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Shrimp Pond Waste: A Source of Manure for Coconut

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Abstract

Background: Pond waste from shrimp farming in brackish-water is a solid waste that has no identified use, rather become an environmental problem. This study aims to evaluate the potential use of shrimp pond waste as a manure for monoculture coconut plantations.

Methods: The treatments were T1- No fertilizer, T2- Inorganic fertilizer (N, P, K and Mg) and T3- Raw Shrimp Pond Waste (RSPW) with Muriate of Potash. Treatments were arranged in a Randomized Complete Block Design with 3 replicates. After treatment application the soil properties were evaluated by analysing soil pH, electrical conductivity (EC), Organic Carbon (OC), Total N, Available P, Exchangeable K and soil bulk density. Additionally, Water holding capacity (WHC) of soil as a result of addition of RSPW was also evaluated. Foliar nutrient levels of palms were also analysed for primary nutrients, six months after treatment applications.

Results: Results showed that treated soils with RSPW has been given the highest EC (0.63 dS/m) compared to all other treatments. There was no significant difference among the treatments in soil pH, OC, total N and exchangeable K. Available P is also not significantly different between T2 and T3, but significantly higher than the control. The WHC of soil increased by 31 % as a result of adding RSPW. The foliar nutrient levels were higher than critical values in T2 and T3.

Conclusions: According to the results, SPW has the potential of using as a fertilizer for coconut while long term effects need further investigations.

Keywords: Coconut, Organic Fertilizer, Shrimp Pond Waste, Soil Nutrients, Soil Properties

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INTRODUCTION

Coconut (*Cocos nucifera* L.) is a perennial tropical tree, which belongs to the family *Arecaceae*. It grows on a wide variety of soils and tolerates salinity and pH range of 5 to 8. However, coconut thrives best on well-drained soils of at least 1.5 m depth with no hardpans [1]. Fertility status of the soil is one of the main factors that influences the performance of coconut [2]. High amount of nutrients is removed through the harvest as well as other uses of different parts of the coconut palm. These nutrients should be replenished through regular fertilizing to maintain productivity of coconut palms [3]. Inorganic fertilizers, organic fertilizers or fertilizer mixtures are widely used to provide the nutrient requirement of palms.

The nutrient requirement of young coconut palms is different from that of adult coconut palms. The order of the nutrient requirement for young coconut palm is N>P>K>Mg and for adult coconut palm is K>Mg>N>P [4]. Accordingly, separate fertilizer recommendations have been developed for young palms and bearing palms. Even though growers are willing to use organic or natural sources of fertilizers/manures, lack of availability tend to limit the use of organic manure [5]. Furthermore, low levels of K in organic manure restricts the total replacement of inorganic fertilizer to supply nutrient requirement of adult coconut palms. Therefore, it is recommended to add muriate of potash or other K source together with organic manure, especially for tropical soils, which are comparatively low in K [6].

Shrimp farming in brackish-water ponds is a rapidly growing industry in many tropical nations, including Sri Lanka [7]. Shrimp aquaculture predominantly occurs in lagoon-based water systems [8]. During shrimp culture, a mixture of gasses, liquids, semi-solids and solid forms are continuously produced as waste products. When pond water is discharged, some of these materials settles out on the bottom and becomes semi-solid and solid waste [9].

Discharge of pond waste from shrimp farming has been a serious problem in most of the coastal areas in tropical countries. It is due to difficulties in acquiring new sites for disposal. This waste discharge process of shrimp farming has already caused numerous environmental issues such as deterioration of coastal water quality and hydrology, detrimental impacts on aquatic organisms, mangroves and terrestrial vegetation.

Therefore, investigating the potential use of shrimp pond waste (SPW) is a pressing need. The salt content of this material can be a problem in its application to terrestrial vegetation. The tolerance level of different plant species varies widely, while some crops such as coconut have relatively higher tolerance levels. The characteristics of SPW may vary with pond water quality, rainfall of the area and pond inputs [9].

Among the limited number of studies conducted on the issues related to discharge of SPW, a study from Indonesia has attempted to develop an organic fertilizer to be used in cultivating *Caulerpa lentiilifera* [10]. Further, Latt [9] has studied the effect of SPW on papaya, banana, rubber and jasmine plantations in Thailand. Papaya plants have shown less tolerance as they had produced more leaves but no fruits. However, banana, rubber and jasmine plantations have not reported any negative effects.

Shrimp pond waste consist of solids; residue of pond inputs such as unconsumed feed, biological wastes from the shrimp and other organisms (plankton, bacteria) and dissolved matter such as ammonia, urea, carbon dioxide and phosphorous [11]. In addition, SPW has a considerable amount of organic matter, total nitrogen and phosphorous [9]. Further, SPW also contain clay and silt particles responsible for increasing the water holding capacity. Water holding capacity is an important factor that represents the ability of soil to hold water.

It is a property widely considered in irrigation scheduling, crop selection, groundwater contamination considerations and estimation of runoff. It varies with soil texture and organic matter [12]. Accordingly, soils with smaller particles such as silt and clay have a higher volume of microspores and allows the soil to hold more water than soils with large particles like sand.

The uneven distribution patterns of rainfall over time, combined with intense insolation, results in low soil water content causing moisture stress on crops during dry spells [13]. As a rich organic clayey material SPW has a potential to enhance the water holding capacity in the soil while enhancing soil fertility. Therefore, this study aims to evaluate the potential of pond waste from shrimp farming as a manure for adult coconut plantations, in terms of supplying nutrients and conditioning the soil, to enhance the soil properties.

METHODOLOGY

Study Area

The experiment was carried out at an adult coconut plantation in the Low Country Intermediate Zone of Sri Lanka in 2018. The plantation was a monoculture of coconut palms belonging to 20 – 25 year range, with an annual inorganic fertilizer application history. This adult coconut plantation in the Intermediate Zone was selected to represent the major coconut growing areas of the country. Shrimp pond waste samples were collected from a shrimp farm in the North-western province, Sri Lanka.

Study Design & Sample Collection

There were three treatments; T1: No fertilizer (Control); T2: Inorganic fertilizer treatment (Recommended fertilizer mixture + Dolomite) and T3: 30 kg of RSPW + 1.25 kg of Muriate of Potash (MOP). The rate of shrimp pond waste application was decided based on the current recommendations of organic manure and farm yard manure for coconut palm [14].

The experiment was designed based on the Randomized Complete Block Design with three treatments. There were six palms in each plot, from which three palms were selected randomly for sampling. Treatments were applied when the soil was moist after rains. The Manure Circle (MC); the circular area around the tree, which is of 1.8 m radius from the tree was cleaned. Then treatments were applied in the MC, mixed with soil immediately and covered with a mulch from fallen coconut fronds.

Soil samples were collected from 3 points of the MC at the depth of 10 – 20 cm from individual palms, before treatment application and three months after application. Collected samples were air-dried and analysed for their soil properties.

Analysis of Soil Samples

Soil pH and Electrical Conductivity (EC) were determined using a glass electrode pH meter (Mi 180 Bench Meter, Milwaukee) [15-16]. Soil Organic Carbon (OC) was determined using Walkley and Black method [17]. Kjeldahl distillation method [18] was used to determine the Total and Available N. Available P was analysed using the Olsen method [19] and absorbance was measured at 880 nm wave length using a spectrophotometer (Shimadzu Europe - UV mini 1240). Potassium was determined by extraction with Ammonium acetate solution and analysed using a flame photometer (Sherwood Scientific, UK – Model 360). Soil bulk density was determined using the core sample method [20].

Water holding capacity of soil was determined according to the method described by Mangrich *et al*. [13], separately in a soil column using soil amended with two ratios of SPW (as 10 g and 20 g of SPW per 100 g of soil). Water holding capacity was calculated using equation 1.

$$WHC\ (\%) = \frac{mass_{wet} - mass_{dry}}{mass_{dry}} \times 100\% \qquad [1]$$

Analysis of Leaf Samples

Leaf samples were collected representatively from the index leaf, the 14th leaf from the top, the 1st being the fully opened leaf with its leaflets separated, six months after treatment application. Six leaflets were taken from the mid region of the leaf and composited to form a representative sample. The oven dried leaves were ground and used for chemical analysis. The leaf N was determined in 0.1 g samples digested in Se/H_2S0_4 mixture, while 0.5 g samples digested in a $HNO_3/HCLO_4$ mixture were used for P and K. Nitrogen and P were determined colorimetrically using a Continuous Flow Analyzer and K by an atomic absorption spectrometer.

Statistical Analysis

Analysis of variance (ANOVA) was used to analyse the data using SAS Statistical software (Version 9.4).

RESULTS AND DISCUSSION

The composition of SPW analysed in three replicates are given in the Table 1 with standard deviations (SD). According to the results, SPW contained 2.78% of OC, which indicated its potential to enhance the OC in soil.

Table 1: Chemical Properties of Shrimp Pond Waste (Mean ± SD)

Parameter	Mean ± SD
pH	7.63 ± 0.04
EC (dS/m)	7.79 ± 0.05
OC %	2.78 ± 0.06
Total N %	0.23 ± 0.01
Available P (ppm)	622.04 ± 19.97
Exchangeable K (ppm)	627.89 ± 5.86

Electrical conductivity (EC) of SPW was 7.79 ± 0.05 dS/m. It is a measure of the amount of salts (salinity) in soil. It is also an indicator of nutrient availability. However, EC does not provide a direct measurement of specific ions or salt compounds. However, it has been correlated with the concentrations of ions like nitrates, potassium, sodium, chloride, and sulphate in soil. The pH of the pond waste is in the neutral range, while the total N and exchangeable K was low. However, available P was comparatively high, according to classification given by Dharmakeerthi *et al.* [21].

Soil Properties of Experimental Site

Soil pH of the experimental site was in the neutral range (Table 2). According to the results, EC and OC level of initial soils were also very low. The total N content was also low. However, available P and exchangeable K in this soil were very high according to classification given by Dharmakeerthi *et al.* [21].

Table 2: Chemical and Physical Parameters of the Soil in the Experimental Field

Parameter	Mean ± SD
pH	7.10 ± 0.29
EC (dS/m)	0.12 ± 0.06
OC %	0.69 ± 0.23
Total N %	0.11 ± 0.04
Available P (ppm)	347.88 ± 82.88
Exchangeable K (ppm)	274.98 ± 172.74
Bulk Density (g/cm^3)	1.43 ± 0.06

Soil Properties after Treatment Application

Properties of soils taken representatively from the MC of the palms three months after the application of treatments denote a clear difference in properties after adding SPW.

Soil pH and Electrical Conductivity (EC)

Soil pH of the treatments varied from pH 6.82 to 7.03 and the highest pH of 7.03 was recorded in T1 (control), while the lowest (6.82) value was given by T3 (RSPW), as shown in Table 3. While there was no significant difference among the three treatments, slight reduction of pH due to application of fertilizer and manure was evident. All treatments reported favourable pH levels for coconut. Coconut can be grown well in the range of pH 5 to 8 [1]. Most of the macro nutrients increase their availability in the neutral pH levels.

Soil EC ranged from 0.08 dS/m to 0.63 dS/m and the highest EC was given by T3, while minimum was given by T1 (control). When compared with the initial soil EC, SPW applied treatment had increased the EC of soil (Table 3). It may be due to the increment in the ionic concentration of SPW. However, it is well within the EC levels of coconut growing soils. For a crop like coconut, this might not cause any issue, rather being an advantage as coconut thrives in soils with high EC. Furthermore, ions like sodium are considered to be beneficial for coconut.

Soil Organic Carbon

Soil OC percentage of the treatments varied from 0.6% to 1.2% (Table 4). The T3 recorded the highest OC content of 1.2%. However, OC content among treatments was not statistically significant. Increased OC content leads to multiple benefits with respect to soil fertility [22]. The higher OC content of the SPW may, enhance the soil OC content over the time, which is considered to be of paramount importance in tropical soils.

Table 3: The pH and Electrical Conductivity of Soil under Different Fertilizer Applications (Mean ± SD)

Treatment	pH	Electrical Conductivity (dS/m)
T1	$7.03^{a} \pm 0.28$	$0.08^{c} \pm 0.02$
T2	$6.99^{a} \pm 0.20$	$0.41^{b} \pm 0.16$
T3	$6.82^{a} \pm 0.11$	$0.63^{a} \pm 0.10$

Note: Means with different superscript letters in the same column represent significant differences at P<0.05 level. T1: Control, T2: Inorganic fertilizer applied treatment, T3: Raw shrimp pond waste applied treatment.

Soil Total Nitrogen

Soil total N ranged from 0.13% to 0.18% in all treatments (Table 4). The SPW applied treatment (T3) recorded the highest total N content of 0.18%. The inorganic fertilizer treatment (T2) resulted 0.17% of total N content, while the control showed the lowest (0.13 %).

There was no statistically significant difference in total N percentage among treatments. When compared to initial soil N level, both fertilizer applied and SPW applied treatments had increased the soil N even after three months of application.

Soil Available Phosphorous

Soil available phosphorous ranged from 243.19 ppm to 944.74 ppm in all treatments (Table 4). Available phosphorous content was significantly higher in T2 and T3, compared to the control. This indicates that the SPW has been able to enhance the soil phosphorous to a similar level of inorganic fertilizer applied treatment.

Soil Exchangeable Potassium

Soil exchangeable K of treatments ranged from 99.05 ppm to 985.34 ppm (Table 4). Maximum exchangeable K was recorded by T2, while minimum was recorded by T1 (control). However, there was no significant difference among treatments. When compared with the initial soil, exchangeable K had increased in soil after addition of SPW.

Soil Bulk Density (BD)

Bulk density indicates the compaction of soil and ease of root penetration. Soil BD was significantly lower in T2 and T3, compared to control (T1). However, there was no significant difference between T2 and T3. (Table 5). Bulk density is influenced by some soil properties such as the amount of organic matter in soils, texture, constituent minerals and porosity [23].

Generally, soils with low BD have favourable physical conditions for plant growth. The T3 recorded significantly lower BD than T1 (control soil). This can be considered as an advantage of making favourable conditions to penetrate roots deep into the soil, especially for coconut, which consists of a fibrous root system.

Water Holding Capacity (WHC)

The Water holding capacity (WHC) of normal soil (without adding treatment) was 25.2% (w/w).

Table 4: Chemical Parameters of Soil under Different Fertilizer applications (Mean ± SD)

Treatment	Organic Carbon (%)	Total N %	Available P (ppm)	Exchangeable K (ppm)
T1	0.60[a] ± 0.20	0.13[a] ± 0.02	243.19[b] ± 170.24	99.05[a] ± 49.85
T2	0.78[a] ± 0.22	0.17[a] ± 0.02	944.74[a] ± 268.36	985.34[a] ± 948.48
T3	1.18[a] ± 0.30	0.18[a] ± 0.04	895.92[a] ± 277.93	443.00[a] ± 81.31

Note: Means with different superscript letters in the same column represent significant differences at P<0.05 level. T1: Control, T2: Inorganic fertilizer applied treatment, T3: Raw shrimp pond waste applied treatment.

Table 5: Variation in Bulk Density of Soils under Different Fertilizer Applications (Mean ± SD)

Treatment	Bulk density (g/cm³)
T1	1.25[a] ± 0.20
T2	0.98[b] ± 0.04
T3	1.00[b] ± 0.04

Note: Means with different superscript letters in the same column represent significant differences at P<0.05 level. T1: Control, T2: Inorganic fertilizer applied treatment, T3: Raw shrimp pond waste applied treatment.

The WHC of SPW amended soil was 33.03% (w/w). WHC was significantly increased by adding SPW (Figure 1).

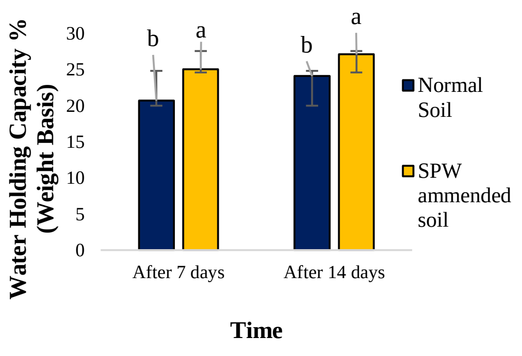

Figure 1: Variations in Water Holding Capacity of Soil Treated with Shrimp Pond Waste After 7 and 14 Days (Mean ±SD)
Note: Means with different letters represent significant differences at p<0.05 level

Foliar Nutrient Levels

The use of foliar nutrient analysis as a tool for the diagnosis of nutritional deficiencies in perennial crops, is now well recognized [24]. In this method, leaf nutrient levels are compared against the critical nutrient levels [25-26]. According to the results of the analysis, foliar nutrient levels of the conventional fertilizer applied treatment and SPW treated palms were above the critical values of the primary nutrients (Table 6). This shows that SPW has been able to provide nutrients in sufficient levels. Especially, nitrogen and phosphorus. Meanwhile, the control treatment reported values lower than critical values for all three primary nutrients.

Table 6: Leaf Nutrient Levels of Palms under Different Fertilizer Applications (Mean ± SD)

Treatment	Nitrogen %	Phosphorus %	Potassium %
T1	1.70 ± 0.02	0.09 ± 0.02	0.90 ± 0.03
T2	2.13 ± 0.02	0.21 ± 0.04	1.31 ± 0.06
T3	2.18 ± 0.04	0.18± 0.03	1.25 ± 0.04
Critical Values	**1.90**	**0.11**	**1.20**

Note: T1: Control, T2: Inorganic fertilizer applied treatment, T3: Raw shrimp pond waste applied treatment.

CONCLUSIONS

Results indicate that Shrimp Pond Waste (SPW) has been able to enhance soil phosphorous, organic carbon and bulk density, while providing sufficient levels of nutrients to the palm. Therefore, it has a potential of enhancing soil fertility and increasing the water holding capacity of soil.

However, soil EC has been increased with the addition of SPW. For a crop like coconut, this may not cause any issue as they thrive in soils with higher EC. However, it is important to study the long term effects to see if there is a risk of salinity build- up as a result of SPW application.

CONFLICT OF INTEREST

The authors would like to declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

KW: Data collection, statistical analysis, and prepared the first draft of manuscript; IH: Designed the research, managed experiment and revised the manuscript.

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