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Controlling invasive barnyard grass (*Echinochloa crus-galli* L.) weed growth using rice (*Oryza sativa* L. var. NSIC RC 218 SR) straw methanolic extract

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Abstract

Weeds are a severe threat to sustainable crop production and although herbicides provide effective weed control, environmental and health concerns push for alternate means of weed control. Allelopathy offers an economical, effective, and environmental-friendly approach to weed management. This experimental study determined the herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract to the growth of *Echinochloa crus-galli* L. (barnyard grass) in terms of germination percentage, height, leaf number, leaf area, root length, root mass/number, shoot mass, and dry weight. Also, the study determined if there are significant differences among the various concentrations of the growth of barnyard grassThe results of the experiment confirmed the allelopathic potential of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract in inhibiting the growth of barnyard grass as observed in the rates of reduction in height, leaf number, leaf area, root number, and dry weight. As the concentrations increase, the herbicidal effects of rice straw methanolic extract also progressively increase. Hence, it is possible that its allelopathic effects on the growth of *Echinochloa crus-galli* L. weed can be comparable with the inhibitory effects of Butachlor.

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Introduction

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. Without weed control, crop losses reach as high as 45 percent to 95 percent, depending on the ecological and climatic conditions (Ampong-Nyarko and De Datta, 2015).

Agriculture worldwide is currently using about 3 million tons of herbicides annually. Herbicide-resistant weeds have become more prolific, which has further expanded the use of herbicides (Shibayama, 2016). The use of herbicides and pesticides in agriculture has grown dramatically over the past 30 years. Currently, approximately 600 active herbicide ingredients are used, but adequate toxicologic data are available for only approximately 100 of these (Weisenburger, 2018).

Synthetic herbicides have been used to control weeds for many years, but their hazards against the environment and public health have raised questions about farmers' reliance on such chemicals (Shibayama, 2016). 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 to 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 an extensive area is covered by rice cultivation, heavy pesticide (insecticides- 1.02 a.i/hm^2, herbicide-0.19 a.i/hm^2, fungicides-0.51 a.i/hm^2) load enters the environment and get accumulated via leaching and biomagnifications (Shende and Bagde, 2016).

The negative impact of commercial herbicides makes it desirable to search for other alternative weed management options (Nirmal Kumar *et al.,* 2017) and allelopathy seems to be one of the options (Tesio and Ferrero, 2018).

Allelopathy is a natural ecological phenomenon. It is an environment-friendly technique that may prove useful as a unique tool for weed management (Molish, 2017; Rice, 2019). 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, 2018).

Many countries today have been venturing into the use of crops with allelopathic properties in agriculture toward the improvement of crop productivity and environmental protection (Cheema and Khaliq, 2013; Singh *et al.,* 2013; Cheema *et al.,* 2014; Khanh *et al.,* 2015; Reeves *et al.,* 2015; Yildirim and Guvenc, 2008; Iqbal *et al.,* 2007; Mahmood *et al.,* 2013; Wortman *et al.,* 2013; Farooq *et al.,* 2014; Silva *et al.,* 2014; Wezel *et al.,* 2014; Haider *et al.,* 2015).

The 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) as a weed infesting rice crops is not yet established. After a survey of the literature, the researcher has not found evidence of published research that used the methanolic 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).

Specifically, the study determined the herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract to the growth of *Echinochloa crus-galli* L. (barnyard grass) weed measured in terms of germination percentage, height, leaf number, leaf area, root length, root mass/number, shoot mass, and dry weight. It also compared the growth of *Echinochloa crus-galli* L. (barnyard grass) weed along the different

aforementioned indicators among the various concentrations of rice straw methanolic extracts to the growth of *Echinochloa crus-galli* L. (barnyard grass) using negative and positive controls to determine if significant differences exist. Such results can provide scientific evidence about the potential of rice straw methanolic extracts in controlling the growth of *Echinochloa crus-galli* L. (barnyard grass), which may likely be comparable to the effects of commercially-available synthetic herbicides.

The current research endeavored to contribute new knowledge and verify the results of previously conducted studies along the field of discovering environment-friendly and sustainable weed management systems by proposing an alternative method of improving rice production by offering an eco-friendly and harmless procedure of weed management in most agricultural systems.

Materials and methods

Research design

This study aimed to evaluate the herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract to the growth of *Echinochloa crus-galli* L. (barnyard grass) weed. To sufficiently address the objectives of the study, the experimental method of research was utilized which followed the standard procedures of plant extraction with the aid of the rotary evaporator. Specifically, it employed the Completely Randomized Design (CRD) with five (5) treatments, including the negative and positive controls, which were replicated four (4) times. Each replicate consisted of three (3) pots (seedling bags). Therefore, a total of twelve (12) seedling bags were utilized per treatment. For each seedling bag, 20 seeds of *Echinochloa crus-galli* L. (barnyard grass) weed were sown.

The different treatments of the study are presented below.

T_1 - distilled water (negative control)

T_2-recommended rate (0.142 g) Butachlor (Machete® 5G) (positive control)

T_3 - 2.5 g *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract/100g soil

T_4 - 3.0 g *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract/100g soil

T_5 - 3.5 g *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract/100g soil

The experiment was conducted for a period of 42 days in a controlled environment in the greenhouse of the College of Arts and Sciences of the South La Union Campus.

Sources of data

The data of the study were drawn from the five treatments involved in the experimentation. As mentioned earlier, five (5) treatments consisting of the three concentrations of rice straw methanolic extracts (2.5g, 3.0g, 3.5g per 100g of soil), and the negative and positive controls, were replicated four (4) times. Each replicate consisted of three (3) seedling bags, hence, a total of twelve (12) seedling bags were utilized per treatment. Additionally, the 12 seedling bags for all the different treatments were sown with 20 seeds of *Echinochloa crus-galli* L. (barnyard grass) weed.

Initially, a total of five (5) *Echinochloa crus-galli* L. (barnyard grass) weeds are expected to be selected through random sampling from each seedling bag for all the replicates from every treatment. Therefore, a total of 15 randomly selected *Echinochloa crus-galli* L. (barnyard grass) weeds that germinated from the sown seeds were expected to be considered from each replicate per treatment for the measurement of the different plant parameters which include the height, leaf number, leaf area, root length, root number, shoot number, and dry weight.

However, in the course of the experiment, the positive control (T_2) and T_5 recorded low germination rates and thus random selection was not possible for the aforementioned treatments considering that the number of *Echinochloa crus-galli* L. (barnyard grass) weed seeds that germinated per replicate is below ten (10). Therefore, total enumeration was employed to T_2 and T_5 which considered all the 17 and 29 *Echinochloa crus-galli* L. (barnyard grass) weeds that grew for T_2 and T_5, respectively.

For T_1, T_3, and T_4, 15 *Echinochloa crus-galli* L. (barnyard grass) weeds were randomly selected from each replicate (five from each seedling bag) per treatment. Thus, a total of 60 *Echinochloa crus-galli* L. (barnyard grass) weeds were considered for data collection. In total, 226 *Echinochloa crus-galli* L. (barnyard grass) weeds were measured in terms of height, leaf number, leaf area, root length, root mass/number, shoot mass, and dry weight. Table 1 below presents the distribution of the 226 *Echinochloa crus-galli* L. (barnyard grass) weeds among the treatments and replicates.

Table 1. Herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the seedling emergence of *Echinochloa crus-galli* L. (barnyard grass) weed.

Treatment	Number of Seeds that Germinated	Percentage	Percent Inhibition against T_2
T_1	239	99.58	-
T_2	17	7.08	0%
T_3	139	57.92	582%
T_4	95	39.58	452%
T_5	29	12.08	53%

Instrumentation and data collection

Materials

To conduct the experimental study, chemical and laboratory equipment were used. For the former, methyl alcohol for the extraction of methanolic extract from rice straw was utilized. Butachlor (Machete® 5G) was used as the positive control.

Procedures

Plant identification and collection

Voucher plant specimens were authenticated by plant taxonomist at Bureau of Plant Industry, Manila. Dried *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw waste was collected from the rice fields in Brgy. San Miguel, Agoo, La Union at harvest stage and was allowed to dry for an additional time under room temperature (28-30°C). After five days, the *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw waste was cut into smaller pieces using scissors into 0.5 to 1cm size.

Bulk extraction

Approximately 5 kilograms of air-dried *Oryza sativa* L. *var. NSIC RC 218 SR (rice)* straw waste was cut into smaller pieces and was homogenized using an electric blender. The homogenized *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw waste was soaked in 1000mL of 100% methanol (MeOH) using an Erlenmeyer flask for two days (48 hours) at room temperature (25°C). The aforementioned container was wrapped with aluminum foil. Then, the soaked *Oryza sativa* L. *var.* NSIC RC 218 SR (rice) straw waste was filtered using filter paper. Crude extraction followed which was conducted at the Natural Product Laboratory of the College of Arts and Sciences at DMMMSU-SLUC, Agoo, La Union. The *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract was evaporated to dryness at 50°C and was kept refrigerated until further use.

Preparation of potting media and application of treatments

The pot soil was obtained from the rice fields in San Miguel, Agoo, La Union. Soil cores were taken at 10 areas per plot at a depth of 10cm after tillage. One step forward was taken in the row and the core was sampled from the resulting footprint. Five soil cores (1.9cm diameter cylinder wet tip hand probe) were taken in a zigzag pattern up between rows 2 and 3 and five soil cores were taken in a zigzag pattern down between rows 4 and 5 using the footprint method. The cores were taken on either side of the row. Further, the core was placed directly into an empty sack and was placed in a cooler at 4°C to preserve the natural components of the soil. About 4 kg of soil was transferred into each seedling bag which was sown with *Echinochloa crus-galli* L. (barnyard grass) seeds. Sixty (60) seedling bags (30cm diameter) were used in the experiment. Each seedling bag was filled with 4 kg field soil and the different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract soil mix (i.e. 2.5 g, 3.0g, and 3.5g dry weight/100g soil) (Karim & Forzwa, 2010). The seedling bags were sown with weed species *Echinochloa crus-galli* L. (barnyard grass) at 20 seeds/seedling bag and mixed thoroughly at 2cm from the soil. The seedling bags were maintained and watered regularly (twice a day) with approximately equal amounts of water. The seeds were allowed to grow for 42 days.

Collection of weed seeds

Seeds of *Echinochloa crus-galli* L. (barnyard grass) weed were collected from the rice fields of Brgy. San Miguel, Agoo, La Union. The seeds were collected after removing the trash and defective seeds by floating them on distilled water. Then, the collected seeds were placed in a glass jar and were kept in a dry place until further use. Before the bioassay, seeds were surface sterilized in a 1:10 (v/v) dilution of commercial hypochlorite bleach for 10 minutes and rinsed several times with distilled water.

Measurement of seed emergence and growth parameters of plants

The allelopathic effect of *O. sativa* L. var NSIC RC 218 SR (rice) methanolic extract as an alternative organic herbicide was measured in terms of growth and development parameters like germination percentage, plant height, leaf number, leaf area, root length, root number, shoot mass, and dry weight.

Germination percentage

The number of germinated seeds was counted 14 days after sowing. Seeds with 2 mm plumules above the soil surface were considered as germinated seeds. The percentage inhibition in seed germination (G) with the different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract relative to that of the positive control was calculated. The germination percentage was calculated using the following formula by Gummert (2010):

$$Germination\ (\%) = \frac{Number\ of\ seeds\ that\ germinated}{Number\ of\ seeds\ on\ the\ pot} \times 100$$

Weed height (cm)

Weed heights of the *Echinochloa crus-galli* L. (barnyard grass) weed were measured periodically (14th, 21st, 28th, 35th, and 42th), after sowing. The height of the weed was measured using a ruler or meter stick from the part nearest to the soil to the top of the main weed shoot. The percentage inhibition of plant height (PH) with the different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract relative to that of the positive control was also estimated.

Leaf number

The leaf numbers of the selected weed were counted periodically after sowing, 14th day after sowing, and every 7th day thereafter until the 42nd day. The percentage inhibition of leaf number (LN) with the different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract relative to that of the positive control was also estimated.

Leaf area (cm²)

The leaf area was measured 42 days after sowing using millimeter graph paper method. Leaf area was calculated using the following formula:

$$leaf\ area\ (cm^2) = \frac{x}{y}$$

where x is the weight (g) of the area covered by the leaf outline on a millimeter graph paper, and y is the weight of onecm² of the same graph paper. In this experiment, however, an online application (Image J) was used.

Image is a public domain Java image processing and analysis program. It runs, either as an online applet or as a downloadable application, on any computer with a Java 1.5 or later virtual machine It can display, edit, analyze, process, save and print 8-bit, 16-bit and 32-bit images. It can read many image formats including TIFF, GIF, JPEG, BMP, DICOM, FITS and 'raw'. It supports 'stacks' (and hyperstacks), a series of images that share a single window. It is multithreaded, so time-consuming operations such as image file reading can be performed in parallel with other operations. It can calculate area and pixel value statistics of user-defined selections. It can measure distances and angles. It can create density histograms and line profile plots. It supports standard image processing functions such as contrast manipulation, sharpening, smoothing, edge detection and median filtering. The percentage inhibition of leaf area (*LA*) with different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract relative to that of the positive control was also estimated.

Root length (mm)

The root length was measured 42 days after sowing using Vernier caliper (mm). The percentage inhibition of root length (RL) with different concentrations of

Oryza sativa L. var. NSIC RC 218 SR (rice) methanolic extract relative to that of the positive control was estimated.

Root number

The root number was measured 42 days after sowing by counting the number of roots. The percentage inhibition of root mass (RM) with different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract relative to that of the positive control was estimated.

Shoot number

The shoot number was counted 42 days after sowing. The percentage inhibition of shoot mass (SM) with different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract relative to that of the positive control was estimated.

Dry weight (entire plant)

The dry weights of the sample *Echinochloa crus-galli* L. (barnyard grass) from each treatment were determined using a digital balance which were recorded after the weed samples were heated in an electric oven at 70°C. The percentage inhibition of dry weight (DW) with different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract relative to that of the positive control was also recorded. The percentage of inhibition in seed germination, plant height, leaf number, leaf area, root length, root mass/number, shoot mass, and dry weight of the entire weed was calculated using the following the formula used by Crispino (2016):

$$Percentage\ of\ inhibition = \frac{treatment - positive\ control}{negative/positive\ control} \times 100$$

Determination of average percent inhibition of weeds

The overall effects of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract to the growth of *Echinochloa crus-galli* L. (barnyard grass) weed were determined using the average percent inhibition formula as shown below (Biswas *et al.*, 2010):

$$Average\ Percent\ Inhibition(API) = \frac{G(\%) + PH(\%) + LN(\%) + LA(\%) + RL(\%) + RM(\%) + SM(\%) + DW(\%)}{8}$$

where *G* is the percentage inhibition in seed germination, *PH* is the percentage inhibition in plant height, *LN* is the percentage inhibition in leaf number, *LA* is the percentage inhibition in leaf area, *RL* is the percentage inhibition in root length, *RN* is the percentage inhibition in root number, *SN* is the percentage inhibition shoot number, and *DW* percentage inhibition in dry weight.

The following data were collected for analysis and as measurement parameters on the growth of *Echinochloa crus-galli* L. (barnyard grass) weed as influenced by the herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract.

- Number of germinated seeds 14 days after sowing.
- Height of *Echinochloa crus-galli* L. (barnyard grass) weed measured periodically after sowing (14th day and 7th day thereafter until the 42nd day).
- Leaf number of *Echinochloa crus-galli* L. (barnyard grass) weed counted periodically after sowing.
- Leaf area (cm) of *Echinochloa crus-galli* L. (barnyard grass) weed counted periodically after sowing.
- Root length (mm) of *Echinochloa crus-galli* L. (barnyard grass) weed measured 42 days after sowing.
- Root number of *Echinochloa crus-galli* L. (barnyard grass) weed measured 42 days after sowing.
- Shoot number of *Echinochloa crus-galli* L. (barnyard grass) weed measured 42 days after sowing.
- Dry weight of *Echinochloa crus-galli* L. (barnyard grass) weed weigh 42 days after sowing.
- Average percent inhibition.

Analysis of Data

The data that were gathered were tabulated and analyzed using SPSS v. 27. Frequency, formulas for leaf area, and means were used in the different measurement parameters. Additionally, the One-way Analysis of Variance (ANOVA) was used to determine if the differences among the various treatments are statistically significant assuming all assumptions pertaining to the said statistics are satisfied,

otherwise, Kruskal-Wallis test was employed. Moreover, real differences between the treatments were further analyzed and adjudged by Tukey HSD statistic or Games-Howell or the corresponding post hoc test for Kruskal-Wallis test in case of statistically significant results. On the other hand, Two-way Mixed-Model ANOVA was utilized for differences in a continuous level variable by group and time. Results of the tests of assumptions were reflected in this study as part of the appendices.

Results and discussion

Herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the growth of *Echinochloa crus-galli* L. (barnyard grass) weed.

Seedling germination

The highest seedling emergence was observed in the negative control (T_1). Further, the lowest seedling emergence was found in the positive control (T_2). From the treatments with different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract, T_5 indicated the lowest germination rate of 12.08 percent, which allowed only 29 seeds to germinate from the 240 seeds sown among the replicates.

The percent inhibition in seedling emergence, among the three treatments with rice straw methanolic extract, was 582%, 452%, and 53% for T_3, T_4, and T_5, respectively. Seedling emergence of *Echinochloa crus-galli* L. was less at 3.5 g due to higher concentrations of the methanolic extract.

Plant height

Table 2 presents the mean height incm of the *Echinochloa crus-galli* L. (barnyard grass) for five consecutive weeks. T_1 indicated the highest plant height for all the five measurements conducted. The lowest plant height is observed in the positive control (T_2).

Table 2. Herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the height of *Echinochloa crus-galli* L. (barnyard grass) weed.

Treatment	14th day		21st day		28th day		35th day		42nd day	
	ht	PI	ht	PI	ht	PI	ht	PI	ht	PI
T_1	9.23	330%	11.73	447%	14.21	563%	16.85	686%	19.50	784%
T_2	2.15	0%	2.12	0%	2.12	0%	2.12	0%	2.21	0%
T_3	7.28	239%	9.49	343%	11.43	433%	13.18	515%	15.03	582%
T_4	5.40	152%	6.64	211%	8.33	289%	10.30	381%	12.18	452%
T_5	3.36	57%	3.36	58%	3.36	58%	3.38	59%	3.38	53%

Legend: ht – Height, PI - percent inhibition against the positive control (T_2)

Among the three treatments of rice straw methanolic extracts, T5 recorded the lowest plant height. T3 and T4 exhibited a decrease in plant height compared to the negative control. The decrease in plant height as the concentration of rice straw methanolic extract increases can be a confirmation of the allelopathic potential of *Oryza sativa* L. var. NSIC RC 218 SR (rice) in controlling *Echinochloa crus-galli* L. (barnyard grass).

Leaf Number

The leaf numbers were counted periodically after sowing, the 14th day after sowing, and every 7th day thereafter until the 42nd day. Table 3 presents the summary of the results along this growth indicator. The number of leaves of the *Echinochloa crus-galli* L. (barnyard grass) weed in the negative control (T_1) constantly increases by 1 as the number of weeks progresses.

Table 3. Herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the leaf number of *Echinochloa crus-galli* L. (barnyard grass) weed.

Treatment	14th day		21st day		28th day		35th day		42nd day	
	No.	PI	No.	PI	No.	PI	No.	PI	No.	PI
T_1	2	100%	3	200%	4	300%	5	400%	6	500%
T_2	1	0%	1	0%	1	0%	1	0%	1	0%
T_3	2	100%	3	200%	4	300%	5	400%	6	500%
T_4	1	0%	1	0%	2	100%	2	100%	2	100%
T_5	1	0%	1	0%	1	0%	1	0%	1	0%

Legend: No. - number of leaves, PI - percent inhibition against the positive control (T_2)

The same observation was noted for T_3 which was applied with 2.5 g of rice straw methanolic extract. Among the treatments with rice allelochemicals, the leaf numbers of *Echinochloa crus-galli* L. (barnyard grass) were observed at a minimum in T_5 due to the higher allelopathic effect of rice methanolic extract. The number of leaves of the *Echinochloa crus-galli* L. (barnyard grass) remained constant in both the positive control and T_5.

Leaf Area

The leaf area was calculated on the 42nd day of the experiment and Image J, which is an application in Biology, was utilized for this purpose. Table 4 presents the average leaf area of *Echinochloa crus-galli* L. (barnyard grass) and the percent inhibition of each treatment with respect to the positive control (T_2).

Table 4. Herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the leaf area of *Echinochloa crus-galli* L. (barnyard grass) weed.

Treatment	Leaf Area (cm^2)	Percent Inhibition against T_2
T_1	158.15	27646%
T_2	0.57	0%
T_3	147.01	25692%
T_4	90.81	15831%
T_5	3.74	556%

The highest leaf area was observed in the negative control and the lowest leaf area was found in the positive control (T_1). Among the treatments with rice allelochemicals, the percent reduction in leaf area was lowest (556%) in the T_5. The leaf area of *Echinochloa crus-galli* L. (barnyard grass) was least at T_5 due to the higher herbicidal activity of rice straw methanolic extract.

Root Length

The herbicidal activity of rice straw methanolic extract on the root length of *Echinochloa crus-galli* L. (barnyard grass) is summarized in table 5. The positive control exhibited the shortest root length. From the three treatments applied with rice straw methanolic extract, T_5 indicated the highest level of herbicidal activity as it produced the shortest roots of the weed. The table above posits that as the concentration of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract progressively increases, its herbicidal effect on the root length of the *Echinochloa crus-galli* L. also increases, hence impeding the growth of the roots of the weeds.

Table 5. Herbicidal Activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the root length of *Echinochloa crus-galli* L. (barnyard grass) weed.

Treatment	Mean Root Length (mm)	Percent Inhibition against T_2
T_1	53.31	499%
T_2	8.90	0%
T_3	45.99	417%
T_4	46.29	420%
T_5	11.14	25%

Root Number

The herbicidal activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the root length of *Echinochloa crus-galli* L. (barnyard grass) and the percentage inhibition with respect to the positive control are presented in table 6. Both the positive control and T_5 recorded the lowest average counts of roots. T_5 has 0% percentage inhibition which means that its herbicidal activity on the number of roots is comparable to that of Butachlor.

Table 6. Herbicidal Activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the root number of *Echinochloa crus-galli* L. (barnyard grass) weed.

Treatment	Root Number	Percent Inhibition against T_2
T_1	12	300%
T_2	3	0%
T_3	11	267%
T_4	8	167%
T_5	3	0%

As previously stated, a higher concentration of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract results in a higher level of herbicidal activity, specifically in the emergence of secondary roots.

Shoot Number

The shoot of *Echinochloa crus-galli* L. (barnyard grass) refers to the part which has a stem, leaves, and flowers. As a monocot, there are only one shoot present in all *Echinochloa crus-galli* L. (barnyard

grass) samples, regardless of the treatments. Further, the study did not report the percentage inhibition against the positive control since the result is indeterminate for all the treatments considering the formula utilized in this study.

Dry Weight

The dry weights of the sample *Echinochloa crus-galli* L. (barnyard grass) from each treatment were determined using a digital balance which was recorded after the weed samples were heated in an electric oven at 70°C. In the context of this study, the percentage inhibition was not calculated, taking into consideration that the dry weight obtained for the positive control (T_2) was zero. Table 7 indicates the dry Weight of *Echinochloa crus-galli* L. (barnyard grass). The negative control exhibited the highest dry weight, while the positive control and T5 had the lowest dry weight. The positive control showed the same result observed with T5.

As the concentration of rice straw methanolic extract increases, the dry weight of the weed decreases.

Table 7. Herbicidal Activity of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the dry Weight of *Echinochloa crus-galli* L. (barnyard grass) weed.

Treatment	Dry weight (g)
T_1	12
T_2	3
T_3	11
T_4	8
T_5	3

Average Percent Inhibition (API)

Table 8 presents the summary of the rate of reduction of the weed parameters as compared to the positive control treatment. Among the treatments with rice straw methanolic extract, T_2 indicated the lowest level of herbicidal activity. T_5 exhibited the highest level of herbicidal activity and indicated an API equal to 67% which suggests that the growth of *Echinochloa crus-galli* L. (barnyard grass) was mostly inhabited by the higher concentration of rice straw methanolic extract.

Table 8. Average Percent Inhibition (API) of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract on the growth of *Echinochloa crus-galli* L. (barnyard grass) weed.

Treatment	Average Percent Inhibition
T_1	2520%
T_2	0%
T_3	2307%
T_4	1400%
T_5	67%

Test of significant differences between the treatments and Echinochloa crus-galli L. (barnyard grass) weed growth parameters

Table 9 posits the differences in the means on all the *Echinochloa crus-galli* L. (barnyard grass) weed growth parameters that were measured and were found statistically significant, as indicated in the *p*-values less than 0.01. Thus, the positive and negative controls and the different concentrations of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract have different herbicidal effects on the growth of the said weed along the height, leaf number, leaf area, root length, root number, and dry weight. As to the height of *Echinochloa crus-galli* L. (barnyard grass), the post hoc analysis revealed statistically no significant difference between the positive control, T_2 (0.142g Butachlor - Machete® 5G) (15.88) and T_5 (3.5 g *Oryza sativa* L. var. NSIC RC 218 SR (rice) methanolic extract/100g soil) (33.47) (p=1.00). However, the rest of the pairs indicated a statistically significant difference. As to leaf number, there was no significant difference between T_2 and T_5 (p=1.00). There is also no statistically significant difference between the effects of T_3 and T_1 which is the negative treatment applied with distilled water (152.92) (p=1.00). All other pairwise comparisons have statistically significant differences. Post hoc test for leaf area reveals that there was no significant difference between T_2 and T_5 (p=1.00). All other group combinations reveal statistically significant differences. As to root length, the Games-Howell test reveals that there was a statistically significant difference in all pairwise comparisons except between T_3 and T_4 where the difference is not significant statistically. Pairwise comparison was also initiated to determine which among the pairs of treatments show

significant differences with regard to root number. Post hoc test reveals that there was no statistically significant difference between T_2 and T_5. Also, no statistically significant difference between T_3 and T_1 (distilled water) (181.97) (p=0.080) was observed. All other pairs of treatments were statistically significant. Along with dry weight, the results of the post hoc test reveal that there was no significant difference between T_2 and T_5. However, there was a statistically significant difference in any other group combination. Generally, there were no statistically significant differences in the effects of the herbicidal activities of T_2 and T_5 on the growth of *Echinochloa crus-galli* L. (barnyard grass) along the height, leaf number, leaf area, root number, and dry weight. Overall, while some rice straw methanolic extract treatments do differ significantly with the effects of the positive control using commercially available and synthetic herbicides, it is worth noting that the use of *Oryza sativa* L. var. NSIC RC 218 SR (rice) straw methanolic extract at 3.0g per 100g of soil resulted to herbicidal activities and rates of reduction in height, leaf number, leaf area, root number, and dry weight that are identical to that of the synthetic herbicide.

Table 9. Results of the test of differences in the effects of the treatments on the growth of *Echinochloa crus-galli* L. (barnyard grass) weed.

Growth Parameters	Computed Value		p-value
	ANOVA (df)	Kruskal-Wallis (df)	
Height		168.367 (4)	< 0.01
Leaf number		134.01 (4)	< 0.01
Leaf area		208.972 (4)	< 0.01
Root length	11443.38 (4, 78.836)		< 0.01
Root number		192.330 (4)	< 0.01
Dry weight		210.090 (4)	< 0.01

*significant at 0.05, ** significant at 0.01

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