CLUSTER FOUR

A G R I C U L T U R E

The earthly green is the color most associated with nature and its bounties. This is also where the leaf-inspired gems take their inspiration from. The toils of agriculture have long reaped results, from milestones in harvesting and food production to significant developments in procedure and emerging technologies. It is through research and scientific breakthroughs that the agricultural sector is overcoming the challenges facing it. These research studies sought to analyze, determine, and test various methods that can provide increased insight into agricultural research and development.

These studies also fall under the Aquatic, Agriculture, and Natural Resources (AANR) Research and Development Agenda. They are in line with the goal of developing improved and sustainable agricultural management.

BASED ON: Harmonized National Research and Development Agenda (HNRDA)

The effect of humic acid and inorganic fertilizer application on the growth and yield of *Ipomoea reptans* Poir. (kangkong)

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Abstract

Humic acid (HA), a plant growth stimulator, has not yet established its credibility despite being utilized for several decades in agriculture. Therefore, this study determined the effect of HA and its combined effect with inorganic fertilizer on the growth and yield of *I. reptans*. In each of the two sites, four plots replicated thrice were constructed with three treatment groups - T0B (HA only), T1 (inorganic fertilizer only), and T2 (HA + inorganic fertilizer) - and one control group (T0A, soil only). The plant height and stem diameter of ten randomly chosen plants were measured every 7 days for 21 days while the crop yield was determined 35 days after sowing. From the analysis, significant differences were found in only one of the two sites. Results showed that the treatment with HA only was significantly higher in plant height and crop yield. Data from this study contributes to the current knowledge of crop production for local farmers and the agricultural community.

Introduction. - Agriculture is an essential part of the Philippine economy as it involves 22.9% of Filipino workers and contributes about 9.2% of the gross domestic product as of 2019. However, there is a decrease in crop production of 0.7% in 2018 and 1.0% in 2019 compared to the years preceding them [1]. To address this, researchers have studied the many factors affecting plant growth and productivity, mainly the effects of nutrient composition [2]. Different fertilizers with varying concentrations of nutrients, mainly nitrogen, phosphorus, and potassium, supply plants with the nutrients necessary for their growth. In addition, the increasing amounts of fertilizer increase plant growth, and there are optimal concentrations of these nutrients for optimizing the growth of certain plants [3]. Aside from these nutrients, plant growth simulators such as humic substances have been studied on their positive effects on plant growth and yield.

Humic substances (HSs) are the brown to black, fully decomposed remains of plant or animal organic matter that compose about 80% of organic matter in dark soils [4]. These substances arise from the physical, chemical, and microbiological transformation of biomolecules, and can be divided into three components: fulvic acids (FAs), humic acids (HAs), and humin [5]. Due to their molecular structure, HSs provide numerous benefits to crop production as they help break up clay and compacted soils, assist in transferring micronutrients from the soil to the plant, enhance water retention, increase seed germination rates and penetration, and stimulate the development of microflora populations in soils [6].

Humic substances have been established to also facilitate plant growth and yield as they increase nutrient availability and improve the physical structure of the soil [7, 8]. These substances also have a role in plant metabolism as they contain growth-triggering hormones such as auxin and gibberellins [9]. These hormones promote cell elongation which mainly affects plant height and the development of plant roots [10]. Furthermore, HA has been shown to increase macronutrient and micronutrient uptake of plants [11].

In the Philippines, one of the commonly-used agricultural plants is upland kangkong, also known as *Ipomoea reptans*, which is one of the most cultivated leafy vegetables in Southeast Asia [12]. Although being primarily used for human consumption, *I. reptans* is also considered a common medicinal plant in some Southeast Asian countries, having purgative, anti-inflammatory, hypolipidemic, antidiabetic, diuretic, antiepileptic, and antimicrobial properties [13]. However, in the Philippines, the growth and yield potential of *I. reptans* has not yet been fully exploited due to the inadequate use of inputs and lack of information on its production [14], which includes the utilization of humic substances among others. Given these conditions, it is necessary to utilize HA in fertilizers and determine whether it improves the growth of *I. reptans*. It is hypothesized that combining HA with fertilizers will improve *I. reptans* growth and yield as HA increases nutrient uptake and photosynthesis and respiration rates of plants [8].

This study focused on the effect of HA and its combined effect with inorganic fertilizer on the

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growth and yield of *I. reptans*. Data from this research can be used to establish the credibility of HA utilization in agriculture, and contribute to the knowledge of the production of *I. reptans* species for local farmers.

This research aims to determine the effect of HA and additionally its combined effect with inorganic fertilizer on the growth and yield of *I. reptans*. Specifically, it aimed to:

(i) measure the plant height (cm), stem diameter (cm), and yield (kg/ha) of *I. reptans*. treated without HA (control; T0A), with HA alone (T0B), without HA but with inorganic fertilizer (T1), and treated with combined HA and inorganic fertilizer (T2);

(ii) determine whether using HA improves growth and yield of *I. reptans* by comparing the means of each parameter per treatment group using One-Way ANOVA;

(iii) determine which among the treatment groups is best used for *I. reptans*. production.

Methods. - The methodology is divided into six (6) parts: plot preparation and seed sowing, randomization, watering and monitoring, treatment application, measuring of parameters, and statistical analysis.

Research sites. The two (2) set-ups were done in Barangay Buray, Oton, Iloilo (10° 42' 12" N 122° 28' 6" E) which has soil classified in the Santa Rita soil series [15] and Barangay Balabag, Malay, Aklan (11° 58' 0" N 121° 55' 39" E) using the same soil series. The locations were chosen due to their proximity to the residences of the researchers for easy monitoring. The data was gathered for 35 days. The research conducted in Oton lasted from January 12, 2021, to February 16, 2021, while the one conducted in Malay lasted from January 19, 2021, to February 25, 2021.

Plot Preparation and Seed Sowing. A plot had dimensions of 30 cm by 40 cm. Before sowing the seeds, the soil was tilled up to 15 cm deep while it was moist. Six (6) planting holes were placed in each plot with three (3) seeds in each planting hole, 1-centimeter deep into the soil [12], which amounted to a total of 18 seeds per unit plot. Commercially available *I. reptans* seeds were used.

Randomization. The replicates and plots were laid out in a randomized complete block design. Each replicate was randomized separately (RCBD) [16, 17]. The 18 plants in each plot were labeled from 1 to 18 respectively. A random number generator from 1 to 18 was used to generate 10 random numbers in each plot to determine which plants were measured. The same selected plants that were measured remained constant throughout the weekly data gathering process.

Watering and Monitoring. The treatment plots were monitored daily. They were watered once at 17:00 with a volume of 500 mL of tap water per plot [18]. The plants were not watered if the surface of the soil is moist to the touch and the soil was also weeded when necessary. A screen was also constructed to protect the plants from any damage from pests.

Treatment Application. Two (2) set-ups were made simultaneously, each having three (3) treatment groups and one (1) control group. The treatments evaluated are as follows — T0B: soil applied with HA; T1: inorganic fertilizer + soil; T2: inorganic fertilizer + HA +soil. On the other hand, the control group that was evaluated was T0A: soil only. For the inorganic fertilizer, 250 kg/ha of urea fertilizer (46% N) was applied 7, 14, 21, and 28 DAS [19]. Five hundred (500) mL of 0.1% (1 g/L) solution of HA was applied in the plot every 14 days [20]. POWHUMUS® WSG 85 was used for the HA, derived as potassium humate, manufactured by HuminTech and contains 68-73% total humic acids [20]. The instructions indicated on the product packaging were the basis for the concentrations used in the study. Ramgo Plant Nutrition: Urea Fertilizer by Ramgo International Corporation was used for the inorganic fertilizer.

Measuring of parameters. The plant height and stem diameter were measured every seven (7) days starting at 14 DAS until 35 DAS and were recorded in centimeters (cm). The plant height was measured in cm from the ground level to the tip of the highest growing point using a ruler with ± 0.1 cm accuracy [21]. On the other hand, the stem diameter was measured in cm at the ground level at the base of the plant using a Vernier caliper with ± 0.05 cm accuracy [21]. The crop yield was determined by measuring the fresh weight in grams (g) using a top-loading balance with an accuracy of ±0.01g. The measured weight was then used in the formula below to determine the crop yield in kilograms per hectare (kg/ha) [22].

$$crop\ yield\ (\frac{kg}{ha}) = \frac{yield/plot\ (in\ g)\ \times\ 10^8 cm^2}{1200\ cm^2\ \times\ 1000}$$

Statistical analysis. The raw data collected was subjected to analysis using One-way Analysis of Variance (ANOVA) at 95% confidence level (α=0.05) using Microsoft Excel 365. It was done on groups of the same time point. The Least Significant Difference post-hoc analysis was then made to determine which groups exist a significant difference.

Safety Procedure. The wearing of proper gardening attire was observed during the conduct of the study. The chemicals used were also stored and sealed properly in a glass bottle and a copy of the chemical's MSDS was also kept at all times.

Results and Discussion. - Means of the gathered data were statistically analyzed using one-way ANOVA, and subjected to the Least Significant Difference (LSD) test as post-hoc analysis.

Kangkong in Oton site vs in Malay site. Significant differences were found in the three parameters—plant height, stem diameter, and crop yield—specifically at 28 and 35 DAS at the Oton site. However, no significant differences ($p \leq 0.05$) among treatments were found in all three parameters within five weeks of cultivation at the Malay site.

The varied set of data gathered from the Malay site may be attributed to the different microclimate parameters present in the areas during the duration of the experiment [23]. Considering that the two sites belong to two different climate types classified by PAGASA, this seems to be the case.

With this, the results that will be presented in this study are purely from the Oton site.

Plant height. Results showed that the plant height means of the treatments at 28 and 35 days after sowing (DAS) are significantly different ($p \leq 0.05$).

As seen in Figure 1, at 28 DAS, the mean plant height of the *I. reptans* treated with 0.1% HA (T0B = 23.40 cm) was significantly higher than those of other treatments — T0A (19.82 cm), T1 (19.69 cm), and T2 (18.38 cm). At 35 DAS, the mean plant height of the *I. reptans* treated with 0.1% HA (T0B = 38.24 cm) was also significantly higher than those of other treatments — T0A (30.73 cm), T1 (28.94 cm), and T2 (31.28 cm).

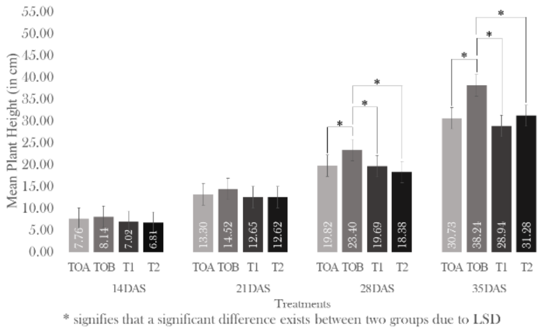

Figure 1. Mean plant height (in cm) of *I. reptans* under different treatments in the Oton site.

This indicates that there was a rise in nitrogen uptake [24]. Nitrogen boosts the growth of plants by stimulating height growth [25]. This may also be attributed to the hormones found in humic substances like auxins and gibberellins, as well as compounds such as amino acids, indole acetic acid, etc. [9][26]. The activation of auxin caused by the HA can induce cell elongation [10][27]. Cell elongation is an obligatory component of plant growth as it refers to the irreversible, rapid, and manifold increase in cell size and volume. It occurs in axial organs, such as stems and roots, wherein cells are elongated predominantly by cell wall growth on the cell lateral sides, resulting in the increase in plant height as plant morphogenesis depends on it [28].

Stem diameter. The One-way ANOVA showed that the stem diameter means of the different treatments were not significantly different ($p \leq 0.05$) as seen in Figure 2.

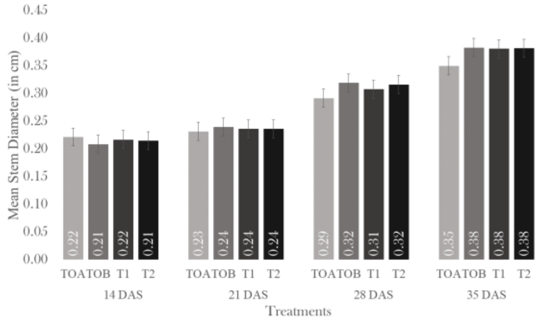

Figure 2. Mean stem diameter (in cm) of *I. reptans* under different treatments in the Oton site.

It can be speculated that there may be an insufficient concentration of Ca^{2+} ions in the soil that HA can keep in a dissolved state [29] and can be absorbed by the plant. This is because Ca^{2+} plays an important role in strengthening plant stems by forming bonds with pectin compounds in plants which are important for plant tissue rigidity and integrity resulting in thicker and stronger stems [30].

Another reason could be because of how cell elongation works which is facilitated by HA. Cell elongation is defined as cells expanding in one dimension to elongate cells and organs [31]. Since the auxins activated by HA induce cell elongation [10] rather than expansion (in all three dimensions), the stem diameter of the plants cannot significantly increase.

Crop yield. One-way ANOVA showed that the crop yield means (in kg/ha) of the different treatments are significantly different ($p \leq 0.05$).

The mean crop yield (kg/ha) of the *I. reptans* treated with 0.1% HA (T0B = 6738.90) was significantly higher ($p \leq 0.05$) than those of other treatments — T0A (4872.20 kg/ha), T1 (4711.10 kg/ha), and T2 (3616.67 kg/ha) (Figure 3). This indicates that the treatment with 0.1% HA (T0B) improves crop yield the most among other treatments.

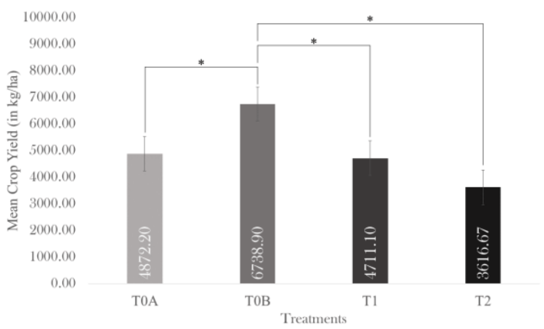

Figure 3. Mean crop yield (in kg/ha) of *I. reptans* under different treatments in the Oton site.

This increase in crop yield is attributed to the aforementioned growth-promoting hormones, auxins and gibberellins, which also play a role in the development of plant roots [32]. Increased vegetative growth and productivity are mainly due to the hormone-like activities of HA as it is involved in cell respiration, oxidative phosphorylation, protein synthesis, photosynthesis, antioxidants, and various enzymatic reactions [28]. The influence of HA is also found in the development of plant roots, thus increasing plant production [24].

Optimal treatment for I. reptans growth and production. Among the four treatments, T0B (soil applied with 0.1% HA) was the best treatment for *I. reptans* growth and production. Despite not having a notable impact on stem diameter, the treatment yielded positive significant effects on plant height and crop yield. Given that these parameters indicate the quality of plant growth and production, it can be deduced that the sole application of HA is the best treatment for *I. reptans*.

This is in contrast however to the initial hypothesis based on the studies conducted by Sangeetha et al. [33] and Zhang et al. [9]. The positive effects of HA and the positive effects of urea separately may improve plant growth and yield when both substances are used in combination. To summarize, HA may contain auxin- and gibberellin-like substances or induce the activity of these to promote cell elongation of axial organs such as stems and roots. Urea provides nitrogen for the plant, as nitrogen boosts the growth of plants by stimulating height growth [34].

It is suspected that plant toxicity by NH_4^+ has occurred due to an increase in soil pH, which generally has adverse effects on higher plants physiologically [35]. The toxicity of NH_4^+ depends upon the substrate-solution concentration of NH_3, the un-ionized form of NH_4^+. Since NH_3 increases as pH increases, this makes NH_4^+ more toxic as the soil becomes more acidic]. Furthermore, a decrease in phosphorus (P) uptake and utilization as an effect of an increase in soil pH due to urea fertilization can also be the case. This has caused plants to use urea inefficiently. Phosphorus (P) deficiency reduces plant growth which is attributed to either decrease in photosynthesis or an increase in energy investment and negatively impacts crop yield and quality [35].

Limitations. The data gathering was conducted within 35 days in two sites with varying climate types and weather conditions, which affected the plant samples even with significant efforts to control the effect of these factors. Although *I. reptans* can already be harvested at this time, the difference in plant growth and yield among treatments can be seen more clearly within a longer timespan. Furthermore, due to the unavailability of laboratory equipment, other parameters such as nutrient uptake, soil moisture, and other soil parameters were not measured.

Despite this, the findings of this study may aid future research in improving the growth and production methods of agricultural crops and in establishing the credibility of humic substances in agriculture.

Conclusion. - Significant differences were found between groups in only one site at 95% confidence level in mean plant height both at 28 and 35 DAS, and mean crop yield. Meanwhile, no significant differences were found in stem diameter means at all seven-day intervals. Post-hoc analysis using Fisher's LSD test showed significant differences between T0A and T0B, T1 and T0B, and T2 and T0B but none in other pairs of treatments in terms of plant height and crop yield. Thus, the sole application of HA produced *I. reptans* with the tallest plant height and largest crop yield among the treatments used.

Recommendations. - Results in this study can be improved by replicating in an enclosed space more suitable for plant growth to avoid the effects of weather conditions and to prevent infiltration and infestation of pests. Other treatments can be utilized such as other types and levels of fertilizers and HA, and the use of other humic substances such as naturally extracted HA or substances. It is also recommended to conduct the study with a larger plant population and sample size for better representation. Certain parameters such as the number of leaves and branches, nutrient uptake, and soil parameters can be evaluated and measured. These parameters help determine their overall effect on plant growth and measure the growth of the plant itself. Replication of these types of studies on other plant species may be done. The use of HA in agriculture is recommended as it has positive results on crop growth and yield.

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References

[1] [PSA] Philippine Statistics Authority. 2020. 2020 Selected statistics on agriculture. Philippines: Philippine Statistics Authority. p. 1–5. ISSN-2012-0362.

[2] Liliane TN, Charles MS. 2020. Factors Affecting Yield of Crops. In: Khan A, editor. Agronomy: Climate Change & Food Security. London (UK): IntechOpen. [cited 2020 Oct 23]. Available from http://bit.ly/lilianecharles 2020.

[3] Purbajanti ED, Slamet W, Fuskhah E. 2019. Effects of organic and inorganic fertilizers on growth, activity of nitrate reductase, and chlorophyll contents of peanuts (Arachis hypogaea L.). In IOP Conference Series: Earth and Environmental Science (Vol. 250, No. 1, p. 012048). IOP Publishing.

[4] Mayhew L. 2004. Humic substances in biological agriculture. Rev ACRES. 34(1–2): 80–88.

[5] Peña-Méndez EM, Havel J, Patočka J. 2005. Humic substances-compounds of still unknown structure: applications in agriculture, industry, environment, and biomedicine. J Appl Biomed. 3(1): 13–24.

[6] Senesi N, Miano TM, Provenzano MR, Brunetti G. 1991. Characterization, differentiation, and classification of humic substances by fluorescence spectroscopy. Soil Sci. 152(4): 259–271.

[7] Mora V, Bacaicoa E, Zamarreno AM, Aguirre E, Garnica M, Fuentes M, García-Mina JM. 2010. Action of humic acid on promotion of cucumber shoot growth involves nitrate-related changes associated with the root-to-shoot distribution of cytokinins, polyamines, and mineral nutrients. J Plant Physiol. 167(8): 633–642.

[8] Zhang L, Zhou JUN, Zhao YG, Zhai Y, Wang KAI, Alva AK, Paramasivam S. 2013. Optimal combination of chemical compound fertilizer and humic acid to improve soil and leaf properties, yield, and quality of apple (Malus domestica) in the loess plateau of China. Pak J Bot. 45(4): 1315–1320.

[9] Tan KH. 2003. Principles of Soil Chemistry. New York (US): Marcel Dekker Inc.

[10] Farabee MJ. 2007. Plant Hormones, Nutrition and Transport [Internet]. Avondale (AZ): Estrella Community College; [cited 23 Nov 2020]. Available from: http://bit.ly/farabee2007.

[11] Nikbakht A, Kafi M, Babalar M, Xia YP, Luo A, Etemadi NA. 2008. Effect of humic acid on plant growth, nutrient uptake, and postharvest life of gerbera. J Plant Nutr. 31(12): 2155–2167.

[12] Palada MC, Chang LC. 2003. Suggested cultural practices for kangkong (No. OTHER). AVRDC-The World Vegetable Center.

[13] Manvar MN. 2011. Pharmacognostical investigations on Ipomoea aquatica Forsk. Int J Pharm Sci Res. 2(11): 2812.

[14] Susila AD, Prasetyo T, Palada MC. 2008. Optimum fertilizer rate for kangkong (Ipomoea reptans L.) production in ultisol Jasinga.

[15] Status of Digital Soil Mapping in BSWM. 2015. Quezon City (PH). Bureau of Soil and Water Management; [cited 2020 Oct 9]. Available from: http://bit.ly/BSWM2015.

[16] Jayaraman K. 1999. A Statistical Manual for Forestry Research. Bangkok (TH): Forestry and Agriculture Organization of the United Nations [cited 2020 Oct 23].

[17] Grant T. 2019. Randomized Complete Block Design. Columbus (OH): Plant Breeding and Genomics; [cited 2020 Oct 23]. Available from: http://bit.ly/grantt2019.

[18] Luyen LT, Preston TR. 2004. Effect of level of urea fertilizer on biomass production of water spinach (Ipomoea aquatica) grown in soil and in water. Livestock Research for Rural Development. [cited 2020 Nov 10] 16(81). Available from: http://bit.ly/luyenpreston 2004.

[19] Sophia K, Preston TR. 2001. Comparison of biodigester effluent and urea as fertilizer for water spinach vegetable. Livestock Research for Rural Development. [cited 2020 Nov 10] 13(59). Available from http://bit.ly/sophia preston2001.

[20] PowHumus® WSG 85. [date unknown]. Grevenbroich (DE): Humintech; [cited 2020 Oct 22]. http://bit.ly/powhumusagnosto.

[21] Ibrahim MH, Rahman NYA, Zain NAM. 2018. Effect of nitrogen rates on growth and quality of water spinach (Ipomea aquatica). Annu Res Rev Biol. 1–12.

[22] Technical guidelines for measuring crop yields in field crops. 2004. Bajo (BT): Agricultural Research and Development Center Bajo Wangdue Phodrang; [cited 2020 Oct 11]. Available from: http://bit.ly/rcbajo2004.

{23] Rahman S. 2002. Performance of summer vegetables under reduced light condition as agroforestry systems [thesis]. [Dhaka, Bangladesh]: Sher-e-Bangla Agricultural University. Chapter 4.2.3. Kangkong; p. 40–43. Available from: http://bit.ly/rahman2002.

[24] Suwardi, Cholili SN, Anwar S. 2019. Application of humic substances with zeolite as carrier to increase the production of water spinach (Ipomoea reptans Poir.). IOP Conf Ser: Earth Environ Sci. 393 (2019): 1–9.

[25] Leiwakabessy FM, Wahjudin UM, Suwarno. 2003. Kesuburan Tanah. Bogor (ID): IPB.

[26] Gardiner DT, Miller RW. 2004. Soil in Our Environment, 10th ed. New Jersey (US): Pearson Education.

[27] Mora V, Baigorri R, Bacaicoa E, Zammareño AM, Garcia-Mina JM. 2012. The humic acid-induced changes in the root concentration of nitric oxide, IAA, and ethylene do not explain the changes in root architecture caused by humic acid in cucumber. Environ Exp Bot. 76: 2432. doi: 10.1016/j.envexpbot.2011.10.001.

[28] Obroucheva NV. 2008. Cell elongation as an inseparable component of growth in terrestrial plants. Russ J Dev Biol. 39(1): 13–24.

[29] Rahmandhias DT and Rachmawati D. 2020. The Effect of Humic Acid on Productivity and Nitrogen Uptake in Kangkong (Ipomoea reptans Poir.). JIPI. 25 (2): 316–322. doi: 10.18343/jipi.25.2.316.

[30] Demarty M, Morvan C, Thellier M. 1984. Calcium and the cell wall. Plant Cell Environ. 7(6): 441–448.

[31] Oh MH, Honey SH, Tax FE. 2020. The control of cell expansion, cell division, and vascular development by brassinosteroids: A historical perspective. Int J Mol Sci. 21(5): 1–15. doi: 10.3390/ijms21051743.

[32] Trevisan S, Francioso O, Quaggioti S, Nardi S. 2010. Humic substances biological activity at

the plant soil interface. Plant Sign Behav. 5(6): 635–643.

[33] Sangeetha M, Singaram P. 2007. Effect of lignite humic acid and inorganic fertilizers on growth and yield of onion. Asian J Soil Sci. 2(1): 108-110.

[34] Witte, CP. 2011. Urea metabolism in plants [Abstract]. Plant Sci. 180(3): 431-438. doi: 10.1016/j.plantsci.2010.11.010.

[35] Goyal SS, Huffaker RC. 1984. Nitrogen toxicity in plants. Nitrogen in crop production. 97-118.

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Effects of hydropriming on the germination of *Oryza sativa* L. NSIC Rc 216 (rice) under sodium chloride (NaCl) stress

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Abstract

Elevated salt concentration can be toxic to plant development. Hydropriming can overcome this by increasing the seeds' stress tolerance. This study determined the effects of hydropriming on the germination of *Oryza sativa* L. var. NSIC Rc 216, a widely used rice variety in the Philippines, subjected to sodium chloride stress. Seeds were hydroprimed for 12, 24, or 48 hours with unprimed rice seeds as control. Seeds were then allowed to germinate for seven days and germination parameters were recorded. Significant differences were recorded with the germination energy percentage (GEP) and speed of germination means (SG). The 48-hour treatment had significantly higher GEP and SG means when compared to the control set-up; however, no significant differences were recorded with the final germination percentage (FGP) and seedling vigor index (SVI). In conclusion, hydropriming had effects on the germination rate of rice under salt stress but not with its overall germination performance.

Introduction. - Rice (*Oryza sativa* L.) is an important staple food crop in the world and in the Philippines, feeding half of the human population [1].

However one of the major problems of the agriculture industry is soil salinity. It affects the plant at almost all of its growth stages and impacts the germination and growth of plants [2]. Highly saline environments can decrease the osmotic potential of soil and make it toxic to seedlings [3]. The growth of rice, in particular, can be negatively affected by increased salt concentration that leads to the reduction of several germination parameters such as its final germination percentage (FGP), germination energy percentage (GEP), and speed of germination (SG) [4].

Hydropriming has been recommended to address the effects of soil salinity [5,6,7]. It is a simple method that only requires distilled water as the priming medium for the seeds before sowing [8]. This process enables the seeds to imbibe water which facilitates the emergence of the seeds' radicle [9,10]. With this, it has the potential to upregulate the tolerance of plants from abiotic stresses by enhancing seed germination, seedling growth, and development [7,10].

Although there have been few studies on the effect of hydropriming on the germination of *O. sativa* L, under salt stress [11, 12, 13], there is limited research on its effect on the variety NSIC Rc 216 subjected to elevated salinity levels.

NSIC Rc 216 rice variety has a wide adaptation under different stresses presented by varying climates across the country thus making it one of the most popular rice varieties in the Philippines [14]. Although it is considered versatile, it was classified as salt-sensitive by Imai and Sevilla [15] which may lead to poor germination and plant growth that can cause yield losses during harvest if subjected to salt stress during germination [4].

This study tested the efficacy of hydropriming in counteracting salt stress in *O. sativa* L., variety NSIC Rc 216, helping determine how generalizable is hydropriming's pro-germination effects to other rice varieties.

More specifically, it aimed to:

(i) determine and calculate the number of seedlings per day, the height of seedlings, and the seed germination parameters: final germination percentage (FGP), germination energy percentage (GEP), speed of germination (SG), and seedling vigor index (SVI);

(ii) determine the effects of different hydropriming durations (12 hours, 24 hours, and 48 hours) on the calculated germination parameters of *Oryza sativa* L. variety NSIC Rc 216 under saline stress; and

(iii) compare and determine if there is a significant difference among the treatments using one-way analysis of variance (ANOVA) and

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Least Significant Difference (LSD) post-hoc analysis using Rstudio and R programming language.

Methods. - Rice seeds were hydroprimed at varying durations (12, 24, or 48 hours) following a completely randomized design (CRD), with unprimed rice seeds as control, as seen in Table 1. They were subsequently air-dried for three (3) hours, then they were allowed to germinate in the prepared germination media and chamber. After seven (7) days, all the germination parameters were measured and recorded. Statistical analysis was then performed.

Table 1. The different hydropriming duration, replicates, and corresponding labels of the different set-ups used.

Hydropriming duration (hours)	No. of seeds per replicate	Replicates
12	50	3
24	50	3
48	50	3
0 (Control)	50	3

Seed authentication, storage, and selection. Rice variety NSIC Rc 216 was acquired from the local farmers at Oluangan, Leon, Iloilo, and authenticated with the help of the Department of Agriculture at Leon, Iloilo.

They were then stored in an airtight container at room temperature until use. The seeds were tested for moisture content to ensure seed viability. Seeds that had moisture content of 14% or less were considered viable, while the rest were discarded.

Seed hydropriming. Fifty (50) seeds per replicate per treatment were selected. They were hydroprimed for 0 (control), 12, 24, and 48 hours using distilled water (Absolute Pure Distilled Drinking Water) with a ratio of 5 mL of water for every 12 rice seeds. The seeds were then air-dried for 3 hours and stored in growing media for germination.

Growing media. A total of 12 Petri dishes, with three (3) layers of filter paper each, were used as growing media. They were kept sealed during the experiment to prevent moisture loss.

Saline stress simulation. To induce salt stress, a 0.15 M saline solution was prepared using a technical grade sodium chloride (NaCl) and distilled water. Ten (10) mL of the prepared solution was then administered evenly to each replicate of each treatment after the hydroprimed and control seeds were sowed on the growing media.

According to Chunthaburee et al. [16], a 0.15 M salt concentration generally induces hyperosmotic stress to rice seeds through ion imbalance.

Growth period and conditions. The Petri dishes were then stored in a germination chamber with LED tubes at a 12-hour light and 12-hour dark photoperiodic cycle with the light intensity maintained at 4000 lux during the light cycle [17]. The seeds were then allowed to germinate for seven (7) days.

Data collection and calculation. Germinated seeds were counted every 24 hours at 6:00 AM, following the procedure by the International Research Institute (IRRI) where both plumule and radicle must be present [18]. After the germination period, 15 sprouted seedlings with the longest lengths (root+shoot) per replicate per set-up were selected and their lengths were recorded. The final germination percentage (FGP), speed of germination (SG), germination energy percentage (GEP), and seedling vigor index (SVI) were then calculated using the following equations [4, 19]:

$$FGP = \frac{No. of\ germinated\ seeds\ on\ the\ 7th\ day}{Number} \times 100$$

$$SG = \frac{No. of\ ger. seeds}{Days\ of\ first\ count} + \cdots + \frac{No. of\ ger. seeds}{Days\ of\ last\ count}$$

$$GEP = \frac{No. of\ seeds\ germinated\ on\ the\ fourth\ day}{Total\ number\ of\ seeds} x\ 100$$

$$SVI = FGP \times seedling\ length\ (root + shoot)$$

Statistical analysis. One-way analysis of variance (ANOVA) was conducted for each calculated parameter of all treatments with a confidence interval of 95% (α=0.05). Least Significant Difference (LSD) post-hoc analysis was then performed using Rstudio (version 1.4.1106, Open Source License).

Safety procedure. The safety data sheet (SDS) for NaCl was secured and the hazards of handling were considered beforehand. NaCl was disposed of in chemical waste containers while the discarded seeds were segregated properly. Proper protective equipment was worn at all times while performing all experimental procedures. All the procedures were done at home to prevent COVID-19 infection.

Results and Discussion. - The study aimed to determine the effects of hydropriming on the germination of *O. sativa* L. var. NSIC Rc 216 under NaCl stress.

After seven days, a germination lag was observed with the control setup for two (2) days and both 12 and 24-hour setup for one (1) day. No germination lag has been observed with the seeds hydroprimed for 48 hours.

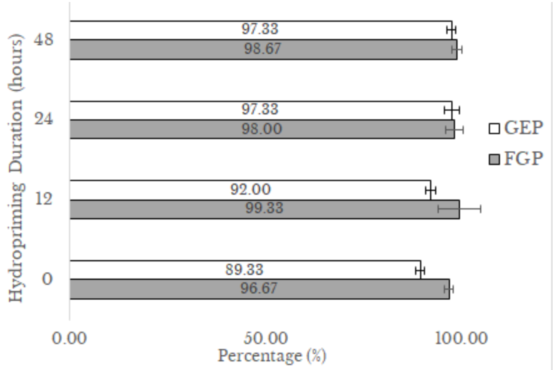

Figure 1. The calculated Final Germination Percentage (FGP) and Germination Energy Percentage (GEP) for all the experimental set-ups.

Final Germination Percentage and Germination Energy Percentage. The highest FGP mean was recorded with the 12 hours of hydropriming of rice, as seen in Figure 1; however, this was not significant when compared to other treatments. The highest recorded GEP mean, on the other hand, was with 24 and 48 hours of hydropriming, both having the same value of 97.33% and were significantly different when compared to the rest of the set-ups with a p-value of 0.03.

The values of both parameters (FGP and GEP) may indicate that hydropriming affects the germination of rice seeds at the earlier stages. This was suggested by the significantly different values for GEP which was a parameter calculated using the data on the 4th day.

With that, seeds germinated faster when hydroprimed at longer durations; however, after some time, seeds hydroprimed at shorter durations germinated as well. This may have caused the FGP values, which was a parameter calculated on the 7th day, to be non-significant.

This is in accordance with the results of Prasad [20] in which GEP also increased with longer durations of hydropriming, with the highest GEP mean recorded with 28 hours of hydropriming. This effect was attributed to the different biological mechanisms triggered by hydropriming, such as the release of enzymes that produce soluble food nutrients for the seeds. This may have enabled the seeds to germinate upon sowing [20].

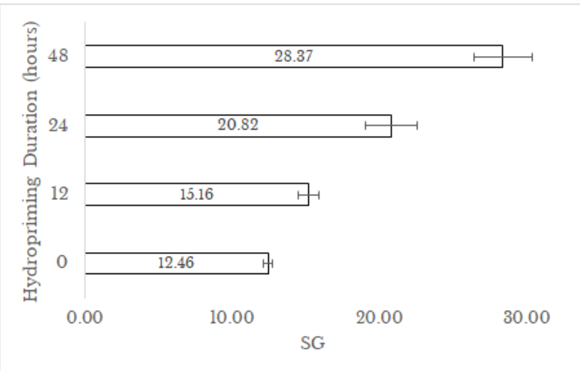

Figure 2. The calculated Speed of Germination (SG) for all the experimental set-ups.

Speed of Germination. The highest SG mean was recorded with the 48-hour hydroprimed seeds, as seen in Figure 2. The SG also increased with longer durations of treatment. This may be caused by the jumpstart in germination through a series of biological and physiological processes such as the acceleration of the emergence phase and multiplication of radicle cells [11, 21, 22]. In the study of Amooaghie [23], it was stated that the early germination stage of plants was "from sowing to seedling emergence" in which they are most vulnerable to external conditions such as salt stress. Hydropriming speeds up the germination process through stimulatory effects through cell division mediation and thus limits the exposure of the seeds to the stressful conditions presented by the environment [11, 24]. This was also in line with the findings of Kaya et al. [9] in which hydropriming of *Helianthus annuus* L. seeds resulted in the acceleration of germination even in low osmotic potential (i.e. salt stress).

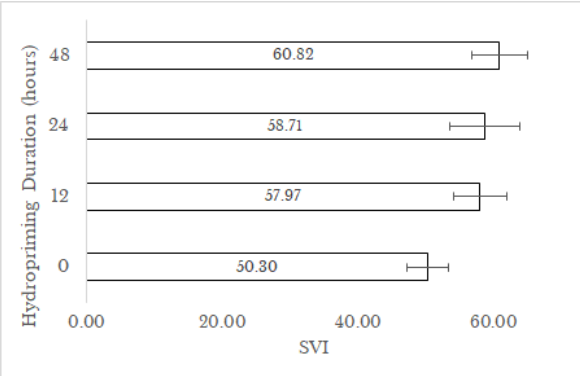

Figure 3. The calculated Seedling Vigor Index (SVI) for all the experimental set-ups.

Seedling Vigor Index. The highest SVI was recorded with 48-hour hydroprimed seeds, as seen in Figure 3. The seedling vigor index increased with the increasing duration of hydropriming; however, it was determined that these values are not significant with a p-value of 0.06. Similar to the FGP, the SVI was not affected probably because the parameter was recorded over a longer period and hydropriming may have only affected the earlier germination stages of rice seeds [24].

The study of Elyasirad et al. [25] had contrasting findings to these results. The study observed that hydropriming *Ferula assa-foetida* has a significant effect on the germination parameters of the seeds, including the SVI [25].

This may be explained by the positive effects of saline content observed by previous studies. An example of this is with Lutts et al. [13] which found out that increased NaCl concentration of up to 50 mM, caused proline accumulation of rice seedlings. This proline accumulation may be responsible for improving the germination of rice seeds by counteracting the effects of salinity by ion detoxification. This protects the plant at the cellular level from osmotic imbalance presented by the saline content of the environment [26]. This may have happened to the unprimed seeds that caused the germination performance in this setup to be comparable to the performance of 48-hour hydroprimed seeds, as evaluated by the SVI.

Limitations. Due to time constraints, this study only observed the effects of hydropriming on limited parameters and only one salinity level has been used. The entire experiment has been done at home which may have affected the overall results of this study specifically with the unavoidable external factors such as humidity, light from other sources within the study site, and resident presence.

Conclusion. - Hydropriming was concluded to only have effects on the early days of rice seed germination, primarily affecting the germination rate but not with the overall germination performance while the rice seeds were being subjected to saline stress. Hydropriming may also be used to accelerate germination of *O. sativa* L.in saline conditions.

Recommendations. - It is highly encouraged to use other Philippine rice varieties to further assess the effects of hydropriming on their germination while being subjected under saline stress. A larger scale of this experiment with a longer duration of observation is also recommended. The replication of the experiment in laboratory and field conditions may also be considered to minimize or completely eliminate the effects of external conditions that can affect the study.

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References

[1] Portilla JC, Pagaduan JMR. 2015. Status of other staple crops as substitute to rice: an assessment in Isabela and Quirino [Philippines]. Philipp J Crop Sci. 39(1): 132–133.

[2] Franco AJ, Esteban C, Rodriguez C. 1993. Effects of salinity on various growth stages of muskmelon cv. Revigal. Int J Hortic Sci. 68(6): 899–904.

[3] Kozlowski TT, Pallardy SG. 1996. Growth Control in Woody Plants. San Diego (CA). Academic Press.

[4] Hakim AM, Juraimi SA, Begum M, Hanafi MM, Ismail MR, Selamat A. 2010. Effect of salt stress on germination and early seedling growth of rice (*Oryza sativa* L.). Af J Biotechnol. 9(13): 1911–1918.

[5] Damalas A, Koutroubas S, Fotiadis S. 2019. Hydro-priming effects on seed germination and field performance of Faba bean in spring sowing. Agriculture. 9(9): 201.

[6] Taylor AG. 2003. SEED DEVELOPMENT | seed treatments. In: Encyclopedia of Applied Plant Sciences. Elsevier. 1291–1298.

[7] Farahani HA, Maroufi K. 2011. Effect of hydropriming on seedling vigour in basil (*Ocimum basilicum* L.) under salinity conditions. Adv Environ Biol. 828–834.

[8] Khalid MF, Hussain S, Anjum MA, Ejaz S, Ahmad M, Jan M, Zafar S, Zakir I, Ali MA, Ahmad N, et al. 2019. Hydropriming for Plant Growth and Stress Tolerance. In: Priming and Pretreatment of Seeds and Seedlings. Singapore: Springer Singapore. 373–384.

[9] Kaya MD, Okçu G, Atak M, Çikili Y, Kolsarici Ö. 2006. Seed treatments to overcome salt and drought stress during germination in sunflower (*Helianthus annuus* L.). Eur J Agron. 24(4): 291–295.

[10] Jayesh V, Meeta J. 2015. Influence of halopriming and hydropriming on seed germination and growth characteristics of *Zea mays* L. cv. GSF-2 under salt stress. Res J Chem Environ. 19(1): 10.

[11] Ibrahim N, Bhadmus Z, Singh A. 2013. Hydro-Priming and Re-Drying Effects on Germination, Emergence, and Growth of Upland Rice (*Oryza sativa* L.). Nig J Basic Appl Sci. 2013: 21(2).

[12] Koirala N, Poudel D, Bohara GP, Ghimire NP, Devkota AR. 2019. Effect of seed priming on germination, emergence, and seedling growth of spring rice (*Oryza sativa* L.) cv. Hardinath-1. Azarian J Agric. 6(1): 7–12.

[13] Lutts S, Majerus V, Kinet JM. 1999. NaCl effects on proline metabolism in rice (*Oryza sativa*) seedlings. Physiol Plant. 105(3): 450–458.

[14] Laborte A, Paguirigan N, Moya P, Nelson A, Sparks, Gregorio G. 2015. Farmers' preference for rice traits: Insights from farm surveys in Central Luzon, Philippines, 1966-2012. PLOS ONE. 10(8):e0136562.

[15] Imai T, Sevilla L. 2012. Screening for salt stress tolerance in different varieties of *Oryza sativa L.* [dissertation]. University of the Philippines Manila. Accessed from: DSpace Repository.

[16] Chunthaburee S, Sanitchon J, Pattanagul W, Theerakulpisut P. 2014. Alleviation of salt stress in seedlings of black glutinous rice by seed priming with spermidine and gibberellic acid. Not Bot Horti Agrobot Cluj Napoca. 42(2):405-413.

[17] Anuradha S, Rao SSR. 2003. Application of brassinosteroids to rice seeds (*Oryza sativ*a L.) reduced the impact of salt stress on growth, prevented photosynthetic pigment loss, and increased nitrate reductase activity. Plant Growth Regul. 40(1): 29–32.

[18] Crop and Environmental Sciences Division (CESD). 2013. Seed Quality Testing Manual. Int Rice Res Ins*t*. 1(1): 1-23

[19] Vashisth A, Nagarajan S. Effect on germination and early growth characteristics in sunflower (Helianthus annuus) seeds exposed to static magnetic field. J Plant Physiol. 167(2):149–156.

[20] Prasad S. 2012. Effect of hydro-priming duration on germination and seedling vigour of rice (*Oryza sativa* L.) cv. J Crop Weed, 8(1):65–71.

[21] Dastanpoor N, Fahimi H, Shariati M, Davazdahemami S, Hashemi SMM. 2013. Effects of hydropriming on seed germination and seedling growth in sage (*Salvia officinalis* L.). Af J Biotechnol. 12(11): 1223–1228.

[22] Mcdonald M. Seed deterioration: Physiology, repair and assessment. 1999. Seed Sci and Technology 27: 177–237.

[23] Amooaghaie R, 2011. The effect of hydro and osmopriming on alfalfa seed germination and antioxidant defenses under salt stress. Af J Biotechnol. 10(33): 6269–6275.

[24] Freeman CE. 1973. Germination responses of a Texas population of ocotillo (*Fouquieria splendens* Engelm.) to constant temperature, water stress, pH and salinity. American midland Naturalist. 252–256.

[25] Elyasirad S, Mousavi SG, Sanjari, G. 2006. Effects of priming and salt stress on seed germination and emergence characteristics of asafetida (*Freula assa foetida*): A laboratory and glasshouse trial. ARPN J Agric Biol Sci. 12(4): 150–160.

[26] Singh M, Singh AK, Nehal N, Sharma N. 2018. Effect of proline on germination and seedling growth of rice (*Oryza sativa* L.) under salt stress. Pharmacogn Phytochem. 7(1): 2449–2452.

Effects of powdered chicken eggshells as a soil amendment on the vegetative growth of *Vigna radiata*

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Abstract

The continuous and excessive generation of eggshells as agricultural and industrial waste results in various environmental problems. However, recent studies have shown that eggshells contain essential compounds that promote plant growth and soil condition. Thus, this study aimed to determine the effects of powdered chicken eggshells (PCES) on the vegetative growth of *Vigna radiata*. Chicken eggshells were air-dried, crushed, and powdered. The plants were then grown on PCES-soil compositions of 0%, 10%, and 15% (w/w). The stalk and root length were statistically compared between treatments using one-way ANOVA and post-hoc Tukey-Kramer test. The results indicate that a significant difference existed for both mean plant length scores between plants grown on untreated soil and PCES-treated soil; PCES was found to improve the vegetative growth of *V. radiata*. However, adverse effects were observed at 15% PCES due to excessive calcium uptake. Hence, quantifying the amount threshold of PCES is necessary.

Introduction. - Food industries continuously produce excessive amounts of waste, making it increasingly crucial to formulate solutions to solve this problem. Eggs are one of the products with extensive production quantities under the industry [1]. Hence, considerable amounts of eggshells are being discarded every day, resulting in various environmental issues such as increased waste in landfill sites and pollution [2]. According to the Food and Agriculture Organization of the United Nations (FAO) [3], the world egg production in 2019 was recorded to be about 83.5 million tonnes. In addition, eggshells constitute about 11% of the total egg weight. Thus, the waste generated can be estimated to be about 9.2 million tonnes per year, globally [1].

An eggshell is composed of 94% calcium carbonate, 1% calcium phosphate, 1% magnesium carbonate, and 4% organic substances [4]. Hence, eggshells are known to contain substantial amounts of calcium, and due to this, they can be utilized for the improvement of plant growth [5,6]. A study conducted by Gaonkar and Chakraborty [7] reported that powdered eggshells increase the pH and calcium content of the soil. Furthermore, the study indicated that chicken eggshells contain larger quantities of calcium carbonate than duck eggshells. Additionally, Ok et al. [8] and Soares et al. [9] reported the successful immobilization of heavy metals such as cadmium, lead, and zinc in contaminated soils through treatment with eggshells. Moreover, a study conducted by Wijaya and Teo [5] reported that eggshells significantly improved the height of *Ocimum basilicum* (sweet basil), which is associated with its calcium content.

These findings are mainly associated with the composition of eggshells as previously mentioned. Furthermore, it must be noted that calcium, an essential mineral for plant growth, is the main constituent sought after eggshells in the study [5,11]. Additionally, the mechanism of entry of this mineral cation to plant cells is via passing through Ca^{2+}-permeable ion channels situated in the plasma membrane [10]. This separates the other components of calcium salts such as the carbonate group for the case of calcium carbonate [11].

The aforementioned information and findings highlight the practical application of eggshells in utilizing their properties to strengthen waste management and agricultural production. Hence, its application as a soil amendment to increase the calcium content of the soil will be beneficial to developing countries. Furthermore, this is in line with the promotion of zero hunger, economic growth, and responsible consumption and production, which are some of the Sustainable Development Goals (SDGs) being targeted by the United Nations (UN) [12].

Vigna radiata (mung beans or “monggo”) is one of the major crops in the Philippines, commonly used in various local dishes. It is an annual, erect or semi-erect legume that is usually cultivated for its seeds or sprouts across Asia [13]. Additionally, it is one of the cheapest protein sources in the Filipino diet as it is easily cultivated [14]. Furthermore, according to the Philippine Statistics Authority (PSA) [15], a production of about 23.8 thousand tonnes of the legume was observed within the second quarter of 2020. Although it shares a considerable fraction of the Philippine agriculture, the effects of eggshells on the vegetative

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growth of *V. radiata* are yet to be explored. Since it can be easily cultivated, it can serve as a model plant to determine the effects of calcium derived from chicken eggshells towards vegetative growth in general, which is a key factor that determines whether or not a plant proceeds to the reproductive stage [14].

To address this gap, the study investigated the effects of powdered chicken eggshells (PCES) on the vegetative growth of *V. radiata*. Specifically, it aimed to:

(i) measure the stalk length of *V. radiata* grown on PCES-soil compositions of 0%, 10%, and 15% (w/w) at 10, 20, and 30 days after planting;

(ii) measure the root length of *V. radiata* grown on PCES-soil compositions of 0%, 10%, and 15% (w/w) at 30 days after planting; and

(iii) determine if a significant difference exists among the mean values for stalk length and root length of *V. radiata* between treatments.

Methods. - Chicken eggshells were air-dried, crushed, and powdered. Then, the acquired PCES were mixed with 400 g of soil at 0%, 10%, and 15% (w/w). *V. radiata* seeds were planted at the PCES-soil compositions and received 50 mL of distilled water every day. The stalk length was measured at 10, 20, and 30 days after planting, and the root length was measured at 30 days after planting.

Preparation of PCES. Chicken eggshells were collected and air-dried for two weeks. The dried eggshells were then crushed and powdered using an electric grinder (Nima Japan 150 W NM-8300). Subsequently, the PCES was acquired from the resulting solid through a sieve (pore size: 0.16 cm).

Formulation of PCES-soil compositions. The soil compositions were prepared at the following PCES percentages: 0%, 10%, and 15% (w/w). Six pots were allotted for each treatment. For each pot, about 400 g of dry loam soil was homogenized with a mass of PCES corresponding to its assigned treatment.

Growing of V. radiata plants. Five *V. radiata* seeds were planted in each pot and about 50 mL of distilled water was allocated to each pot per day. Moreover, the blocking of the pots was randomized every day.

Measurement of morphological lengths. After 10 and 20 days, the stalk length of the plants was measured using Measure © 2020 Apple Inc. (precision: ±1 cm). After 30 days, both the stalk length and root length of the plants were measured using a vernier caliper (precision: ±0.005 cm).

Data Analysis. One-way analysis of variance (ANOVA) test was conducted to determine significant differences at the morphological lengths between treatments, and a post-hoc Tukey-Kramer test was conducted to determine which treatments significantly differed from each other. The tests were conducted at an alpha level of 0.05 (α=0.05) using the Analysis Toolpak add-in of Microsoft® Excel® for Microsoft 365 MSO (16.0.13901.20436) 64-bit.

Safety Procedure. During the conduct of the study, the use of appropriate personal protective equipment (PPE) was observed. Electricity-powered and hazardous equipment were properly handled according to their safety precautions. Lastly, all organic and inorganic waste were disposed of accordingly.

Results and Discussion. - In this study, a significant difference exists between the total means of the morphological lengths of the plants grown on 0% PCES and PCES-treated soil (10% and 15% PCES) at all intervals. Additionally, there was no significant difference between the stalk length of the plants grown on 10% and 15% PCES at all intervals, but interestingly, a significant difference exists between their root lengths. Simply put, the addition of PCES as a soil amendment significantly improved the vegetative growth of *Vigna radiata* (Figures 1 and 2).

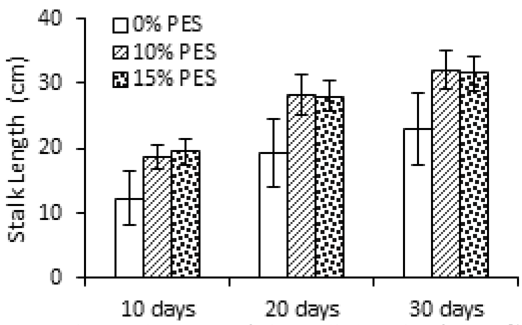

Figure 1. The total means of the stalk length of *V. radiata* grown on 0%, 10%, and 15% PCES after 10, 20, and 30 days.

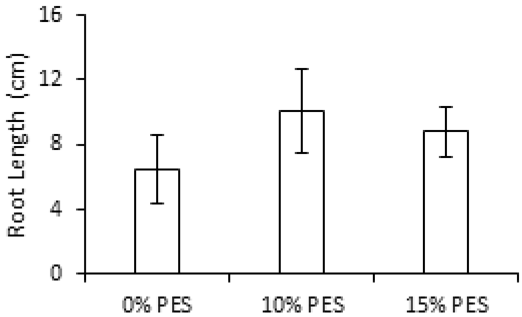

Figure 2. The total means of the root length of *V. radiata* grown on 0%, 10%, and 15% PCES after 30 days.

These findings are mainly associated with the calcium content of eggshells [1,4], where the mineral plays a key role in several physiological processes in plants [5,11]. Furthermore, similar studies conducted by Wijaya and Teo [5] and Gaonkar and Chakraborty [7] reported similar findings as well.

Contrastingly, adverse effects were observed on the plants grown on 15% PCES. As previously mentioned, a significant difference exists between the root lengths of the plants grown on 10% and 15% PCES; it was presented in Figure 2 that this was in favor of the prior treatment. Furthermore, chlorosis was observed on the leaves of the plants grown on 15% PCES. It is known that excessive calcium uptake may lead to disturbances in the ion balance, resulting in an antagonistic effect towards other minerals, such as iron, potassium, and magnesium [11,16]. This results in mineral deficiency, mainly indicated by chlorosis—the decreased green pigmentation in interveinal areas but an increased pigmentation in the veins of the leaves [11,16,17]. In this study, plants grown on 15% PCES had their third and succeeding trifoliates afflicted with chlorosis. Simply put, the younger leaves were afflicted, which was also observed in previous studies that investigated iron and potassium deficiency [11,17] (Figure 3).

Figure 3. The leaves of a *V. radiata* plant grown on 15% PCES afflicted with chlorosis.

As previously mentioned, the occurrence of chlorosis in the plants may be due to the excessive amount of calcium present in the soil composition. Consequently, this results in the deficiency of essential plant growth minerals, such as iron, potassium, and magnesium, due to the induction of an ion imbalance associated with the antagonistic relationship between calcium and the aforementioned cation minerals [11,16,17]. Moreover, a study conducted by Giel and Bojarczuk [11] reported that other than the induction of mineral deficiencies, the addition of calcium salts such as calcium carbonate increases the total nonstructural carbohydrates (TNC) in the roots and leaves of plants. This limits the utilization of photosynthetic products and subsequently causes growth inhibition. Furthermore, this may be attributed to the observed significant difference between the root length of the plants grown on 10% and 15% PCES.

In summary, PCES significantly improved the vegetative growth of *V. radiata* in terms of the morphological lengths measured. However, excessive calcium uptake may have occurred at the plants grown on 15% PCES, which resulted in chlorosis. Furthermore, it is critical to note that calcium uptake was not quantified in this study. The occurrence of chlorosis has been associated with excessive calcium uptake since it is the major component of the PCES—the variable that was varied among treatments. In addition, there is existing literature that correlates mineral deficiencies to interveinal chlorosis, and only the plants grown on 15% PCES were afflicted with chlorosis despite the randomization of the blocking of the pots on a daily basis and the homogenization of the soil compositions.

Limitations. Only two parameters were evaluated to observe vegetative growth, namely, stalk and root length, since the plants were observed for only 30 days due to time constraints. Furthermore, no tests or analyses were done regarding soil parameters, calcium uptake, mineral and TNC content, and chlorosis due to the unavailability of equipment since the study was conducted during a pandemic.

Conclusion. - Powdered chicken eggshells significantly improved the vegetative growth of the *V. radiata* plants. However, excessive amounts induced adverse effects on the plants.

Recommendations. - It is recommended to observe the plants until the reproductive stage to quantify other morphological structures. Furthermore, the analysis of variables correlated with excessive calcium uptake such as mineral and TNC content is advised to quantify the influence of excess calcium. This is to determine which mineral deficiency occurred due to their identical visual indicator—chlorosis. Regarding this, reflectance spectroscopy is suggested to quantify the occurrence of chlorosis. Lastly, it is advised to determine the amount threshold of PCES with regards to the adverse effects and the ideal PCES supplementation for the best mean scores.

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References

[1] Oliveira DA, Benelli P, Amate ER. 2013. A literature review on adding value to solid residues: egg shells. Journal of Cleaner Production. 46(2013): 42–47. doi: 10.1016/j.jclepro.2012.09.045.

[2] Francis AA, Abdel Rahman MK. 2016. The environmental sustainability of calcined calcium phosphates production from the milling of eggshell wastes and phosphoric acid. Journal of Cleaner Production. 137(2016): 1432–1438. doi: 10.1016/j.jclepro.2016.08.029.

[3] Food and Agriculture Organization of the United Nations. 2021. FAOSTAT Database. World: FAO. https://bit.ly/2VoBGy9.

[4] Murakami FS, Rodrigues PO, de Campos CMT, Silva MAS. 2007. Physicochemical study of CaCO3 from egg shells. Ciência e Tecnologia de Alimentos. 27(3): 658–662. doi: 10.1590/S0101-20612007000300035.

[5] Wijaya VT, Teo SS. 2019. Evaluation of eggshell as an organic fertilizer on sweet basil. International Journal of Sustainable Agricultural Research. 6(2): 79–86. doi: 10.18488/journal.70.2019.62.79.86.

[6] Khairnar MD, Nair SS. 2019. Study on eggshell and fruit peels as a fertilizer. International Conference on Sustainable Development. Novateur Publications. 14–15 February. ISBN No. 987-93-87901-05-6.

[7] Gaonkar M, Chakraborty AP. 2016. Application of Eggshell as Fertilizer and Calcium Supplement Tablet. International Journal of Innovative Research in Science, Engineering, and Technology. 5(3): 3520–3525. doi: 10.15680/IJIRSET.2016.0503183.

[8] Ok YS, Lee SS, Jeon WT, Oh SE, Usman ARA, Moon DH. 2011. Application of eggshell waste for the immobilization of cadmium and lead in a contaminated soil. Environmental Geochemistry and Health. 33(2011): 31–39. doi: 10.1007/s10653-010-9362-2.

[9] Soares MAR, Quina MJ, Ferreira RMQ. 2015. Immobilisation of lead and zinc in contaminated soil using compost derived from industrial eggshell. Journal of Environmental Management. 164(2015): 137–145. doi: 10.1016/j.jenvman.2015.08.042.

[10] White PJ, Broadley MR. 2003. Calcium in Plants. Annals of Botany. 92(4): 487–511. doi: 10.1093/aob/mcg164.

[11] Giel P, Bojarczuk K. 2010. Effects of high concentrations of calcium salts in the substrate and its pH on the growth of selected rhododendron cultivars. Acta Societatis Botanicorum Ploniae. 80(2): 105–114. doi: 10.5586/ASBP.2011.021.

[12] [UN] United Nations. 2020 September 19. Sustainable Development Goals [Internet] [cited 2020 October 22]. Available from: https://bit.ly/3941J2y.

[13] Huezé V, Tran G, Bastianelli D, Lebas F. 2015. Mung bean (*Vigna radiata*). Feedipedia, a programme by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/235 Last updated on July 3, 2015.

[14] Balinado LO, Manzano RME, Ate CN, Fernandez M, Chan MA. 2019. Early Vegetative Growth Responses of *Vigna radiata* L. (Mungbean) cv NSIC Mg 17 to Boron Toxicity. Journal of Nature Studies. 18(1): 11–21.

[15] PSA. 2020. Major Vegetables and Rootcrops Quarterly Bulletin. 14(2): ISSN 2094-618x. https://bit.ly/35TOmjs.

[16] Samborska IA, Kalaji HM, Sieczko L, Goltsev V, Borucki W, Jajoo A. 2018. Structural and functional disorder in the photosynthetic apparatus of radish plants under magnesium deficiency. Functional Plant Biology. 45(2018): 668–679. doi: 10.1071/FP17241.

[17] Rustioni L, Grossi D, Brancadoro L, Failla O. 2018. Iron, magnesium, nitrogen, and potassium deficiency symptom discrimination by reflectance spectroscopy in grapevine leaves. Scientia Horticulturae. 241(2018): 152–159. doi: 10.1016/J.SCIENTA.2018.06.097.

Comparison of the percent adsorption of raw corn husk and raw rice husk for bunker fuel

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Abstract

Oil spills are detrimental to the environment and its inhabitants. In this study, raw corn husks (RCH) and raw rice husks (RRH) were used as sorbents for bunker fuel. Adsorption tests were performed by subjecting the sorbents in bunker fuel. The mean percent adsorption of RCH, RRH, and sorbent pad were 10.1%, 3.75%, and 56.8%, respectively. It was found that RCH exhibited a significantly higher mean percent adsorption than RRH which was most likely due to its relatively higher cellulose content. Additionally, sorbent pad exhibited a significantly higher mean percent adsorption than the husks possibly due to its higher saturation point. Although the adsorption percentages of RCH and RRH were significantly less than that of sorbent pads, their ability to adsorb made them viable sorbents for bunker fuel removal, and when compared, RCH would be the better sorbent over RRH.

Introduction. - Oil spill incidents pose a serious threat to the marine environment. These spills may be caused by accidents involving oil tankers and pipes, natural disasters, and runoffs [1]. Spills including crude oil from tankers, refined petroleum products, and heavy fuels such as bunker fuel are a major environmental concern. This is because most components of the oil-like polycyclic aromatic hydrocarbons (PAHs) are toxic to both aquatic and terrestrial organisms, and induce irreversible effects to the environment [2,3]. Bunker C fuel (No. 6 oil), which powers marine vessels, is the most common in these incidents [4]. Bunker fuel evaporates in small percentages and presents a higher viscosity relative to the other oil types [5].

Adsorption is an economically advantageous and eco-friendly approach in remediating oil spill incidents. It is a process wherein oil particles are attracted to the surface of the sorbent. The process relies on the adhesion of the oil particles to the sorbent surface and cohesive properties of oil which allow greater amounts of oil to be retained by the sorbent [8].

Studies have investigated the adsorption capabilities of different agricultural wastes on crude oil [1,7,9]. The use of rice husks and corn husks as sorbents for oil spill remediation removes environmental pollutants while minimizing the negative impacts of burning and disposal of agricultural by-products [10]. It was concluded in the study of Razavi et al. [7] that the oil adsorption capacity of raw rice husk on crude oil was independent of pH. They added that the particle size of the sorbent and viscosity of the oil would significantly affect the adsorption capacity wherein directly proportional relationships would be observed between the adsorptive capability and the two parameters. Biological structures were also found to affect adsorption capacity [11,12]. Furthermore, previous studies have utilized pre-treated husks in removing environmental pollutants such as dyes, heavy metals, and certain organic compounds [1,9]. However, it should be noted that these pre-treatment steps may be time-consuming and costly [10]. Thus, the use of husks in their raw state would be highly advantageous, especially in emergency oil spill situations.

Previous studies have found that cellulose content is higher in raw corn husk (RCH) than in raw rice husk (RRH) [13,14,15,16,17]. It was also observed that when the cellulose content was increased, the adsorption capacity of husks also increased [11,12]. Therefore, it is hypothesized that RCH will exhibit a significantly higher fuel percent adsorption compared to RRH.

This study aimed to determine and compare the percent adsorption of RRH, RCH, and sorbent pads for bunker fuel. It specifically aimed to:

(i) determine the weight of the sorbents before and after adsorption; and

(ii) calculate and compare the percent adsorption of the three sorbents.

Methods. - The corn husks and rice husks were washed, sun-dried, ground, sifted, wrapped in polypropylene fabric, and then submerged in pure

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bunker fuel. Commercially available polypropylene sorbent pads, also wrapped in polypropylene fabric, were used as a positive control. The samples were allowed to drain before weighing to determine the percent adsorption of the three sorbents (RRH, RCH, and sorbent pads). The mean percent adsorption of the three sorbents were then determined and compared using One-Way Analysis of Variance (ANOVA). Ten samples were conducted per sorbent.

Materials. RCH and RRH were gathered from San Joaquin, Iloilo, and Roxas City, Capiz, respectively, while sorbent pads were obtained from the Philippine Coast Guard Station in Bo. Obrero, Iloilo City. Bunker fuel was procured from the Iloilo City Public Safety and Transportation Management Office.

Preparation. RCH and RRH were washed, sun-dried, subjected to grinding, then sifted using a 2 mm sieve. Ground husks then underwent the coning and quartering method thrice for randomization. Five grams of each sorbent was wrapped in polypropylene fabric. Polypropylene fabric was used as a container for easy retrieval of the ground sorbents after submersion in bunker fuel.

Adsorption. Wrapped RCH was soaked in 80.0 g of bunker fuel for 3 hours and was allowed to drip until the point when no further dripping was observed. Finally, the resulting sorbent was weighed using a calibrated digital weighing scale. Similar procedures were followed for the RRH and sorbent pads. Ten samples were tested for each sorbent. To control the effect of the polypropylene fabric on fuel sorption, three samples of empty polypropylene pouches of the same dimensions as those used in wrapping the sorbents were subjected into the fuel under the same experimental conditions. Their weights were then taken, and averaged. The calculated average weight of 10.62 grams was subtracted from the weights of the sorbents wrapped in polypropylene fabric with adsorbed fuel.

Data Analysis. The percent adsorption for each sorbent was calculated using the following formula adapted from the study of Razavi et al. [1]:

$$\%\,Adsorption = \left(\frac{S_t - S_0}{W_{fuel}}\right) \times 100$$

Where:
S_t = the weight (in grams) of the sorbent after adsorption
S_o = the weight (in grams) of the sorbent before adsorption
W_{fuel} = the weight of the fuel before adsorption in grams.

Statistical Analysis. One-way ANOVA was conducted to compare the three mean percent adsorption using Microsoft Excel 2016 with Real Statistics Resource Pack software (Release 7.2) and QI Macros statistical process control (SPC) software package plugin, version 2021.01. The level of significance was at 0.05. The Levene's test was used for the homogeneity of variances and the Tukey test for post-hoc analysis. Both were executed using the same program. To check for normality, the Shapiro-Wilk test was conducted using the software JASP 0.14.1.

Safety Procedure. Excess bunker fuel and used sorbents were stored in a closed container and were handed over to the community waste disposal team.

Results and Discussion. - Table 1 shows the average weights (in grams) of each sorbent before and after fuel adsorption.

Table 1. Mean and standard deviation of the weights before and after fuel adsorption (in grams) of RCH, RRH, and sorbent pad.

Sorbent	Before Adsorption (g)	After Adsorption (g)
RCH	5.00	13.2 ± 1.89
RRH	5.00	8.00 ± 0.78
Sorbent Pad	5.00	50.4 ± 1.74

Figure 1 shows the respective mean percent adsorption of the three sorbents for bunker fuel.

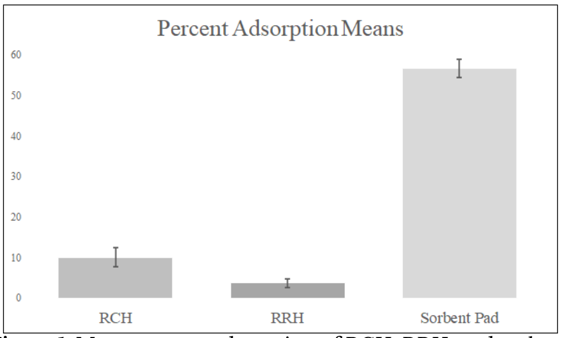

Figure 1. Mean percent adsorption of RCH, RRH, and sorbent pad for bunker fuel.

RCH yielded a mean percent adsorption of 10.1 ± 2.40. The RRH on the other hand had mean adsorption of 3.75% ± 1.03. Finally, for the sorbent pad, the mean adsorption was 56.8% ± 2.29.

Using the Shapiro-Wilk test, data was confirmed to have a normal distribution. Additionally, there was a statistically significant difference between groups as determined by one-way ANOVA ($F(2,27) = 2090.11$, $p = .000$). Data was found to satisfy the assumption of homogeneity of variances through Levene's test ($p = 0.093 > 0.05$). Tukey post hoc test revealed that RCH (10.13% ± 2.40%, $p = .000$) exhibited a significantly higher mean percent adsorption than RRH (3.75% ± 1.03%, $p = .000$), and sorbent pad (56.77% ± 2.29%, $p = .000$) exhibited a significantly higher mean percent adsorption than RCH.

The significantly higher percent adsorption of RCH over RRH could be attributed to the cellulose content of the sorbents. The cellulose content in RCH is generally greater than that in RRH [13, 14, 15, 16, 17], where the mentioned studies only featured either of the husks. In addition to this, characterization studies using the Technical Association of Pulp and Paper Industry (TAPPI) method of identifying the chemical composition of husks revealed that cellulose in corn husks reached 31-39% while only a maximum of 31%

was present in rice husks [18, 19]. Cellulose was found to play a key role in maintaining the mesopore structure of activated carbon as a sorbent [11]. Mesopores function in accelerating diffusion into micropores and increasing the equilibrium coverage of the micropore surface which contains adsorptive sites wherein the inner layers possess higher adsorption energies [12].

According to the International Tanker Owners Pollution Federation Limited (ITOPF) [8], sorbent materials for oil spills should attract oil to their surface or incorporate the oil in the material itself. RCH and RRH exhibited mean percent adsorption of 10.19% ± 2.40 and 3.76% ± 1.02, respectively. The exhibited percent adsorption, although low, can qualify RCH and RRH as sorbent materials. In addition, there is no basis for comparison for the RRH results since the methods used in this study were not similar to other related studies. With this, due to the husks' biodegradability, high supply, simple preparation, low cost, but low adsorption capacity, RCH and RRH could be potential sorbents only for emergency bunker fuel spill situations, in cases when the commercially used sorbent pads are unavailable.

It was also found that the sorbent pad exhibited a significantly higher percent adsorption compared to the other two organic sorbents. This was concurrent with the information that polypropylene sorbent pads can recover up to 20% more oil than natural organic sorbents [17]. Although natural-based materials are inexpensive, abundant, and environmentally friendly, their relatively lower oleophilic property makes their adsorption capacity inferior to some synthetic materials which are engineered for the sole purpose of adsorbing fuels [18, 19]. Furthermore, the difference in the packing of the sorbent pad and the husks may have affected the surface area of each sorbent, which is another factor that influences adsorption [8]. Since the sorbent pads were laid in sheets, they may have had greater surface area than the ground husks, therefore yielding a significantly greater percent adsorption

In conducting the experiments, the sorbent pad was first tested to identify the ideal contact time and bunker fuel dosage, which is the least possible amount of fuel and time for the sorbent pad to be completely soaked. The contact time should ensure the sorbent has reached its maximum saturation [23]. It was found out that five grams of sorbent pad were completely saturated when immersed in 80 grams of bunker fuel at the 3-hour mark. A contact time of three hours, bunker fuel dosage of 80 grams, and initial sorbent weight of five grams were uniformly followed for the final data gathering for all three sorbents.

The dripping time after adsorption used for the final data gathering was 15 minutes which was observed during the preliminary data gathering to be the point of no dripping. Dripping time should reach the point of no dripping to ensure that the fuel loosely held by the sorbent is lost to report an accurate adsorption capacity [23]. This can also be backed by the study of Said et al. [24] which also utilized the same length of fuel dripping.

To avoid the interference of the possible fuel adsorption of the polypropylene fabric that was used to wrap the sorbents, its mean fuel adsorption was also separately measured thrice following the same contact and dripping times as the final data gathering. The mean fuel adsorption of the polypropylene fabric was then subtracted from the total weight of the sorbent after the fuel adsorption in calculating for the percent adsorption of the final data.

Limitations. Due to the lack of resources, mathematical models were not used in presenting the results. In addition, there was no basis for comparison for the RRH results since the methods used in this study were not similar to other related studies. Lastly, due to the unavailability of the necessary equipment, the uniformity of the packing of the sorbents in the polypropylene fabric was not followed wherein the husks were in powder form while the sorbent pads were laid in sheets when subjected to bunker fuel.

Conclusion. - The adsorption percentages of RCH and RRH were significantly less than that of sorbent pads, and when compared, RCH would be the better sorbent over RRH. Despite the limited inclusion of adsorption parameters, this study showed a simple preliminary measure of screening oil adsorption capacities of ground sorbents for possible usage in oil spills.

Recommendations. - It is recommended that future studies conduct adsorption isotherm modelling to investigate the interaction mechanism between the adsorbent and the adsorbate. Furthermore, future studies can also test different physical modifications such as size and surface area variations to RCH and RRH and determine any significant differences with respect to their adsorption capacities. In addition, it is recommended that the size and morphology of the tested sorbents be characterized by electron microscopy techniques and their chemical composition by spectroscopic techniques like infrared spectroscopy. It is also recommended that when comparing different sorbents, the packing should be uniform for all tested sorbents. Lastly, it is recommended to test the adsorption capacities of RCH and RRH on other oil pollutants in an oil/water mixture.

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References

[1] Razavi Z, Mirghaffari N, Rezaei B. 2014. Performance comparison of raw and thermal modified rice husk for decontamination of oil polluted water. Clean (Weinh). 43(2): 182–190.

[2] Briggs IL, Briggs BC. 2018. The political ecology of oil and gas activities in the Nigerian aquatic ecosystem. Cambridge (MA): Academic Press. Petroleum industry activities and human health; p. 143–147.

[3] Gammoun A, Tahiri S, Albizane A, Azzi M, De la Guardia M. 2007. Decontamination of water polluted with oil through the use of

tanned solid wastes. Environ Eng Sci. 6(5): 553–559.

[4] Schnurr REJ, Walker TR. 2019. Reference module in earth systems and environmental sciences. Elsevier. Marine Transportation and Energy Use.

[5] Fingas M. 2017. Oil spill science and technology. Houston (TX): Gulf Publishing Company. Introduction to spill modeling; p. 419–453.

[6] Tsamo C, Kidwang GD, Dahaina DC. 2020. Removal of Rhodamine B from aqueous solution using silica extracted from rice husk. SN Appl Sci. 2(2): 256–268.

[7] Razavi Z, Mirghaffari N, Rezaei B. 2013. Adsorption of crude and engine oils from water using raw rice husk. Water Sci Technol. 69(5): 947–952.

[8] ITOPF. 2012. Use of sorbent materials in oil spill response. Canterbury: Impact PR and Design Limited (UK). Report No.: 8.

[9] Husseien M, Amer AA, El-Maghraby A, Hamedallah N. 2009. A comprehensive characterization of corn stalk and study of carbonized corn stalk in dye and gas oil sorption. J Anal Appl Pyrolysis. 86(2009): 360–363.

[10] Ahmaruzzaman M, Gupta VK. 2011. Rice husk and its ash as low-cost adsorbents in water and wastewater treatment. Ind Eng Chem Res. 50: 13589–13613

[11] Xue Y, Du C, Wu Z, Zhang L. 2018. Relationship of cellulose and lignin contents in biomass to the structure and RB-19 adsorption behavior of activated carbon. New J Chem. 42(20): 16493-16502.

[12] Hsieh CT, Teng H. 2000. Influence of mesopore volume and adsorbate size on adsorption capacities of activated carbons in aqueous solutions. Carbon. 38(6): 863–869.

[13] Rahman IA, Ismail J, Osman H. 1997. Effect of nitric acid digestion on organic materials and silica in rice husk. J Mater Chem. 7(8): 1505–1509.

[14] Jantip S, Suwanruji P. 2011. Preparation and properties of microcrystalline cellulose from corn residues. Adv Mat Res. 332-334. 1781–1784.

[15] Ibrahim MIJ, Sapuan SM, Zainudin ES, Zuhri MYM. 2019. Extraction, chemical composition, and characterization of potential lignocellulosic biomasses and polymers from corn plant parts. BioResources. 14(3): 6485–6500.

[16] Chabannes, Bénézet JC, Clerc L. 2014. Use of raw rice husk as natural aggregate in a lightweight insulating concrete: An innovative application. Constr Build Mater. 70: 428–438.

[17] Aremu MO, Aperolola SO, Dabonyan OO. 2015. Suitability of Nigerian corn husk and plantain stalk for pulp and paper production. Eur. Sci. 11(30): 146–152.

[18] Johar N, Dufresne A. 2012. Extraction, preparation and characterization of cellulose fibres and nanocrystals from rice husk. Ind Crops Prod. 37(1): 93–99.

[19] Mendes CA, Adnet FA, Leite MCA, Furtado CR, De Sousa AM. 2015. Chemical, physical, mechanical, thermal, and morphological characterization of corn husk residue. Cellulose Chem Technol. 49 (9–10): 727–735.

[20] Fingas M. 2011. Oil spill science and technology. Houston (TX): Gulf Publishing Company. Introduction to spill modeling; p. 303–337.

[21] Chol HM, Cloud RM. 1992. Natural sorbents in oil spill cleanup. Environ Sci Technol. 26: 772–776.

[22] Zamparas M, Tzivras D, Dracopoulos V, Ioannides T. 2020. Application of sorbents for oil spill cleanup focusing on natural-based modified materials: a review. Molecules. 25(4522): 1–22.

[23] Bazargan A, Tan J, McKay G. 2015. Standardization of oil sorbent performance testing. J Test Eval. 43(6): 1271–8.

[24] Said AA-EA, Ludwick AG, Aglan HA. 2009. Usefulness of raw bagasse for oil absorption: a comparison of raw and acylated bagasse and their components. Bioresour Technol. 100(6): 2219–2222.