RESEARCH ARTICLE

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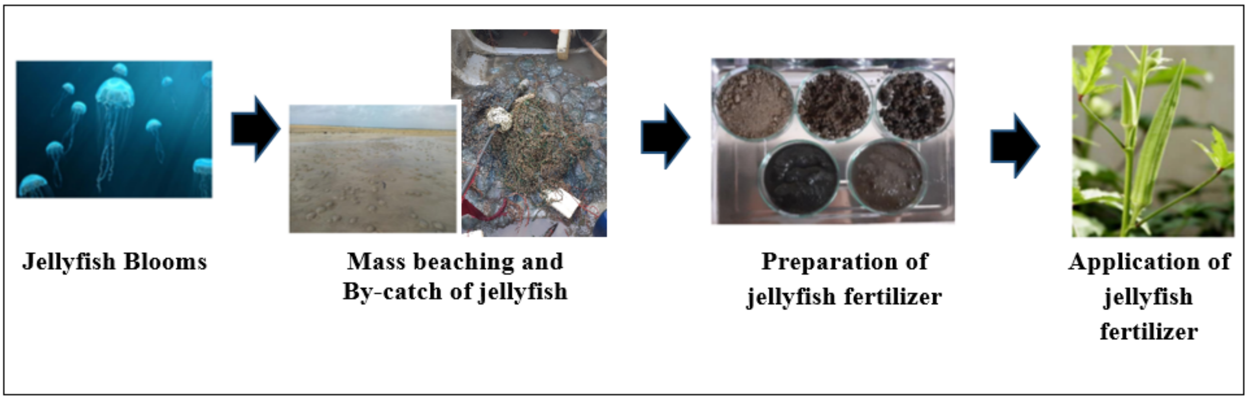
V.D. Samaraweera and D.C.T. Dissanayake*



Highlights

- Jellyfish form seasonal blooms and are a nuisance in coastal areas.
- Four jellyfish species in the coastal waters of Sri Lanka were identified as suitable candidates to prepare organic fertilizers.
- Okra plants treated with jellyfish fertilizers showed promising results compared to commercial grade compost Fertilizer.
- Further studies on the potential use of jellyfish as commercially available organic fertilizers are recommended.

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Use of Jellyfish as a potential organic fertilizer and its effect on the growth of okra, *Abelmoschus esculentus*

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Abstract: Jellyfish are free-floating gelatinous animals belonging to the subphylum Medusozoa of the phylum Cnidaria. Nineteen jellyfish species have been reported in Sri Lanka and their abundance is found to be high (making 15,600 tons biomass per year). The seasonal occurrence of jellyfish blooms is widespread along the coast of Sri Lanka, interfering with human activities, including tourism and fisheries. This study aims to assess the possibility of using jellyfish blooms as a commercially available organic fertilizer. Highly abundant four jellyfish species, *Lychnorhiza malayensis, Chrysaora* sp., *Chiropsoides buitendijki,* and *Marivagia stellata* in the coastal waters of Sri Lanka were selected for this study. Using the traditional composting procedure, jellyfish fertilizers were prepared and the total nitrogen, phosphorus, potassium, water holding capacity, and pH of each fertilizer were assessed using standard procedures. The effectiveness of these fertilizers was tested by treating them separately on Okra (*Abelmoschus esculentus*) plants (n = 10 per treatment) once a week with a positive (commercial-grade compost) and negative control. Height, number of leaves, flowers, and fruits of each plant were recorded weekly for 10 weeks. All jellyfish fertilizers had higher phosphorus (10.01-22.09 g/kg), and lower potassium (0.66-1.88 g/kg) levels than the commercial-grade compost (~10 g/kg; ~5 g/kg, respectively), and their nitrogen levels ranged from 6.24 to 23.34 g/kg. The fertilizers prepared using *L. malayensis* (15.12 g/kg) and *Chrysaora* sp. (23.34 g/kg) showed significantly higher nitrogen content than that of commercial-grade compost (10 g/kg; $p < 0.05$; ANOVA). The average height and growth rate of plants treated with jellyfish fertilizers and commercial-grade compost were mostly within the same range during the experimental period of 10 weeks. Plants treated with jellyfish fertilizers showed flowering between 35 to 40 days, where compost-treated plants showed no evidence of flowering within the experimental period. Further studies are warranted on the potential use of jellyfish as a potential organic fertilizer that can be widely promoted locally.

***Keywords*:** Jellyfish; compost, fertilizer; okra plants; Sri Lanka.

INTRODUCTION

Jellyfish is the common name given to the medusa stage of free-floating gelatinous animals belonging to the subphylum Medusozoa of the Phylum Cnidaria (Purcell *et al.,* 2007; Richardson *et al.,* 2009). Jellyfish are essential components of the marine food web, where they act as a prey as well as a predator (Kogovšek *et al.,* 2014). Dense aggregations of jellyfish are known as jellyfish blooms. Generally, jellyfish blooms are considered a seasonal and natural feature of a healthy pelagic ecosystem. However, remarkable and rapid increases in jellyfish populations have recently been reported worldwide (Purcell *et al.,* 2007; Richardson *et al.,* 2009; Brotz *et al.,* 2012), interfering with human activities in coastal environments in various ways.

Jellyfish blooms affect tourism as their stings can bring about many health hazards to beachgoers and swimmers (Richardson *et al.,* 2009). Meanwhile, fisheries and aquaculture industries are also harmed by jellyfish blooms through clogging fishing gear and killing fish in cages and pens. Fish eggs and larvae are largely eaten by jellyfish, affecting fish population sustainability and the ecosystem balance. Large jellyfish blooms clog cooling water intake systems in power plants and other structures in coastal areas (Fukushi *et al*., 2004; Purcell *et al*., 2007; Falkenhaug, 2014; Santhanam, 2020). The collapse of jellyfish blooms largely adds organic materials to the water, promoting microbial-dominated food webs in oceanic waters (Kogovšek *et al*., 2014). As a result, proper management of jellyfish blooms is crucial to control these negative impacts. Mechanical collection of jellyfish is widely recommended in many countries to control blooms, while jellyfish product development and biological control are also used as management practices (Fukushi *et al*., 2004; Purcell *et al*., 2007).

Jellyfish fisheries have a long history in Asia, and the Chinese have exploited jellyfish as an important food source for more than thousand years (Hsieh *et al*., 2001; Lynam *et al.,* 2006). Jellyfish fisheries also exist in India, Indonesia, Japan, Malaysia and the Philippines (Richardson *et al.*, 2009). The use of jellyfish blooms in the agricultural industry has been widely discussed. Chun *et al.* (2012) reported the potential benefit of jellyfish for seedling growth, while Emadodin *et al*. (2019) investigated its importance as a seed germinator. The possible applications of jellyfish as a fertilizer, weedicide and insecticide have also been investigated (Hussein and Saleh 2014; Hussein *et al.,* 2015; Emadodin *et al*., 2019).

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Sri Lanka, a small tropical island situated in the southeast of the Indian subcontinent, regularly reports the seasonal occurrence of jellyfish blooms along its coastline. According to a survey carried out by Nansen (2018), jellyfish make the most significant biomass (15,600 tons per year) in the coastal waters of Sri Lanka. Although few attempts have been made to study the taxonomy of jellyfish distributed around the country, studies focused on assessing their economic value and commercial utilization are still lacking. Therefore, this study aims to investigate the feasibility of utilizing jellyfish as an organic fertilizer in order to utilize jellyfish blooms more economically.

MATERIALS AND METHODS

Sample collection

Highly abundant four jellyfish species, *Lychnorhiza malayensis, Chrysaora* sp., *Chiropsoides buitendijki,* and *Marivagia stellata* in the coastal waters of Sri Lanka were selected for this study. Approximately 15 kg of each species were collected from Beruwala (06°50′59″N, 079°97′86″E), and Mullaitivu (09°26′73″N, 080°82′18″E) areas where dense blooms of experimental species were reported during the study period. Jellyfish were collected mainly using hand nets, packed in ice, and carefully transported to the laboratory of the Department of Zoology, University of Sri Jayewardenepura. The morphological features such as the shape of the bell and oral arms, the number of oral arms, tentacles, marginal lappets, and the structure of the gastrovascular canal were used to identify each species, and their taxonomic status was confirmed using available keys (Cornelius, 1995; Thiel, 1978) and expert assistance.

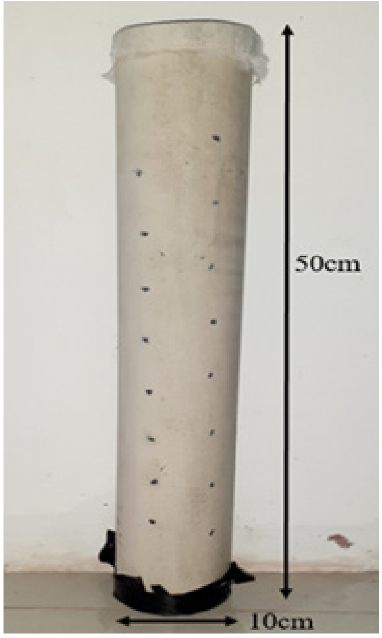


Figure 1: An experimental set-up used to prepare jellyfish fertilizers of medusa stage of *Lychnorhiza malayensis*, *Chrysaora* sp., *Chiropsoides buitendijki* and *Marivagia stellata* Jellyfish and soil 5 cm thick alternate layers were placed in thermoplastic pipes covered with black polythene at the bottom and small mesh nets on top.

Fertilizer preparation

Four different jellyfish fertilizers were prepared using the medusa stage of *L. malayensis*, *Chrysaora* sp., *C. buitendijki* and *M. stellata*. Thermoplastic pipes, each with a 50 cm height and a 10 cm diameter, were used to prepare fertilizers. The bottom of each pipe was covered with black polythene, then jellyfish and soil samples (w: w/ 1:1) were added as 5 cm thick alternate layers, and the upper part of the pipe was covered with a small mesh net (Figure 1). All the pipes were labeled appropriately and kept for two months without being disturbed.

Following a two-month decomposition period, jellyfish fertilizers were obtained. Total moisture, pH, total nitrogen, total phosphorus, total potassium, and water holding capacity of the prepared jellyfish fertilizers and commercial-grade compost were measured following the standard test procedures.

The moisture content of each fertilizer was determined by drying the samples in a thermostat oven at 105°C until a constant weight was obtained (AOAC, 2006). The pH of the prepared jellyfish fertilizers and commercial-grade compost were determined using a calibrated pH meter (C6010, Belgium) following the procedure described by Motsara and Roy (2008). A saturated Ag_2SO_4 solution was used to extract the nitrogen from each fertilizer. The total nitrogen content was measured using a UV-Visible spectrophotometer (JENWAY 6305, United Kingdom) set at 420 nm (Schulte *et al*., 1987). The phosphorus in each fertilizer was extracted using NH_4F and HCl solutions, and the color development was measured using a UV-Visible spectrophotometer (JENWAY 6305, United Kingdom) set at 645 nm as proposed by Schulte *et al.* (1987). An ammonium acetate solution was used to extract the potassium from the fertilizer. The potassium concentration was quantified using an atomic absorption spectrometer (iCE 3000 AA05121002vl.30) following the procedure proposed by Barghouthi *et al.* (2012). The water holding capacity of each fertilizer was determined using the method described by Ni *et al.* (2012). All the soil samples used for composting were obtained from the same place, and all these parameters were performed on soil samples too.

Evaluating the effect of jellyfish fertilizers over a commercial-grade compost

Okra (*Abelmoschus esculentus*) plants were chosen to assess the effectiveness of jellyfish fertilizers because they are short-lived, easy to grow and can manage in pot experiments, and show variations in growth with variable nutrient content (Akanbi *et al*., 2010). The pot experiment was conducted according to the randomized complete block design and okra plants with ~2cm height (1 week after sowing) were used. Six treatments, including four jellyfish fertilizers ((T1 - *Lychnohiza malayensis,* T2 - *Chrysaora* sp., T3 - *Chiropsoides buitendijki,* T4 - *Marivagia stellata*, positive control (T5- commercial-grade compost) and negative control (T6- Soil without fertilizer) were tested in this experiment by maintaining ten replicates for each treatment (Figure 2).

Around 15g of fertilizer was directly applied to the individual replicate plant once a week, and 10 ml of water was sprayed into each plant daily in the morning. The height, number of leaves, flowers, and fruits of each replicate plant were recorded weekly for 10 weeks.

Statistical analysis

Total nitrogen, phosphorus, and potassium concentration of each fertilizer were statistically compared using Analysis of Variance (ANOVA). Similarly, the mean height of okra plants subjected to six different treatments was computed and compared using ANOVA followed by Tukey's multiple comparison tests. Differences were considered to be significant when $p < 0.05$. All the statistical tests were performed in Minitab 20 for Windows statistical package.

RESULTS

Table 1 summarizes the basic characteristic features of four jellyfish species used to prepare fertilizer. *Lychnohiza malayensis* and *M. stellata* are from the order Rhizostomeae, while *Chrysaora* sp. and *C. buitendijki* belong to the orders Semaeostomeae and Chirodropida, respectively.

The composition of prepared jellyfish fertilizers was analyzed and compared with commercial-grade compost (Table 2). The color of jellyfish fertilizers ranges from dark brown to black in color. Fertilizers prepared using *C. buitendijki* and *M. stellata* were fine-textured, while the others were rather coarse-textured. The moisture content of the experimental fertilizers ranged from 26.87% to 59.68%. Although the moisture content of jellyfish fertilizer prepared using *Chrysaora* sp. was similar to commercial-grade compost, others reported higher moisture contents, with the highest value being in the fertilizer formulated using *L. malayensis.* Although the pH of all the jellyfish fertilizers was lower than the commercial-grade compost (7.5), it was very close to the neutral pH of 7 except in the jellyfish fertilizer prepared using *C. buitendijki* (5.86).

The nitrogen concentration of jellyfish fertilizers prepared using *L. malayensis* and *Chrysaora* sp. was higher than that of commercial-grade compost fertilizer ($p < 0.05$; ANOVA), but it was lower in the other two fertilizers ($p > 0.05$; ANOVA). The fertilizer prepared using *C. buitendijki* reported significantly higher phosphorus content (22.9 g/kg) than the other jellyfish fertilizers and commercial-grade compost ($p<0.05$; ANOVA). All the jellyfish fertilizers reported lower K concentrations than the commercial-grade compost ($p<0.05$; ANOVA). The water holding capacity of jellyfish fertilizers was comparable to that of compost, except in the fertilizers prepared using *Chrysaora* sp. and *C. buitendijki.*

Performance of okra treated with different fertilizers

The effectiveness of jellyfish fertilizers was assessed with *Abelmoschus esculentus* (Okra) for 10 weeks. All plants treated with fertilizers showed a significantly higher mean height than the negative control ($p<0.05$; ANOVA). Although the mean height of Okra plants treated with jellyfish fertilizers and compost remained almost similar up to the 7th week, the compost-treated plants demonstrated a somewhat better growth afterwards. Similarly, T3 and T2 treated plants slowed down in their performance after seven weeks (Figures 3).

The growth rates of *A. esculentus* plants (height increment per week in cm) subjected to 6 different treatments were computed and compared (Table 3). Except for the plants subjected to treatment T4, the growth rate of all the other plants increased gradually from the first week to the third week reporting its maximum growth rate mainly in the third week. Although it is difficult to see any clear trend in the growth rate of these plants afterward, a relatively high growth rate was reported again in all the plants during the fifth week. The plants subjected to T5 treatment (a negative control) mostly showed a lower growth rate than other treatments.

The time taken for the appearance of flower buds in *A. esculentus* plants treated with different fertilizers (T1, T2, T3 and T4) were 40 ± 7, 38 ± 7, and 35 ± 7 and 37 ± 6 days respectively. Flower buds first appeared in T3-treated plants, and all other plants treated with jellyfish fertilizers also reported flower buds within 35-40 days. However, any flower bud or fruit development was not observed in positive or negative controls.

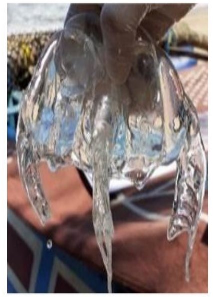
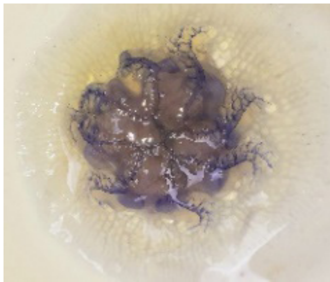
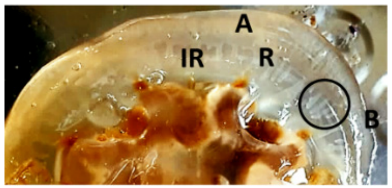
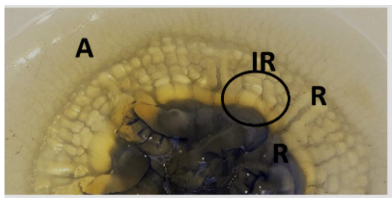
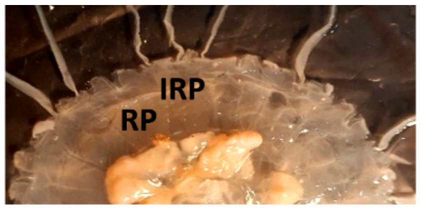
DISCUSSION

Commercial utilization of jellyfish in various industries such as agriculture, food, and pharmaceuticals has been explored in many countries (Hussein *et al.,* 2015). However, such activities were not attempted in Sri Lanka though it is reported large jellyfish blooms around the country from time to time. As an island nation with an agriculture-based economy, it is worth to investigate the possible uses of jellyfish as a fertilizer since there is a growing demand for organic agriculture products both locally and globally.

Some previous studies have attempted to use jellyfish as a fertilizer (Chun *et al*., 2012; Fukushi *et al*., 2004), and in the present study explored the potential of using four jellyfish species for the first time, namely *L. malayensis, Chrysaora* sp., *C. buitendijki*, and *M. stellata* as an organic fertilizer. It is difficult to compost jellyfish samples themselves because they are spoiled and liquidized, emitting a foul odor when they decompose. To overcome this problem, jellyfish samples were decomposed with soil.

The reported high moisture content in jellyfish fertilizers could be linked to the high body moisture content in jellyfish. For example, the moisture contents of fertilizers prepared from jellyfish *L. malayensis* and *Chrysaora* sp. were reported as 59.68% and 26.87% respectively. Previous studies have reported that jellyfish fertilizer increases soil moisture due to jellyfish's colloidal and hydrophobic nature (Chun *et al*., 2012). According to Emadodin *et al.* (2019), jellyfish dry matter can absorb and hold water in the soil, and Kim *et al*. (2012) reported that jellyfish fertilizer could hold water around the plants nearly seven times the fertilizer's weight. This study also reports the high water holding capacity of prepared jellyfish fertilizers and the potential of using jellyfish as a liquid

Table 1: Taxonomic features of four jellyfish species used to prepare jellyfish fertilizers.

Feature	*Lychnorhiza malayensis*	*Marivagia stellata*	*Chrysaora* sp.	*Chiropsoides buitendijki*
Dorsal view				
Ventral view				
Structure of gastrovascular canal				

Shape of the bell	Bell is thick and transparent. V shaped four gonadal masses can be observed Eight triangular brown marks are present on the ventral surface of the bell. 8 marginal lappets per octant and lack tentacles	Bell is thin and fragile. Brown dots, streaks, and star-like patches clustered in the central part. 6 marginal lappets per octant lack tentacles	Bell is thin and flexible. 16 red dots lines extended from center to outer margin. 2 velar lappets and 3 tentacles per octant.	Bell is thick and cuboidal, rigid mesoglea. The apical dome and interradii pillars are thicker. Four pedalia are at the side of the bell with 5 or 6 fingers and each finger has tentacles that decrease in size sequentially
shape and number of the oral arm	8 transparent oral arms fused together at the base	8 transparent oral arms fused at the base	Very long and curtain-like 4 oral arms with red pigment dots	Long, hollow 8 gastric saccules inside the bell.
Venom and stinging	Harmless	Harmless	Consider as dangerous	Consider as dangerous

Table 2: Composition and properties of jellyfish fertilizers and the controls.

	T1	T2	T3	T4	T5	T6
External appearance						
Texture	Coarse	Coarse	Fine	Fine	Fine	Silt
Moisture %	59.68	26.87	31.98	36.37	28.50	1.32
Water holding capacity (g per g of fertilizer)	0.247	0.426	0.328	0.278	0.275	0.227
pH	6.54	6.42	5.86	6.72	7.5	6.68
Total Nitrogen (g/ kg)	15.12 [a]	23.34[a]	6.24[b]	6.42[b]	10.00[b]	-
Total Phosphorus (g/kg)	12.95[a]	10.01[a]	22.09[b]	12.93[a]	10.00[a]	7.63[a]
Total K (g/kg)	1.19[a]	1.88[a]	1.79[a]	0.66[a]	5.00[b]	0.60[a]

(T1: *Lychnohiza malayensis*, T2: *Chrysaora* sp., T3: *Chiropsoides buitendijki*, T4: *Marivagia stellata*, T5: Positive control; commercially available compost fertilizer, T6: negative control; soil)

Table 3: Growth rate of *Abelmoschus esculentus* plants subjected to 6 different fertilizer.

Treatments	Growth rate (height increment of the plant per week in cm)								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
T1	1.50	3.75	4.50	2.50	4.25	3.75	3.25	2.75	4.00
T2	3.00	2.00	5.50	1.75	3.25	2.50	1.75	2.75	2.00
T3	2.48	4.25	4.75	1.50	3.00	3.25	1.50	1.25	3.75
T4	0.50	4.75	4.25	1.25	4.75	2.00	1.75	4.25	4.25
T5	2.00	3.50	4.50	3.25	3.75	3.25	3.75	2.50	3.00
T6	1.25	1.87	1.38	0.75	2.75	2.00	0.75	1.75	0.50

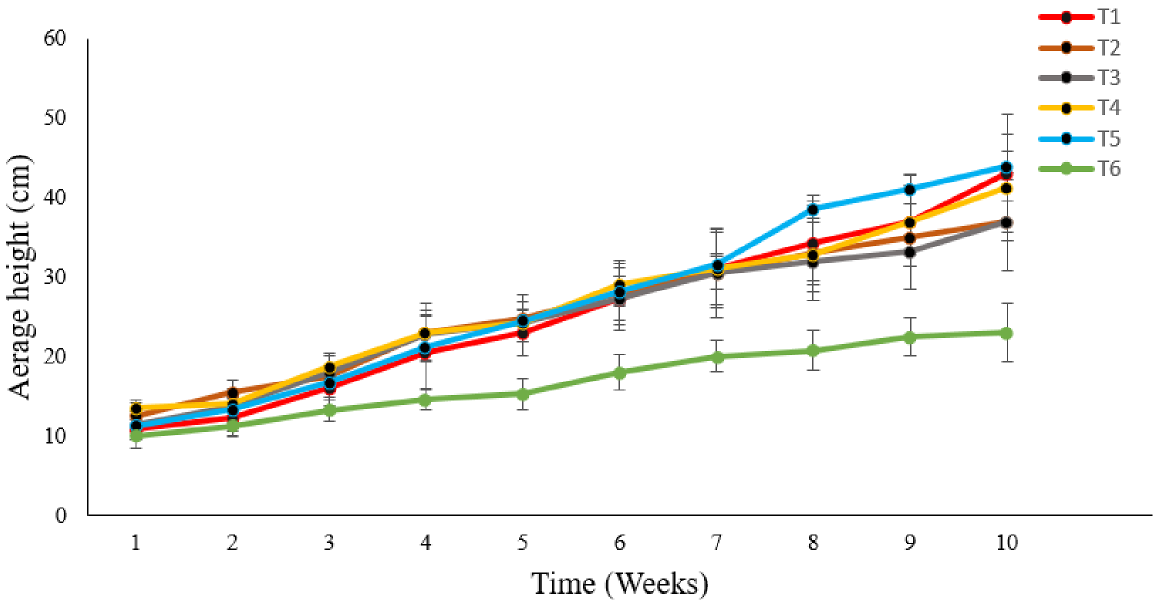


Figure 3: Weekly average height (± SD in cm) of *Abelmoschus esculentus* plants subjected to different fertilizer treatments. T1- *Lychnohiza malayensis*, T2-*Chrysaora* sp., T3- *Chiropsoides buitendijki*, T4- *Marivagia stellata*, T5: Positive control; commercially available compost fertilizer, T6: negative control; soil for 10 weeks.

fertilizer can also be explored in future studies.

A detrimental effect of jellyfish fertilizers, due to high amount of Cl^- has been widely discussed in previous literature (Fukushi *et al.,* 2004; Arai, 2005). In this study, jellyfish were mixed with soil, and this mixture was kept for around two months in an open area. It is believed that keeping this mixture for more than two months by exposing it to direct sunlight would facilitate the evaporation of Cl^- from the system. Furthermore, this setup also helped to manage the bad smell produced by jellyfish while they are decomposed.

According to Chun *et al.* (2012), the application of jellyfish increases soil productivity through enhanced soil nutrients such as N, P, and K. According to Fukushi *et al*. (2004) N, P, K level of fresh jellyfish *Aurelia aurita* was reported as 96.6, 46, 501 mg/kg, respectively, while 954, 153, 667 mg/kg in *Chrysoara melanaster*. All tested jellyfish fertilizers reported a higher level of phosphorus and lower potassium levels than the commercial-grade compost used in this study. Similarly, jellyfish fertilizers prepared using *L. malayensis* and *C. buitendijki* had a higher nitrogen levels than that of commercially available compost. This could be mainly due to variations in N, P, and K composition of the body tissues, mucus, and protein compounds of different jellyfish species.

It is documented that jellyfish fertilizers increase the nitrogen, phosphorus, and potassium concentrations in the soil (Fukushi *et al*., 2004). According to Chun *et al.* (2012), the application of 11.1 g of jellyfish to 1 kg of soil reported the presence of 10.8 mg/kg, 99.6 mg/kg, and 349 mg/kg of N, P, and K, respectively in the soil. According to the results of the present study, jellyfish fertilizers enhanced the growth of okra plants similar to the commercial-grade compost. Enhanced growth and survival of crop plants after applying jellyfish fertilizers were reported in many previous studies, and Fukushi *et al.* (2004) reported an increase in average vegetable harvests when applying jellyfish fertilizers.

Generally, nitrogen enhances height and the number of leaves in plants, while phosphorus is needed to initiate flowering and fruiting. Potassium plays a significant role as a plant enzyme activator (Uchida, 2000). Low potassium content in jellyfish fertilizers could be linked to the body composition of the jellyfish used in this study. According to Khong *et al. (*2016), jellyfish acquire potassium mainly by consuming diatoms, thus their K content varies with species, life-history stages, and geographical location. Further studies are required to assess how this low level of K in jellyfish fertilizers impacts plant development.

Flowering and fruiting of okra plants treated with fertilizer prepared using *C. buitendijki* were observed in a relatively shorter time period compared to other treatments. This could be due to the presence of a high phosphorus concentration in jellyfish fertilizers in comparison to commercially-available compost. Initiation of reproduction could be a possible reason for the reduced growth rate of plants treated with fertilizers prepared using *C. buitendijki* and *M. stellata* after the 6th week. This preliminary study reveals the possibility of using jellyfish as an organic fertilizer. Further development of these fertilizers is suggested in order to utilize the highly abundant jellyfish blooms economically. As most countries are now promoting organic agriculture, this would be a timely concept.

CONCLUSION

This study suggests the possible uses of jellyfish as an organic fertilizer. Four jellyfish species, *L. malayensis*, *Chrysaora* sp., *C. buitendijki,* and *M. stellata* were identified as suitable candidates to prepare fertilizer. It is recommended to carry out further studies at field level to utilize the abundant jellyfish resources around the country for a sustainable organic farming.

ACKNOWLEDGMENT

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DECLARATION OF CONFLICT OF INTEREST

Authors declare that there are no conflicts of interest.

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