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RESEARCH ARTICLE

Effect of plant extracts on the growth and yield of ratoon lowland rice (*Oryza sativa* L.) when exposed to high temperatures

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Abstract

The study attempts to determine the reaction of ratoon lowland rice *(Oryza sativa* L.) to foliar application of plant extracts when exposed to high temperatures. To determine the best plant extracts that promote growth and produce higher grain yield to ratoon lowland rice, and evaluate the profitability of rice ratooning to foliar application of plant extracts when exposed to high temperatures. The experiment was conducted adopting a Randomized Complete Block Design (RCBD) with the spraying of plant extracts as treatment. Results revealed that spraying of fermented *Gliricidia sepium (Jacq.) Steud)* + *Musa sapientum* bract extracts produced a higher grain yield than control plants, and also in those ratoon plants applied with super harvest commercial foliar fertilizer. Foliar application of pure *Musa sapientum* bract extracts is also a potential natural foliar fertilizer, achieving higher productivity. Based on profitability analysis, spraying of fermented *Gliricidia sepium (Jacq.) Steud* + *Musa sapientum* bract extracts achieved a higher gross margin (USD 511.40) followed by *Musa sapientum* bract extracts with a gross margin of USD 495.40. Spraying of plant extracts to lowland rice did not influence all growth parameters evaluated, maybe due to exposure of the plants under high temperatures coupled with unpredictable weather conditions. This study postulated that the option of using plant extracts is one of the most vital approaches to enhancing rice productivity in low-yielding areas due to soil problems (acidity & alkalinity) if plants are relatively grown under favorable growing temperatures, not beyond 35 degrees centigrade.

Keywords: Banana bracts; foliar application; horseradish tree; Madre de cacao; ratoon.

1. Introduction

Rice (*Oryza sativa* Linn.) is the chief food crop for beyond fifty percent of the world's populace (GRISP, 2013; Grossa, 2014; Fukugawa and Ziska, 2019; Seck *et al.*, 2012). This crop is the dominant staple food source for human consumption (Faruq *et al.*, 2014). In the Philippines, rice plays a vital role in national food security and livelihood for most rural Filipino households. With the country's growing population every year, rice production should suffice the growing population's needs. Bañoc and Asio, (2019) reported that the cultivation of lowland rice in the Philippines is mostly distinguished by low productivity. In this response, using high-yielding and stressed tolerant varieties, proper fertilization and water management, effective pest and disease control, and ratooning can be an excellent strategy to address the current situation. Ratooning is described as the practice of growing a crop from the stubbles of the previous crop. According to Chauhan *et al.* (1985), the ability of rice plants to regenerate new tillers after harvest is seen to be one practical way to increase rice production per

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unit area and per unit of time. Rice ratooning has been successfully adopted in many countries, including India, Japan, the USA, and the Philippines (Faruq *et al.,* 2014; Bañoc and Asio, 2019). As stated by (Mahadevappa, 1998), ratooning of rice can be a good solution for intensifying sustainable rice production.

Global studies have been continuously done aiming for an increase in yield for ratooned rice. With the advent of advanced technology, fertilizer management for rice ratooning mainly focuses on biodegradable plant materials as a soil amendment, or foliar fertilizers such as plant extracts. An example of plant materials that are utilized as foliar sprays is fermented plant juice (FPJ) which was used mainly by resourceful poor farmers as a nutrient source for their crops. FPJ is usually made from young leaves of plants, and these were fermented using molasses or sugar to draw out the plant's juices, providing a lactic acid bacteria food source. As those bacteria continuously fermented those plant materials, they consequently draw out the chlorophyll content and the nutrients associated with chlorophyll, including nitrogen, phosphorous, and magnesium of that particular plant material. FPJ is concentrated with an enzyme that is beneficial for plants' photosynthesis, thus enhancing the photosynthetic capability of plants. The FPJ as the nutrient source is high if they were used as soil amendment instead of foliar spray (Sulok *et al.,* 2021).

According to some research, besides the commonly used plant material for FPJ, kakawate and moringa leaf extracts have recently benefited crops, especially those belonging to the cereals category. Abusuwar and Abohassan (2017) conducted a field experiment on three cereal forage crops, namely, *Sorghum bicolor, Pennisetum typhoideum, and Sorghum Sudanese* under stress environment of soil and water salinity in an arid climate. Results of the experiment revealed that the application of one ml of moringa juice mixed with 10 ml of distilled water (1:10 by volume) increases the concentration of cytokinin hormones, which resulted in increased plant height, stem diameter, and several leaves compared to another ratio of moringa to distilled water. Moringa juice, according to (Muhammad, 2014) is rich in growth hormones, especially zeatin. Price (2007), Muhamman *et al.* (2013), and Amirigbal *et al.* (2014) have claimed that micronutrients were found in moringa leaf juice that increases the growth and yield of various crops from cereals, forages, tuber crops, etc. Moringa leaf extract positively affects wheat's plant height, several tillers, increased grain yield, and delayed senescence (Rehman *et al.,* 2017). Mustapha (2019) reported that moringa leaf extract increases maize's growth parameters and output during their field trial in Nigeria, ensuring food security in the country.

The increase in growth parameters and yield of crops presented by several authors may have been due to the rich nitrogen content extracted from the leaves during fermentation in FPJ. There are limited studies that investigate the effect of different plant-based extracts especially if applied during fluctuating climate and weather conditions. Hence, this study attempts to determine the response of ratoon lowland rice *(Oryza sativa* L.) var. NSIC Rc222 to foliar application of plant extracts when exposed to high temperatures. To determine the best plant extracts that promote growth and produce higher grain yield to ratoon lowland rice, and evaluate the profitability of rice ratooning as influenced by foliar application of plant extracts when exposed to high temperatures.

2. Materials and methods

The experiment was conducted in the rice field of the Visayas State University (VSU), Visca, Baybay City, Leyte, Philippines last April 16, 2021, until June 20, 2021. Ten soil samples were randomly collected from the experimental area at a depth of 20 cm deep before applying foliar fertilizer. Soil samples were composited, air, dried, pulverized, and passed through a 2 mm wire mesh. The composited soil samples were submitted to the Central Analytical Service Laboratory (CASL), PhilRootcrops, Visayas State University, Visca, Baybay City, Leyte, Philippines. Soil samples were analyzed for the determination of pH (potentiometric method at 1:1 soil water ratio), percent organic matter (OM) (Walkley- Black Method), usable phosphorus (P) (Olsen's Extraction Method), percent total nitrogen (N) (Kjeldahl method), and replaceable potassium (K).

The experimental trial was set out in a Randomized Complete Block Design (RCBD), with three replications. Each treatment plot measured 3.6 m × 3.0 m and was separated by one meter and 0.5 m alleyways between replication and treatments, respectively. The application of plant-based natural foliar fertilizers was defined as treatment. The designated treatments were as follows:

T_0 = No foliar application (control)

T_1 = Spraying of super harvest commercial foliar fertilizer

T_2 = Spraying of fermented horseradish tree (*Moringa oleifera*) extracts

T_3 = Spraying of fermented Madre de cacao (*Gliricidia sepium (Jacq.) Steud)*) extracts

T_4 = Spraying of fermented banana bract (*Musa sapientum*) extracts

T_5 = Spraying of fermented *Moringa oleifera* + *Gliricidia sepium (Jacq.) Steud* extracts

T_6 = Spraying of fermented *Gliricidia sepium (Jacq.) Steud* + *Musa sapientum* extracts

T_7 = Spraying of fermented *Moringa oleifera* + *Musa sapientum* extracts

After harvesting the main crop, the rice stubbles were cut 30 cm above the soil surface using a sickle. Cutting of rice stubbles was done right after the main crop was harvested.

2.1. Procurement, preparation, and application of plant-based natural foliar fertilizers

Collection of all plant-based natural fertilizers was done. The collected materials were horseradish tree (*Moringa oleifera)* leaves, Madre de cacao *(Gliricidia sepium* (Jacq.) Steud) leaves, and banana *(Musa sapientum)* bract. In preparing plant-based natural fertilizers, one kilogram of procured materials was weighed, washed, and then chopped into small pieces using sharp knives separately. After chopping into small bits, this was added with a kilogram of molasses in each plant material used. The ratio of plant-based materials to molasses is 1:1. After adding molasses, the prepared materials were mixed thoroughly before placing them into an airtight container covered with Manila paper, and this was kept under dark conditions and exposed for a one-month fermentation process. After the fermentation period, the fermented materials were extracted manually using a clean cheesecloth and filter to separate the liquid materials from the solid particles. The fermented plant extracts were applied two weeks after harvesting the main crop. It was done weekly for eight consecutive periods at a rate of 250 ml per four liters of water for pure plant extract application, the same rate as the other plant extracts prepared. The mixed plant extracts were applied in the same manner as the pure plant-based extracts at a rate of 150 ml per plant-based extract for four liters of water.

2.2. Care and management, and harvesting

The Golden Apple Snails (L.) were controlled by handpicking the snails and egg clusters. Lannate insecticide at one sachet per 16 L water plus insecticide containing Lambda-cyhalothrin was sprayed at the milking stage of ratoon lowland rice to control rice bug infestation. For weed control, hand weeding was done starting 15 days after harvesting of the main crop until three days of operation.

After the hand-weeding operation, the experimental area was irrigated to a depth of 2 cm. The water level was raised to 5 cm during the reproductive period, and irrigation water was always available during the reproductive growth phase. The entire field was drained two weeks before harvesting to facilitate ease in the harvesting operation of the ratoon crop.

Harvesting was done using a sharp scythe when the grains in each plot had achieved about 85 percent maturity. The harvested panicles were threshed then the grains were dried for three days under the sun and cleaned through winnowing per treatment before data gathering.

2.3. Data gathered

The agronomic characteristics of ratoon crops gathered were the plant height and fresh straw yield (t ha^{-1}). The plant height (cm) was determined by measuring ten sample hills at random in each treatment plot from the ground level up to the tip of the tallest part of the plant at maturity. For the fresh straw yield (t ha^{-1}), all plants in the harvestable area in each plot, excluding two border rows at each side and two end hills in each row, were cut from the ground and then weighed without panicles. The plot yield was converted to a per-hectare basis using the following formula:

$$\text{Fresh straw yield (t ha}^{-1}) = \frac{\text{Straw yield (kg)}}{\text{Harvestable area (6.16)}} \times \frac{10{,}000\ \text{m}^2\text{ha}^{-1}}{1{,}000\ \text{kg}^{-1}}$$

The yield and yield component parameters gathered were the numbers of productive tillers per hill and the grain yield (t ha^{-1}). The number of productive tillers was determined by counting the tillers that developed panicles from ten sample hills in each treatment plot at maturity. The grain yield (t ha^{-1}) was determined after the grains from the harvestable area of each treatment plot were harvested and threshed. The grains were sundried and cleaned before weighing. The weight per plot was converted into ton per hectare using the formula below:

$$\text{Grain yield (t ha}^{-1}) = \frac{\text{plot yield (kg)}}{\text{Harvestable area (6.16)}} \times \frac{10{,}000\ \text{m}^2\text{ha}^{-1}}{1{,}000\ \text{kg}^{-1}}$$

2.4. Cost and return, and statistical analyses

Production cost was determined by recording all the expenses incurred from harvesting the plant crop until harvesting, threshing, and drying harvested grains of the ratoon crop. These include the cost of labor, plant materials used, and other activities adopted. Gross income was determined by multiplying the grain yield per plot by the current price of palay per kilogram and converted to a per hectare basis. Net return adopting gross margin was determined using the formula:

Gross Margin = Gross income - Total variable cost

The data were statistically analyzed using the computer software Statistical Tool for Agriculture Research (STAR). The mean comparison was made using the Honestly Significant Difference (HSD) or Tukey’s test.

3. Results and Discussion

3.1. Soil Chemical Analysis

The result of the initial soil analysis taken from the experimental plots showed mean chemical properties such as soil pH of 5.760, 2.375 % organic matter (OM), 0.174 % total nitrogen (N), 1.477 mg kg^{-1} usable phosphorus (P), and 0.261 me 100g^{-1} of replaceable potassium (K) (Table 1). The result signifies that the soil is moderately acidic in pH, low in OM and total N, deficient in usable P, and has a high amount of transmutable K (Landon, J. R. 1991).

Final soil analysis results revealed that the soil pH is slightly higher when compared to the initial findings. A slight increase in total N, OM, and replaceable K was observed. Although, there was a very high rise in the usable P noted. The abrupt increase in the obtainable P might be due to the mineralization of nutrients from the crop residue of the previous cropping. The result of soil analysis was similar to the study of (Baňoc *et al.*, 2022) stipulated that the slight increase in the total N, OM, and K and a higher increase in usable P might be due to the mineralization of nutrients from the decomposed primary and ratoon crops. The increase in obtainable P and other aforementioned nutrients improves root growth which contributes a great effect on the entire growth reactions of plants (Masood *et al.*, 2011), and this contributed to better root growth and nutrient uptake of plants (Hussein *et al.*, 2014). The improvement of growth was influenced by the promotion of root elongation resulting in to increase in root weight (Ram *et al.*, 2016), as these nutrients are required by the enhancement of root tips albeit responsible for high metabolism and fast division of cells (Gyaneshwar *et al.*, 2002). Thereby, the increase in nutrients especially usable P remarkably increased the biomass of plants (Amanullah, 2015).

Table 1. Chemical properties of the soil before and after harvest of ratoon lowland rice (*Oryza sativa* L.) var. NSIC Rc222 to foliar application of plant extracts when exposed to high temperatures

Soil analysis	Soil pH (1:2:5)	Organic Matter (%)	Total N (%)	Usable P (mg kg^{-1})	Transmutable K (me100 g^{-1}soil)
Initial	5.76	2.38	0.174	1.477	0.261
Final	5.85	3.47	0.253	4.190	0.700

Table 2. Data on total weekly rainfall (mm), average daily minimum and maximum temperatures (^{0}C), and relative humidity (%) during the entire duration of the study, April 16 to June 17, 2021, was obtained from PAGASA Station, Visayas State University (VSU), Visca Baybay City, Leyte, Philippines

Weeks	Total Rainfall (mm)	Temperature (^{0}C)		Relative humidity (%)
		Minimum	Maximum	
April 16-22	4.45	24.3	42.8	85.5
April 23-29	0.45	25.8	39.8	79.5
April 30-May 06	5.2	24.8	41.8	83.5
May 7-13	4.1	24.2	42.2	84.5
May 14-20	9.55	23.8	43.2	86.5
May 21-27	1.0	24.6	41.8	83.5
May 28 - June 03	92.6	24.2	41.5	83.6
June 4-10	8.2	21.5	42.3	84.8
June 11-18	3.5	23.4	41.5	81.1
Total	129.05	216.6	376.9	752.5
Mean	14.34	24.07	41.88	83.61

3.2. Agronomic characteristics and yield and yield component parameters

The agronomic characteristics and yield and yield component parameters of ratoon lowland rice (*Oryza sativa* L.) var. NSIC Rc222 in response to foliar application of plant extracts when exposed to high temperatures is presented in Table 3. Statistical analysis revealed that plant height (cm), the number of productive tillers, fresh straw yield (t ha^{-1}), and grain yield (t ha^{-1}) were not significantly ($p \geq 0.05$) influenced by foliar application of plant extracts used when exposed to high temperatures, as an actual data on maximum temperatures throughout the growing period is reflected in Table 2.

Spraying of fermented *Moringa oleifera* + *Gliricidia sepium* extracts (T_5) emanated a more extended plant height (92.20 cm) when compared to all other treatments tested, most especially the non-applied control plants (T_0) with only 87.37 cm. The foliar application of fermented *Moringa oleifera* extracts (T_2) increased more number of productive tillers, although not remarkable with other treatments; however, the non-applied control (T_0) produced the least number of productive tillers (11.1). For fresh straw yield (t ha^{-1}), spraying of super harvest commercial foliar fertilizer obtained a higher yield of fresh straws (2.45 t ha^{-1}) than those of other treatments tested, most especially in those plants not applied with the plant extracts (T_0).

For the grain yield (t ha^{-1}), the foliar application of fermented *Gliricidia sepium* + *Musa sapientum* bract extracts (T_6) produced a higher grain yield (1.81 t ha^{-1}) compared to all treatments tested. Ratoon plants followed it under T_4, T_2, T_1, T_5, T_3, and T_7, with grain yields ranging from 1.42 to 1.77 t ha^{-1}. Although not significant but the non-applied control (T_0) produced the least productivity with a grain yield of 1.38 t ha^{-1}.

The result explained by the output of Adigbo *et al.* (2012) mentioned that non-synthetic liquid fertilizer is low in effectiveness and efficiency when compared to synthetic granular fertilizer. However, Talboys *et al.* (2020) concluded that a dual application through seed dressing and foliar application is one of the best options in offering higher efficiency in applying nutrients relative to its uptake rate and grain productivity than one dose application of liquid organic fertilizer. For this study, the reaction of the ratoon crop to the application of plant extracts was not efficient, thus adsorption and translocation of sprayed plant extracts were hampered due to the high temperatures experienced by the growing ratoon crop. Several factors can affect the foliar-applied materials to plants. As such the most vital factor is the environment where plants were grown. Environmental factors such as relative humidity, temperature, and light can influence the uptake and movement of applied nutrients by adjusting the plant reactions and properties of formulation (Fernandez and Eichert, 2009; Fernandez *et al.*, 2013). The effectiveness of nutrients is engulfed by the physiological traits of the crop species like leaf shape, leaf surface architecture, cuticle composition, the presence of leaf hairs, and phenological stage (Wu *et al.*, 2010; Erenoglu *et al.*, 2011; Kutman *et al.*, 2012).

Table 3. Response of ratoon lowland rice (*Oryza sativa* L.) var. NSIC Rc222 to foliar application of plant extracts when exposed to high temperatures

Treatment	Plant height (cm)	No. of productive tillers	Fresh straw yield (t ha^{-1})	Grain yield (t ha^{-1})
T_0 = No foliar application (control)	87.37	11.10	1.61	1.38
T_1 = Spraying of super harvest	91.57	12.03	2.45	1.75
T_2 = Spraying of fermented *Moringa oleifera* extract	91.09	13.53	2.15	1.75
T_3 = Spraying of fermented *Gliricidia Sepium (Jacq.) Steud* extract	88.60	12.93	1.94	1.54
T_4 = Spraying of fermented *Musa sapientum* bract extract	90.97	12.03	1.96	1.77
T_5 = Spraying of fermented *Moringa oleifera* + *Gliricidia Sepium* extracts	92.20	11.83	2.28	1.66
T_6 = Spraying of fermented *Gliricidia sepium* + *Musa sapientum* bract extracts	88.59	12.33	2.11	1.81
T_7 = Spraying of fermented *Moringa oleifera* + *Musa sapientum* bract extracts	87.59	11.37	1.78	1.42
Mean	89.74	12.15	2.03	1.64
F value	0.78^{ns}	0.98^{ns}	1.96^{ns}	1.29^{ns}
CV %	4.19	11.40	16.51	15.64

Means with the same letter and without letter designations in a column are not significantly different at a 5% significance level, Tukey's Studentized Range (HSD) Test.

All of the aforementioned factors connect to alter the absorption and movement of applied nutrients and finally the responses of plants (Fernandez et al., 2013). The improvement in the usefulness and competence of foliar-applied nutrients would require a sound understanding of the overall factors for the growth and development of plants. The utmost importance is the environmental principles that regulate the absorption, translocation, and utilization of applied nutrients to plants. Thereby, foliar application of plant extracts at high temperatures dries quickly, thus reducing the adsorption and nutrient transformation in the solution (Nutri Ag., 2000). However, the effect of the different plant extracts varied as observed in their productivity levels (Table 3). The differences in their effect on lowland rice can be justified by the finding of Yaseen and Takacs-Hajos (2020) that generally plants or plant extracts contain rich in antioxidants, antibiotics, nutrients that include vitamins and minerals, proteins, carotenoids, and the availability of high concentrations of various hormones including zeatin that can eventually improve the productivity of various crops ranging from 10 to 45 percent. This was supported by the output of Maishanu *et al.* (2017) strongly emphasized that plant extracts particularly moringa leaf extract (MLE) contains an adequate and proportionate amount of micronutrients that can finally support the growth, yield, and yield components of various crops. Abd-El-Hack *et al.* (2018) stipulated that MLE might act a significant role in accelerating the growth of tomatoes, peanuts, maize, and wheat at their early growth stages. They further stated that MLE contributes a big role as a natural plant growth enhancer that can eventually adjust the plants to any environmental problems especially limited soil moisture or drought and maybe high temperatures.

3.3. Cost and return analysis

Cost and return of ratoon lowland rice var. NSIC Rc222 as influenced by the foliar application of plant extracts when exposed to high temperatures is presented in Table 4. Profitability analysis revealed that ratoon rice plants applied with fermented *Gliricidia sepium (Jacq.) Steud* + *Musa sapientum* bract extracts (T_6) obtained a high gross income (USD 724.00) and gross margin (USD 511.40) compared to all other treatments economically analyzed. It was closely followed by the foliar application of fermented *Musa sapientum* bract extracts (T_4) with a gross income of USD 708.00) and a gross margin of USD 495.40. Ratoon rice plants applied with super harvest (T_1) achieved a gross income of (USD 700.00) and a gross margin of (USD 490.40), and those unsprayed ratoon rice plants (T_0) achieved the lowest gross income and gross margin of USD 552.00 and USD 391.40, respectively. Economic analysis revealed the high gross margin of ratoon rice plants applied with fermented *Gliricidia sepium* (Jacq.) Steud + *Musa sapientum* bract extracts (T_6) were mainly attributed to high ratoon's grain yield (1.81 t ha^{-1}) which might be due to the support of nutrients and other growth hormones responsible for better growth and development. It was coupled with a low total variable cost (USD 212.60) incurred by foliar application of fermented *Gliricidia sepium* (Jacq.) Steud + *Musa sapientum* bract extracts used.

4. Conclusion

Spraying plant extracts at a specified rate of 250 ml per four liters of water did not significantly influence the productivity of ratoon lowland rice under environmental conditions that experienced high temperatures. Application of fermented *Gliricidia sepium* (Jacq.) Steud + *Musa sapientum* bract extracts and fermented *Musa sapientum* bract extracts are potential natural foliar fertilizers for ratoon lowland rice during the dry season. These two kinds of fermented extracts achieved higher gross incomes and gross margins compared to unsprayed control ratoon plants and even those plants sprayed with commercial synthetic foliar fertilizer (super harvest).

Table 4. Production cost per hectare of ratoon lowland rice (*Oryza sativa* L.) var. NSIC Rc222 as influenced by foliar application of plant extracts when exposed to high temperatures

Treatment	Grain yield (t ha[1])	Gross income (PHP)	Total variable cost (PHP)	Gross margin (PHP)
T_0 = No foliar application (control)	1.38	552.00	160.60	391.40
T_1 = Spraying of super harvest	1.75	700.00	209.60	490.40
T_2 = Spraying of fermented *Moringa oleifera* extracts	1.75	700.00	212.60	487.40
T_3 = Spraying of fermented *Gliricidia sepium* extracts	1.54	616.00	212.60	403.40
T_4 = Spraying of fermented *Musa sapientum* bract extracts	1.77	708.00	212.60	495.40
T_5 = Spraying of fermented *Moringa oleifera* + *Gliricidia sepium* extracts	1.66	664.00	212.60	451.40
T_6 = Spraying of fermented *Gliricidia sepium* + *Musa sapientum* bract extracts	1.81	724.00	212.60	511.40
T_7 = Spraying of fermented *Moringa oleifera* + *Musa sapientum* bract extracts	1.42	568.00	212.60	355.40
Mean	1.64	656.00	205.73	317.48

5. Recommendations

A pure application of plant extract is not recommended for ratoon lowland rice in areas that experienced high temperatures coupled with unpredictable weather conditions. Although fermented *Gliricidia sepium* (Jacq.) Steud + *Musa sapientum* bract extracts and fermented *Musa sapientum* bract extracts alone are potential organic foliar fertilizers for ratoon lowland rice if given at a higher dosage in areas under favorable climate and weather conditions that experienced temperatures, not beyond 35 degrees centigrade. A follow-up study is conducted in areas with favorable climates and experience optimum temperatures ranging from 20 to 35 degrees centigrade to compare the results of this research undertaking.

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The authors disclosed no conflict of interest starting from the conduct of the study, data analysis, and writing until the publication of this research work.

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