1. Tests of significant differences were also performed on the data gathered from the different treatments involving *Ludwigia octovalvis* (primrose-willow). In terms of plant height of the *Ludwigia octovalvis* (primrose-willow), the distributions were similar for all groups as assessed by visual inspection of a boxplot.

Table 10. Summary of test of difference between *Oryza sativa* L. (RICE) fine cutting soil mix and *Ludwigia octovalvis* (primrose-willow) growth and dry weight.

Parameters	Test		
	df	ANOVA /Welch ANOVA/ Kruskal-Wallis	p-value
Plant Height	(4)	92.54**	< 0.01
Leaf number	(4, 95)	145.23**	<0.01
Leaf Area	(4)	91.65**	<0.01
Dry Weight	(4, 46.33)	65.98**	<0.01

**significant at 0.01 level of significance

The results of the analyses, however, reveal that the median plant heights of the *Ludwigia octovalvis* (primrose-willow) were statistically significantly different among the different treatments. The findings suggest that the height of *Ludwigia octovalvis* (primrose-willow) varies significantly among the treatments.

From the result of the one-way ANOVA test, leaf number was statistically significantly different among the five treatments. Statistically, the negative treatment T_0 and the positive treatment T_1 indicated the highest and lowest average number of leaves of *Ludwigia octovalvis* (primrose-willow), respectively. Among the treatments applied with *Oryza sativa* L. (rice) fine cuttings, T_4 with 30 g of it posted the greatest reduction rate in terms of the number of leaves. Further, the Kruskal-Wallis test results reveal that the median leaf area was statistically significantly different across the five treatments. Also, Welch-ANOVA test posits that the seedling dry weight was statistically significantly different among the concentrations of *Oryza sativa* L. (rice) fine cutting soil mix. Notably, the dry weight of the *Ludwigia octovalvis* (primrose-willow) decreased from the T_0 (15.76 ± 1.95), to T_2 (13.06 ± 1.36), to T_3 (11.32 ± 1.39) to T_4 (9.26 ± 0.91) to T_1 (8.25 ± 2.04), in that order.

Consistently, from the results of the current study, it can be said that the negative treatment and positive treatment recorded the highest and lowest observations, respectively, in all the plant growth parameters of *Ludwigia octovalvis* (primrose-willow). On the other hand, among the treatments applied with *Oryza sativa* L. (rice) fine cuttings, T_2 and T_4 indicated the lowest and the highest, respectively. As observed, the height, leaf number, leaf area, and dry weight of *Ludwigia octovalvis* (primrose-willow) tend to decrease with the increase in concentrations of the *Oryza sativa* L. (rice) fine cuttings. Consequently, it can be said that a higher amount of *Oryza sativa* L. (rice) fine cuttings mixed in soil can cause greater reduction rate on the growth of *Ludwigia octovalvis* (primrose-willow).

Subsequently, pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons for height and leaf area, Tukey HSD for leaf number, and Games-Howell post hoc analysis for dry weight. Table 11 summarizes the pairwise comparisons between the treatments.

Table 11. Pairwise comparisons between treatments.

Pairs	Plant Height	Leaf Number	Leaf area	Dry Weight
$T_4 - T_1$	-13.050	0.250	10.850	1.006
$T_4 - T_3$	-36.450*	-1.900*	35.425*	-2.067*
$T_4 - T_2$	-56.500*	-3.200*	55.475*	-3.804*
$T_4 - T_0$	76.500*	-4.500*	75.375*	-6.496*
$T_1 - T_3$	23.400*	-2.150*	-24.575*	-3.072*
$T_1 - T_2$	43.450*	-3.450*	-44.625*	-4.809*
$T_1 - T_0$	63.450*	-4.750*	64.525*	-7.502*
$T_3 - T_2$	20.050*	-1.300*	20.050*	-1.737*
$T_3 - T_0$	40.050*	-2.600*	39.950*	-4.430*
$T_2 - T_0$	20.000*	-1.300*	19.900*	-2.693*

The table suggests that there are statistically significant differences for all the combinations ($p < 0.05$) in all the growth parameters of *Ludwigia octovalvis* (primrose-willow) except for the pair T_1T_4.

The hindering effect found in this study is similar to the findings of the study of Singh *et al.* (2013) and Batish *et al.* (2004) where they found that the plant height of *Ludwigia octovalvis* (primrose-willow) was reduced due to the allelopathic effect of *Oryza sativa* L. (rice). Relevant literatures recognize that crops such as rice may release allelochemicals in the soil surrounding the roots or into the water surrounding the plants. These allelochemicals exhibit suppression of adjacent weed species hence allelochemicals are considered potentially viable bioherbicides (Bo *et al.*, 2019, Dilday *et al.*, 2009 Ahn *et al.*, 2005, Seal *et al.*, 2004, Gealy *et al.*, 2003, Olofsdotter *et al.*, 1999; Dilday *et al.*, 1994). Weeds pose an important biological constraint to crop productivity. Some weeds are economically destructive and the attempt to control them has met with limited success (Amb & Ahluwalia, 2016). From the findings presented herein, it can be presumed that the current study provides scientific evidence derived from a greenhouse-based experiment that the *Oryza sativa* L. (rice) fine cutting soil mix can have a potential to prevent or inhibit the growth of *Ludwigia octovalvis* (primrose-willow). Among the *Oryza sativa* L. (rice) fine cuttings treatments, the treatment with 30 g or even higher can reduce the growth of *Ludwigia octovalvis* (primrose-willow) as much as the reduction rate caused by Butachlor Machete® 5G. The only difference, however, is that the *Oryza sativa* L. (rice) fine cuttings soil mixture is more environment-friendly and poses no harm as compared to synthetic herbicides.

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