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RESEARCH ARTICLE

Ratooning response of lowland rice (*Oryza sativa* L.) to foliar application of seaweed extracts grown under high maximum temperatures

Bañoc, D.M.*

Department of Agronomy, Visayas State University, Visca, Baybay City, 6521 Leyte, Philippines.

Abstract

This research work aimed to determine the response of ratoon lowland rice *(Oryza sativa* L.) to foliar application of seaweed extracts grown under high maximum temperatures. To determine the best seaweed extracts that can promote growth and produce a higher grain yield of ratoon lowland rice. Evaluate the profitability of rice ratooning as influenced by foliar application of seaweed extracts grown under high maximum temperatures. The experiment was implemented following a Randomized Complete Block Design (RCBD) with the spraying of seaweed extracts as a treatment. The different seaweed extracts used were Guso *(Eucheuma dentilatum)*, Samo (*Sargassum aquifolium)*, and Loci *(Sargassum polycystum)*. Results revealed that spraying with fermented *Sargassum polycystum* extract achieved a higher grain yield (1.24 t ha^{-1}) and eventually a higher gross margin (USD 283.40) of ratoon lowland rice than unsprayed control and those plants sprayed Algafer commercial foliar fertilizer. Foliar application of seaweed extracts did not influence all parameters gathered even though higher productivity in plants applied with *Sargassum polycystum* and *Sargassum aquifolium* extracts. The real effect of foliar application might be due to the plant's exposure to high maximum temperatures that might reduce the absorption and translocation of applied nutrients into the ratoon crops. Thereby decreasing productivity but still higher compared to commercial foliar fertilizer. This study speculated that foliar application of seaweed extracts is one of the best options to alleviate the crop productivity that might experience low yield due to soil problems, although enhancing its productiveness when plants are grown under normal environmental conditions.

Keywords: Algafer Foliar Fertilizer; Extract; Seaweeds; Strategy; Temperatures.

1. Introduction

Rice (*Oryza sativa* L.) belongs to the family Poaceae (Pearsall *et al.*, 1995), is primarily considered a staple crop for half of the global populace, and can provide a decent livelihood to billions of people worldwide (Tobias *et al.*, 2012). The crop is considered the second-largest food source for many Asian people (Niyaki *et al.*, 2010). This is widely consumed only as a staple food but also as a primary source of nutrition, income, and employment. Every year, the world's population increases; the need to produce more rice has been one of the top priorities of the agriculture sector to suffice the need of the growing populace. However, crop production is affected by several factors, and nutrient management is the leading strategy for enhancing productivity.

Regarding nutrient management, crop performance is greatly affected by sufficient nutrients to satisfy plants' needs. It aims primarily to supply essential nutrient elements which plants need for tremendous growth and development. Fertilizers are used in adopting the said approach, and these are applied by various methods to make the nutrients readily available to crops, reduce fertilizer losses, and ease of application. One of the methods is the foliar

***Corresponding author: Dionesio M. Bañoc**
Email: dionesio.banoc@vsu.edu.ph
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application of nutrients to increase and exploit the crop's genetic potential. Furthermore, it is considered an efficient and economical method of supplementing nutrient requirements and enhancing nutrient availability (Raut *et al.,* 2017). Verma *et al.* (2000) stressed that foliar fertilization entails the application of nutrients to foliage and their absorption. The advantages of foliar fertilization were more noticeable to growing conditions restricting nutrients from the soil. Liquid extracts from seaweeds are now gaining popularity as foliar materials for some crops including grasses, cereals, and vegetables (Crouch and Van Staden, 1994; Karthikeyan and Shanmugam, 2016). The utilization of seaweed extracts becomes popular due to their useful usage as an organic component for sustainable agriculture (Russo and Berlyn, 1990). When applied as a foliar fertilizer, the seaweed extracts can enhance the rate of cell division and eventually promote the elongation of plant cells. These materials being organic and biodegradable is essential in sustainable agriculture (Cassan *et al.,* 1992), and it comes from an imperishable source and can be harvested without harming the crop (Lawson, 2022). Seaweed extracts at 15 % were recommended to spray into the rice plants during the vegetative and productive stages (Sunarpi *et al.,* 2010). They further stipulated that extracts of Sargassum species including polycystum, *Hydrolathrus sp*. *Turbeneria ornate*, and *Turbenarya marayama* were able to influence the growth of rice plants. However, only *Hydrolathrus sp*. extracts could augment both the growth and mass production of rice plants. The application of seaweeds as organic foliar fertilizer was mainly applied in the main plant, but the application for the ratoon crop, especially lowland rice, was unknown particularly if applied during a period that experienced very high maximum temperatures. Rice ratooning is one of the potential and alternative approaches to increase rice production if given proper nutrient management. If suitable crop management practices are employed, the ratoon crop yield may reach 50 % or more of the main crop. Rice ratoon incurs 50-60 % less labor than the main crop as it does not require tillage, seeds, transplanting, and lesser crop maintenance costs (Chauhan *et al.,* 1985), in as much as the growth duration of ratoon rice crops ranges only from 40-90 days. The performance of ratoon crops varies mainly according to nutrient management, water availability, and pest and disease management. Verkleij (1992) stated that the use of seaweed extracts is easier and more common than using other raw seaweeds due to their availability, ease of preparation, and application. This is because seaweed extract application resulted in more excellent root-to-shoot ratios than untreated control in tested crops such as maize, tomato, and wheat plants. Research on the use of seaweed extracts in rice ratooning is limited especially if plants were exposed to high temperatures. Hence, this study aimed to 1) determine the response of ratoon lowland rice *(Oryza sativa* L.) var. NSIC Rc222 to foliar application of seaweed extracts when grown under high maximum temperatures, 2) identify the best seaweed extracts that can promote growth and produce higher grain yield for ratoon lowland rice which experienced high maximum temperatures, 3) evaluate the profitability of rice ratooning as influenced by foliar application of seaweed extracts to lowland rice which experienced high maximum temperatures.

2. Materials and methods

The experiment was established at the research area of the Visayas State University (VSU), Visca, Baybay City, Leyte, the Philippines from April 17, 2021, until June 18, 2021, when ratooned plants experienced very high maximum temperatures (Table 2). The research site is characterized by experiencing type four climate wherein this was exposed to precipitation which is more or less evenly distributed all around the year. The study sites' geographical coordinates possess a latitude of ten ^{0} 41' North and a longitude of 124 ^{0} 48' East (Maplandia.com. 2021). The experimental area possesses geomorphology (vertisols) and soil type of entisols (Asio, 1996; Carating *et al.*, 2014), with an elevation of 104 m above sea level (https:/elevation.maplogs.com). Ten soil samples were randomly collected from the experimental area at a depth of 20 cm deep before applying foliar. They were composited, air dried, pulverized, and sieved by 2 mm wire mesh. Chemical properties of a representative soil mixture were analyzed for pH (potentiometric method at 1:1 soil water ratio), percent organic matter (OM) (Walkley- Black Method), obtainable phosphorus (P) (Olsen's Extraction Method), and percent total nitrogen (Kjeldahl method) and convertible potassium (K) in the Central Analytical Service Laboratory (CASL), PhilRootcrops, Visayas State University, Visca, Baybay City, Leyte, the Philippines. The experiment was set out in a Randomized Complete Block Design (RCBD), with three replications. The different seaweed extracts were designated as treatments. The plot size was 4.0 m × 2.4 m and was separated by alleyways of one m between replications and 0.5 m between treatments. The designated treatments were as follows:

T_0= No foliar application (control)

T_1= Spraying of Algafer commercial foliar fertilizer

T_2= Spraying of fermented Guso (*Eucheuma dentilatum*) extract

T_3= Spraying of fermented Samo (*Sargassum aquifolium*) extract

T_4= Spraying of fermented Loci (*Sargassum polycystum*) extract

T_5= Spraying of fermented Guso (*Eucheuma dentilatum*) + Samo (*Sargassum aquifolium*) + Loci (*Sargassum polycystum*) extract

2.1. Preparation and application of seaweed extracts as a natural foliar fertilizer

The different seaweeds were procured from the seashore of Baybay City and neighboring municipal seawaters. Seaweeds are excessive in ash (37.15 – 46.19 %), dietary fibers (25.05 – 39.6 %) low in lipid content (0.29 – 1.11 %) (Mantajun *et al.*, 2009). These seaweeds carry 12.01 – 15.53 % macro-elements (Na, K, Ca, and Mg) and 7.35 – 71.53 % mg 100g^{-1} trace elements (Fe, Zn, Cu, Se, and I). Each of the seaweeds, Guso (*Eucheuma dentilatum*, Burman), Samo (*Sargassum aquifolium*, Turner), and Loci (*Sargassum polycystum*, Fucales) was weighed at one kilogram before being washed with water, cut into small pieces with a knife and finally placed in a separate plastic pail and covered tightly with Manila paper ready for fermentation. One kg of each prepared seaweed material was added with one kg of molasses and exposed to the fermentation process for one month. The procedure with the other plant-based ingredients was repeated, and also fermented for a similar period. The fermented seaweed materials were extracted, and the extracted juice was strained to remove small particles to prevent the mechanical sprayer from clogging during the spraying operation. Fermented seaweed materials were applied two weeks after harvesting the primary crop at a rate of 250 ml per four liters of water. The mixed seaweed-based application followed the same procedure as the pure seaweed-based application. However, the rate of varied seaweed-based application was 83.4 ml *Eucheuma dentilatum* + 83.4 ml *Sargassum aquifolium* + 83.4 ml *Sargassum polycystum* per four liters of water.

2.2. Care and management, and harvesting of ratoon crop

For rice ratooning, Golden Apple Snails (GAS) and rice bugs were the most prevalent pests of the ratoon crop, particularly during the early tillering and reproductive growth phase of the crop. The GAS was controlled by handpicking the snails and egg clusters during early tillering. Methomyl (Lannate) insecticide at one sachet per 16 L water and lambda-cyhalothrin was sprayed at the milking stage to prevent rice bug infestation of ratoon plants. For weed control, hand weeding was done 15 days after harvesting the main crop, and spot weeding was also undertaken 15 days thereafter. The experimental area was irrigated to a depth of 2 to 3 cm two weeks after harvesting the main crop. The water level was raised to 5 cm during the reproductive period of ratoon crops. The entire field was drained two weeks before harvesting to facilitate the reaping of the ratoon crop. Harvesting was done with a sharp sickle when approximately 85 percent of the grains in each plot had ripened. The 85 % maturity was observed as indicated by leaves turning golden brown or yellow and panicle grains becoming firm and amber in color. All sample plants in ratoon crops were cut at the base, excluding the two border rows plot^{-1} and one hill on both ends of each row. Harvested panicles were threshed, and the grains were sundried for three days (14 % moisture) and cleaned separately per treatment.

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 fresh straw 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.

2.4. Cost and return and statistical analyses

Production cost was determined by recording all the expenses incurred from harvesting of the main crop up to drying of the harvested ratoon crop. These include the cost of labor, planting materials, seaweeds, and fertilizer cost. Gross income was determined by multiplying the grain yield per plot by the current price of unmilled grains per kilogram and converted to a per hectare basis. The gross margin was determined by subtracting the gross income from the incurred 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 (Table 1) taken from the different treatments showed mean chemical properties of soil pH (4.76), organic matter (OM) (2.517), total nitrogen (N) (0.187), obtainable phosphorus (P) (1.516 mg kg^{-1}), and convertible potassium (K) of 0.238 me 100g^{-1} (Table 1). The result implies that the soil is very strongly acidic in pH, low in OM and total N, deficient in obtainable P, and has high convertible K (Landon, 1991). Final soil analysis revealed that all elements analyzed were increased, mainly obtainable P and convertible K (Table 1). The increasing nutrients during the final analysis might be due to the mineralization of all nutrients (OM, N, P & K) of the decomposed crop residues from the previous primary crop (Baňoc *et al.*, 2022). The result construed with the output of Dudenhoeffer (2012) that the existence of macronutrients particularly P in greater amounts would result in favorable reactions in modifying soil pH and the availability of such macronutrients in the soil. However, under acidic soil conditions in this study, the usable P triggers insoluble complexes with Al and Fe cations (Pierre and Norman, 1953). Reactions within the soil led to early absorption (Dudenhoeffer, 2012), and transform strong bondage with other elements that make phosphorus unobtainable for plant growth and development. Macronutrients such as P and K are crucial nutrients by the crop for revitalizing plant growth (Mullin, 2009), and no other elements can swap for their supreme roles in physiological and biochemical processes (Syers *et al.*, 2008). Mullin (2009) mentioned that the physiological and biochemical processes of macronutrients particularly P & K enhance photosynthesis, respiration, energy transformation, nucleic acid biosynthesis, cell division, and enlargement of the applied crop components. These nutrients were considered indispensable elements for growth, sugar and starch utilization, photosynthesis, nucleus formation, and cell division (Nkaa *et al.*, 2014). Thereby, an adequate amount of macronutrients would result in speedy growth, development, and early maturity of the crop (Nkuna, 2019).

Table 1. Chemical properties of the soil before and after harvest of ratoon lowland rice var. NSIC Rc222 as affected by application of seaweed extracts grown under high maximum temperatures

Soil samples	Soil pH (1:2.5)	Organic matter (%)	Total N (%)	Obtainable P (mg kg^{-1})	Convertible K (me100 g^{-1}soil)
Before	4.76	2.52	0.187	1.516	0.238
After	5.06	3.18	0.225	4.569	0.577

3.2. Meteorological conditions of the experimental area

The meteorological data on average monthly rainfall, and minimum and maximum temperatures (from April 17 to June 18, 2021) were taken from the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) stations in VSU, Baybay City, Leyte, Philippines (Table 2) (Maplandia.com. 2021). The highest rainfall for the entire duration of the study was observed in week seven with 92.6 mm while the lowest was noted in the second week with 0.45 mm. The total amount of rainfall throughout the growth duration of the ratooned crop was 129.05 mm (Table 2). De Datta (1981) stipulated that the sufficient amount of rainfall to produce supreme productivity is between 900 – 1,000 mm during the growing season, thereby, the amount of rainfall recorded was not enough for the growing ratoon crop.

Table 2. The 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 17 to June 18, 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

However, the growing ratoon crop was supplied with irrigation water for its proper growth and development starting from vegetative until the ripening growth phase. The average minimum and maximum temperatures experienced throughout the growing period of the ratoon crop were 24.07 and 41.88-degree centigrade, respectively. Relative to the temperature requirement of the crop, the maximum temperature experienced by the aforesaid crop was beyond the normal temperature for optimum growth, which was only 29 degree-centigrade as stipulated by Yin *et al.* (1996). Relative humidity recorded was 83.61 % which was also beyond the optimum relative humidity for rice plants which ranged from 60 to 80 % (Weerakoon *et al.,* 2008).

3.3. Agronomic characteristics and yield and yield component parameters

Agronomic, yield, and yield component parameters of ratoon lowland rice (*Oryza sativa* L.) NSIC Rc222 as influenced by foliar application of seaweed extracts when exposed to high maximum temperatures are shown in Table 3. The study revealed that all of the parameters mentioned above were not significantly ($p \leq 0.05$) affected by such foliar application of seaweed extracts due to exposure to high maximum temperatures. The result was not similar to the findings of Sunarpi *et al.* (2010) stated that rice plants applied with Algafer foliar fertilizer promoted the agronomic parameters of lowland rice.

Ratoon lowland rice applied with fermented *Eucheuma dentilatum* extract (T_2) obtained a more extended plant height (88.78 cm) when compared to all other treatments tested (Sunarpi *et al.,* 2010), especially in those plants applied with Algafer foliar fertilizer (T_1) with a plant height of 83.55 cm. Regarding the number of productive tillers hill^{-1}, spraying Algafer foliar fertilizer (T_1) achieved a slightly abundant number of productive tillers (10.89 tillers) compared to all other treatments evaluated. For fresh straw yield (t ha^{-1}), foliar application of fermented *Eucheuma dentilatum* extract (T_3) obtained a slightly higher fresh straw yield (1.31 t ha^{-1}) comparing other treatments. It was followed by rice plants applied with fermented *Eucheuma dentilatum* + *Sargassum aquifolium* + *Sargassum polycystum* (T_5) extracts, foliar application of fermented *Sargassum aquifolium* extract (T_3), non-applied control plants (T_0), plants sprayed with fermented *Sargassum polycystum* extract (T_4), and lastly, those rice plants sprayed with Algafer foliar fertilizer (T_1) with fresh straw yields of 1.24 t ha^{-1}, 1.21 t ha^{-1}, 1.21 t ha^{-1}, 1.19 t ha^{-1}, and 1.15 t ha^{-1}, respectively.

For grain yield (t ha^{-1}), foliar application of fermented *Sargassum polycystum* extract (T_4) produced a higher grain yield (1.24 t ha^{-1}) than those of other treatments adopted. It was closely followed by the foliar application of fermented *Sargassum aquifolium* extract (T_3) with a grain yield of 1.20 t ha^{-1}. Plants sprayed with fermented *Eucheuma dentilatum* extract (T_2), and a combination of fermented *Eucheuma dentilatum* + *Sargassum aquifolium* + *Sargassum polycystum* (T_5) extracts, similar grain yields were obtained of 1.07 t ha^{-1}. Although the grain yield of ratoon lowland rice sprayed with Algafer (T_1) received the lowest grain yield (0.98 t ha^{-1}). The result construed with the findings of (Adigbo *et al.,* 2012) reported that organic liquid fertilizer is less effective and efficient than inorganic granular fertilizer. Talboys *et al.* (2020) concluded that a double combination of seed dressing and foliar application is one of the best alternatives in offering higher efficiency in using applied nutrients relative to its uptake rate and grain productivity than single liquid organic fertilizer. In this study, the effect of foliar application of seaweed extracts was not efficiently utilized by the ratoon crop, thereby translocation of sprayed foliar fertilizers was hampered due to high temperatures of the foliage of the growing ratoon crop. This was mainly observed in the ratoon crop sprayed with Algafer commercial foliar fertilizer.

Numerous factors regulated the performance of foliar nutrients but these are afflicted by physicochemical properties of the formulation, the environment, and the characteristics of the crops. Physicochemical properties like solubility, pH, surface tension, etc. are all snared a vital part in determining the adequacy of nutrient uptake into the applied foliage (Fernandez and Eichert, 2009; Fernandez *et al.*, 2013). Environmental factors such as relative humidity, temperature, and light also influence the nutrient uptake and movement of foliar sprays by regulating both plant response and properties of formulation (Fernandez and Eichert, 2009; Fernandez *et al.*, 2013). The effectiveness of nutrients is overwhelmed by the physiological traits of the crop and species qualities, i.e., 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). All these factors link to modify the adsorption and transformation of foliar nutrients and eventually the plant response (Fernandez *et al.*, 2013).

Improving the competence and usefulness of applied foliar fertilizers will require a good understanding of the physical, chemical, biological, and environmental principles that manage the absorption, translocation, and utilization of supplied nutrients by plants. The complexity of factors that regulate the adequacy of foliar nutrients can be illustrated by taking into consideration the performance of mineral elements and compounds known to have contrasting leaf absorption rates and flexibility within plant tissues and organs (Fernandez *et al.*, 2013). Thus, foliar application of seaweed extracts at high temperatures dries rapidly, thereby decreasing the absorption and transformation of nutrients in the solution (Nutri Ag. 2000). Das *et al.* (2014) claimed that rice plants exposed to a high temperature beyond 35/25 degrees centigrade severely affected the extrusion of panicle, hampered flowering conditions, and poor the development of anthesing spikelets. Besides, there was also a remarkable reduction in the viability and tube length of pollens, low anther dehiscence, and less pollen production in the stigma, although they reported that there was a remarkable reduction in lowland rice than Upland cultivar.

Table 3. Reaction of ratoon lowland rice (*Oryza sativa* L.) var. NSIC Rc222 to foliar application of seaweed extracts grown under high maximum temperatures

Treatment	Plant height (cm)	No of productive tillers hill^{-1}	Fresh straw yield (t ha^{-1})	Grain yield (t ha^{-1})
T_0= No foliar application (control)	87.50	9.56	1.21	1.02
T_1= Spraying of Algafer foliar fertilizer	83.55	10.89	1.15	0.98
T_2= Spraying of fermented Guso extracts	88.78	10.11	1.31	1.07
T_3= Spraying of fermented Samo extracts	86.61	9.83	1.21	1.20
T_4= Spraying of fermented Loci extracts	85.45	10.39	1.19	1.24
T_5= Spraying of fermented Guso + Samo + Loci extracts	87.50	9.44	1.24	1.07
Mean	86.56	10.04	1.22	1.10
F value	0.69^{ns}	0.77^{ns}	0.18^{ns}	0.88^{ns}
CV (a) %	4.44	10.70	18.10	17.31

Results of the study strongly emphasized that the foliar application of fermented *Sargassum polycystum*, which produces higher grain yield, is a potential seaweed-based natural fertilizer for ratoon lowland rice. However, such an increase in yield was not significant. This type of seaweed might be translocated within the inner plant system for increasing productivity even if the crops were exposed to high maximum temperatures than the commercial foliar fertilizer (Algafer). The availability of this material is high in the area since this type of seaweed or seagrass is abundantly grown in the marine protected areas within Baybay City and other neighboring municipal sea waters in the western part of Leyte province.

3.4. Cost and return analysis

Cost and return analysis of ratoon lowland rice var. NSIC Rc222 as influenced by foliar application of seaweed extracts is presented in Table 4. Economic analysis revealed that foliar application of fermented *Sargassum polycystum* extract (T_4) obtained a higher gross income (USD 496.00) and gross margin (USD 283.00) due to the higher grain yield of ratooned. It was closely followed by ratoon rice plants sprayed with fermented *Sargassum aquifolium* extract (T_3) with a gross income (USD 480.00) and a gross margin of USD 267.40. On the other hand, the lowest gross income (USD 392.00) and gross margin (USD 192.90.) were achieved in ratoon rice plants applied with Algafer foliar fertilizer (T_1).

Generally, ratoon rice plants applied with seaweed extracts obtained higher gross incomes and gross margins than those ratoon rice plants sprayed with Algafer foliar fertilizer (T_1). As such, the high gross income and gross margin of ratoon rice plants applied with fermented *Sargassum polycystum* extract (T_4) were due to the high grain yield (1.24 t ha^{-1}) produced by the treatment above. Besides, the low total variable cost (USD 212.60) of such treatment contributed to higher profitability than those ratoon rice plants applied with Algafer commercial foliar fertilizer (T_1).

Table 4. Production cost per hectare (t ha^{-1}) of ratoon lowland rice (*Oryza sativa* L.) var NSIC Rc222 to foliar application of seaweed extracts grown under high maximum temperatures

Treatment	Grain yield (t ha^{-1})	Gross income (USD)	Total variable cost (USD)	Gross margin (USD)
T_0= No foliar application (control)	1.02	408.00	1654.60	242.40
T_1= Spraying of Algafer foliar fertilizer	0.98	392.00	199.10	192.90
T_2= Spraying of fermented Guso Extracts	1.07	428.00	196.600	231.40
T_3= Spraying of fermented Samo Extracts	1.20	480.00	212.60	267.40
T_4= Spraying of fermented Loci extracts	1.24	496.00	212.60	283.40
T_5= Spraying of fermented Guso + Samo + Loci extracts	1.07	428.00	194.20	233.80
Mean	1.10	.00	.00	.00

4. Conclusion

The application of seaweed extracts did not significantly influence ratoon lowland rice productivity when grown under a type four climate (rainfall is uniformly distributed all around the year) due to plants' exposure to high maximum temperatures and unpredictable weather conditions during the conduct of the study. However, spraying fermented *Sargassum polycystum* extract is still a potential seaweed-based natural fertilizer for ratoon lowland rice, given the higher application rate and conducive environment for foliar application. Likewise, the fermented *Sargassum aquifolium* extract is an alternative option for rice ratooning especially if applied with combined granular N fertilizer (urea) during the dry season.

5. Recommendations

The spraying of seaweed extracts at a lower application rate is not recommended in ratoon lowland rice grown under type four climates that experience high maximum temperatures. The application of fermented *Sargassum polycystum* and *Sargassum aquifolium* extract as a cost-reducing strategy is still an alternative foliar fertilizer for rice ratooning during the dry season, particularly with a distinct dry period and experiencing optimum maximum temperatures, not beyond 35 degrees centigrade. A better comprehension of the complicated scheme neighboring the utmost delivery of the seaweed extracts to sink cells and organs is vital for developing the efficacy and performance of foliar fertilizers (Fernandez *et al.*, 2013).

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Institutional Review Board Statement

All Institutional Review Board Statements are confirmed and approved.

Data Availability Statement

Data presented in this study are available on fair request from the respective author.

Ethics Approval and Consent to Participate

This work was carried out in the Agronomy department and followed all the department instructions.

Consent for Publication

Not applicable.

Conflicts of Interest

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.

6. References

Adigbo, S.O., Olojede, M.O., Harris, P.J.C., Ajayi, O. (2012). 'Ratooned lowland Nerica rice varieties as an option for triple cropping in inland valleys of derived Savannah in Nigeria.', *Experimental Agriculture,* 48 (2012), pp. 551-562.

Asio, V.B. (1996). *'Characteristics, weathering, formation, and degradation of soils from volcanic rocks in Leyte, Philippines. Hohenheimer Bodenkundliche Hefte*. Vol. 33, Stuttgart, Germany.

Baňoc, D.M., Sevillano, R.B., Asio, V.B. (2022). 'Ratooning response of lowland rice (*Oryza sativa* L.) varieties to cutting height of ratoon crop', *SVU*- International *Journal of Agricultural Sciences*, 4(1), pp. 99-110.

Carating, R.B., Galanta, R.G., Bacatio, C.D. (2014). *'The soils of the Philippines',* World Soils Book Series. Dordrecht, The Netherlands: Springer. 346 pp. doi: 10.1007/978-94-017-8682-9-5.

Cassan, L., Jeannin, I., Lamaze, T., Morot-Gaudry, J.F. (1992). 'The effect of the Ascophyllum nodosum extract Goemar GA 14 on the growth of spinach', *Botanica Marina*, 35, pp. 437-439. doi:10.1515/botm.1992.35.5.437.

Chauhan, J.S., Lopez, F.S.S., Vergara, B.S. (1985). *'Rice ratoon crop root system',* Int. Rice Res. Newsl, 10(2), p. 2.

Crouch, I.J., Van Staden, J. (1994). 'Commercial seaweed products as biostimulants in horticulture', *Journal of Home Consumer Horticulture*, 1, pp. 19-76. doi:10.1300/J280v01n01-03.

Das, S., Krishnan, P., Nayak, M., Ramakrishnan, B. (2014). 'High-temperature stress effects on pollens of rice (*Oryza sativa* L.) genotypes', *Environmental and Experimental Botany*, 101(2014), pp. 36-46.

De Datta, S.K. (1981). *'Principles and Practices of Rice Production',* John Wiley and Sons, New York. 158 pp.

Dudenhoeffer, C.J. (2012). *'Enhanced Efficiency of Phosphorus Application for Corn.*', MSc. Thesis. University of Missouri, USA.

Erenoglu, E.B., Kutman, U.B., Ceylan, Y., Yildiz, D., Cakmak, I. (2011). 'Improved nitrogen nutrition enhances root uptake, root-to-shoot translocation, and remobilization of zinc (65Zn) in wheat', *New Phytol.,* 189, pp. 438-448. doi:10.1111/j.1469-8137.2010.03488x.

Fernandez, V., Eichert, T. (2009). 'Uptake of hydrophilic solutes through plant leaves: Current state of knowledge and perspectives of foliar fertilization', *Critical Reviews in Plant Science,* 28, pp. 36-68.

Fernandez, V., Sotiropoulos, T., Brown, P.H. (2013). *'Foliar Fertilization. Scientific Principles and Field Practices.*', 1st Edition. Publisher: International Fertilizer Industry Association (IFA): ISBN-979-10-92366-00-6.

Karthikeyan, K., Shanmugam, M. (2016). 'Development of a protocol for the application of commercial bio-stimulant manufactured from *Kappaphycus alvarezii* in selected vegetable crops', *Journal of Experimental Biology and Agricultural Sciences*, 4(1), pp. 92-102. doi:10.18006/2016.

Kutman, V. B., Kutman, B. Y., Ceylan, Y., Ova, E. A., Cakmak, I. (2012). 'Contributions of root uptake and remobilization to grain zinc accumulation in wheat depending on post-anthesis zinc availability and nitrogen nutrition.', *Plant & Soil*, 361, pp. 177-187. 10.1007/s11104-012-1300x.

Landon, J.R. (1991). *'Booker Tropical Soil Manual. A handbook for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics'*, Longman Science and Technical John Wiley and Sons, Inc. 605 third Avenue, New York, NY 10158, 474 .

Lawson, C. (2022). *'The Benefits and Uses of Liquid Seaweed Fertilizer.'*, Dengarden - dengarden.com/gardening/The benefits - of - using - liquid-seaweed - fertilizer.

Mantajun, P., Mohamed, S., Mustapha, N.M., Muhammad, K. (2009). 'Nutrient content of tropical edible seaweeds, *Eucheuma cottonii*, *Caulerpa lentillifera* and *Sargassum polycystum*', *Journal of Applied Phycology*, 21, pp. 75-80.

Maplandia.com. (2021). *'Google maps world gazetteer',* Maplandia.com/Philippines/region- 8/leyte/baybay city.

Mullin, G. (2009). *'Phosphorus, Agriculture and the Environment.'*, Virginia State University, USA.

Niyaki, S.A.N., Radjabi, R., Allahyari, M.S. (2010). 'Social Factors Critical for Adoption of Biological Control agents *Trichogramma* spp. Egg parasitoid of rice stem borer *Chilo suppressalis* in North of Iran.', *American-Eurasian J. Agri. Environ. Sci.*, 9(2), pp. 133-139.

Nkaa, F.A., Nwokeocha, O.W., Ihuoma, O. (2014). 'Effect of Phosphorus Fertilizer on Growth and Yield of Cowpea (*Vigna unguiculata* L.)', *Journal of Pharmacy and Biological Sciences,* 9(5), pp. 74-82.

Nkuna, M.K. (2019). *'Effect of phosphorus application on the performance of four cowpea varieties and two maize varieties under strip intercropping in Limpopo Province.'*, MSc. Dissertation, Faculty of Science and Agriculture, University of Limpopo, South Africa.

Nutri Ag. (2020). *'Factors influencing the uptake of foliar feeds.'*, Nutria.com/factors-influencing-the-uptake-of-foliar-feeds/#; 2 text= Temperature, of % 20 the % 20 nutrients % 20 in % 20 solution.

Pearsall, D.M., Piperno, D.R., Dinan, E.H., Umlauf, M., Zhao, Z., Benfer, R.A. Jr. (1995). 'Distinguishing rice (*Oryza sativa* Poaceae) from Wild Oryza Species through Phytolith Analysis:', *Results of Preliminary Research. Economic Botany*, 49(2), pp. 183-196. https://www.jstar.org/stable/4255715.

Pierre, W.H., Norman, A.G. (1953). *'Soil and Fertilizer Phosphorus in Crop Nutrition.'*, Agronomy, Volume 4, Academic Press Inc., Publishers, New York.

Raut, S.D., Mahadkar, U.V., Nitave, S.S., Rajemahadik, V.A. (2017). 'Effect of different methods of fertilizer application and varying tillage conditions on nutrient content, uptake, quality, and soil fertility of horse gram.’, *Environment & Ecology*, 35 (2D), pp. 1429-1433, April-June 2017. ISSN 0970-0420.

Russo, R.O., Berlyn, G.P. (1990). ‘The use of organic biostimulants to help low-input sustainable agriculture.’, *Journal of Sustainable Agriculture*, 1(2), pp. 19-42. doi:10.1300/J064v01n02-04.

Sunarpi, J.A., Kurnianingsih, R., Julisaniah, N., Nikmatullah, A. (2010). ‘Effect of seaweed extracts on growth and yield of rice plants’, *Nusantara Bioscience*, 2, pp. 73-77. doi: 10.13057/nusbiosci/no20204.

Syers, J.K., Johnston, A.E., Curtin, D. (2008). *‘Efficiency of Soil and Fertilizer Phosphorus Use: Reconciling Changing Concepts of Phosphorus Behaviour with Agronomic Information.’*, Food and Agriculture Organization of the United Nations. Rome, Italy.

Talboys, P.J., Healey, J.R., Withers, P.J.A., Roose, T., Edwards, A.C., Pavinato, P.S., Jones, D.L. (2020). ‘Combining Seed Dressing and Foliar Application of Phosphorus Fertilizer Can Give Similar Crop Growth and Yield Benefits to Soil Application Together with Greater Recovery Rates.’, *Front. Agron.*, 04 December 2020/. https://doi.org/10.3389/fagro.2020.605655.

Tobias, A., Molina, I., Valera, H.G., Mottaleb, K.A., Mohanty, S. (2012). *‘Handbook on Rice Policy for Asia. Los Baňos, Laguna, Philippines.’*, International Rice Research Institute. 47 p.

Verkleij, F.N. (1992). ‘Seaweed extracts in agriculture and horticulture: A review.’, *Biological Agricultural and Horticulture*, 8 (4), pp. 309-324. doi:10.1080/01448765.1992.9754608.

Verma, V.K., Sehgal, O.P., Shiman, S.R. (2000). ‘Effect of nitrogen and GA3 on Carnation’, *Journal of Ornamental Horticulture*, (New series). 3(1), p. 64.

Weerakoon, W.M.W., Maruyama, A., Ohba, K. (2008). ‘Impact of Humidity on Temperature-Induced Grain Sterility in Rice (*Oryza sativa* L.)’, *Journal of Agronomy and Crop Science*, 194(2), pp. 135-140.

Wu, C.Y., Lu, L.L., Yang, X.E., Feng, Y., Wei, Y.Y., Hao, H.L. (2010). ‘Uptake, translocation, and remobilization of the zinc absorbed at different growth stages by rice genotypes of different Zn densities’, *J. Agric. Food Chem.*, 58, pp. 6767-6773.

Yin, X., Kroeff, M.J., Goudriaan, J. (1996). ‘Differential effects of dry and night temperatures on development to flowering in rice.’, *Annals of Botany*, 77, pp. 203-213.

https:/elevation.maplogs.com/poi/baybay_city_leyte_philippines.524451.html.