Effects of Organic, Inorganic and Compound Fertilizer on Growth and Quality of Water Spinach (*Ipomoea aquatica*) under Polyculture Condition

Norfakhrina Mohd Noor\textsuperscript{a}, Nur Amalina Mohd Ropi\textsuperscript{a}, Kian-Kai Cheng\textsuperscript{ab} and HongYeng Leong\textsuperscript{a,}\textsuperscript{b}\textsuperscript{*}

\textsuperscript{a}Innovation Centre in Agritechnology for Advanced Bioprocessing, Universiti Teknologi Malaysia, 84600 Pagoh, Malaysia
\textsuperscript{b}School of Chemical and Energy Engineering, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia

*Corresponding author: hongyeng@utm.my

Received: 31/03/2021, Accepted: 16/09/2021, Available Online: 15/03/2022

**ABSTRACT**

Fertilizer management and soil nutrient profile affect plant growth. However, each plant species is unique and may require different nutrients for best growth. This study aimed to investigate the effect of organic fertilizer, inorganic fertilizer and compound fertilizer applications on the plant growth of water spinach (*Ipomoea aquatica*) under polyculture system. In the present study, water spinach (*Ipomoea aquatica*) were grown under a polyculture planting condition with okra (*Abelmoschus esculentus*) and yardlong bean (*Vigna unguiculata* subsp. *sesquipedali*), and treated with five different types of fertilizer regime (T1: without fertilizer, T2: organic fertilizer, T3: inorganic fertilizer, T4: compound fertilizer and T5: organic + inorganic fertilizer). For each treatment group, a total amount of 9 g m\textsuperscript{-2} of nitrogen, phosphorus and potassium each were applied throughout the experiment. The present results showed that under polyculture condition, no significant difference was observed in the total weight, root weight, root length and leaf number of water spinach under different treatments (p>0.05). However, significant difference (p<0.05) was found for plant height of water spinach among the five treatment groups. Furthermore, the weight of roots and shoots of water spinach was found to have positive correlation (T1: R\textsuperscript{2}=0.672; T2: R\textsuperscript{2}=0.799; T3: R\textsuperscript{2}=0.442; T4: R\textsuperscript{2}=0.779; T5: R\textsuperscript{2}=0.804). In addition to crop growth, the fertilizer application also influenced the soil pH, EC, organic matter and moisture content after one cropping season. In this study, the growth of water spinach following application of organic fertilizer was found comparable to the inorganic fertilizer treatment. Incorporation of organic and inorganic fertilizer (T5) served the best condition for the growth of water spinach under the polyculture system.

**Keywords:** Fertilizer, Plant growth, Integrated Farming, Soil Condition, Leafy Vegetables
INTRODUCTION

Fertilizer management, soil types and soil nutrients profile cause different growth, yield, and quality of a plant species. Plants required suitable soil condition for optimum yield and better quality (Chowdhury et al., 2008). Study in a local soil on characteristics of a plant growth is important to develop good management practices for higher crop yield with better quality (Oshiro et al., 2016). Fertilizer is one of the most important supporting element and complementary substance for plant growth. It provides a balanced mineral supply required by a specific plant. For optimum plant growth, adequate amount of mineral is needed from fertilizer application instead of relying on the mineral present in the soil. The physical appearance of plant symbolized of the utilization of mineral by the system of plant (Chang et al., 2010).

Fertilizer can be categorized as organic and inorganic fertilizers. Both have been widely used in agriculture sector. Most of the active substances in organic fertilizer come from manure and waste (Uddin et al., 2012). Organic fertilizer can improve fertility and physio-chemical properties of the soils. Moreover, addition of organic fertilizer can reduce phytotoxicity issue related to acidic soil (Kashem and Singh, 2001). Meanwhile inorganic fertilizer is produced by natural-based chemical processing which has been considered as environmental unfriendly. Prolong used of inorganic fertilizer lead the infertile soil with low quantity of microbial biomass and available nutrient (Shimbo et al., 2001; Liu, 2009). However, inorganic fertilizer is still widely used by commercial farms as it is effective in promoting plant growth and yield. Other types of fertilizer that is in trend now is compound fertilizer. Compound fertilizer is defined as an organic fertilizer which fortified with straight fertilizer either nitrogen, phosphorus or potassium that promotes root growth and nutrient release from organic matters (Chen, 2006). The use of inorganic fertilizer, organic fertilizer or compound fertilizer may lead to different results in the terms of nutrient supply, crop growth and environmental impact.

A plant species requires a balanced fertilizer to maximize growth, yield, and quality. Different type of plants responds differently toward fertilizers element (Akamine et al., 2007; Chowdhury et al., 2008; Hafsi et al., 2011). The major nutrients (Nitrogen, N; Phosphorus, P; Potassium, K) solely or in combination maintain growth, yield, and quality of plants (Nakano and Morita, 2009; Hafsi et al., 2011). Nitrogen influences formation of chlorophyll, stomatal conductance, and photosynthetic efficiency which influence of increasing vegetative parameter (Akamine et al., 2007). Potassium plays catalytic roles that regulates functions of various minerals in plants and increase the N uptake efficiency of plants. Insufficient K causes yellowing of shoot, poor growth, and low resistance to cold and drought (Yan et al., 2012). Phosphorus provides better absorption of other nutrients and promotes root growth (Akamine et al., 2007).

Water spinach is a member of Convolvulaceae and very common in Asian countries distributed in humid areas from subtropical to temperate zones. This plant takes a relatively short time to grow (about 26 to 35 days until harvest) and is highly resistant to common pest (Zhou et al., 2011; Zhou et al., 2019). Water spinach yielded the best productivity when established from seed compare to vegetative cutting (Bunyeth and Preston, 2004). It has been reported that water spinach crop responded better to both organic and inorganic fertilizer (Mohd Noor et al., 2018). This plant is rich in carbohydrates, vitamins and minerals. For example, antioxidant compound loaded in water spinach can eliminates free radicals from the human body (Mariani, et al., 2019). In this study, okra and yard long bean were selected to poly crop with water spinach because both pose less competition of nutrient. Water spinach is a leafy vegetable often required high nitrogen input. On the other hand, okra is fruit vegetable that require high potassium while yard long bean is a nitrogen fixing vegetable which require less input of nitrogen.

Previous research works suggested the crop yield under polyculture system were higher than monocultures (Andow, 1991). Farmers often able to reduce the use of fertilizer under polyculture cropping systems as polyculture system has yield advantages under low nutrient input condition (Liebman, 2018). Nowadays, people are more concern on health, there is an increasing demand for healthy food and healthy lifestyle. The demand on healthy food drives the farmer to use organic fertilizer to boost the growing process of the plants (Ekelund and Tjärnemo, 2004). However, the growth of plant has been claimed to be slower following treatment with
organic fertilizer, as compared to inorganic fertilizer (Suge et al., 2011; Han et al., 2016). The hypothesis of this study is that water spinach treated with organic fertilizer may have comparable plant growth with plant treated inorganic fertilizer under polyculture system. Thus, this research aims to investigate the effect of organic, inorganic fertilizer and compound fertilizer on growth and quality of water spinach under polyculture system.

MATERIALS AND METHODS

Study site
Field experiment was conducted at research farm (2°09’22”N, 102°44’00”E) of Universiti Teknologi Malaysia Pagoh (UTM-Pagoh) for one crop cycle of water spinach (4 weeks) from June 2018 to July 2018. The weather of the study location was classified as tropical. Based on the data collected from weather station, the average surface wetness and relative air humidity during the experiment were 0.5640 m/m³ and 23.75 °C, respectively. The type of soil is sandy loam with brown colour.

Cultivation selection and seed materials
Seeds of water spinach, *Ipomoea aquatica*, were sown in seed trays (5cm-diameter) containing commercial garden peatmoss.

Experimental Design
After 5 days, the *Ipomoea aquatica* seedlings were transplanted to 15 rows of planting beds (3 x 6 ft). The seedlings were polycultured with okra and yardlong bean. The plants were applied with three types of commercial fertilizer: organic certified fertilizer (Midori Fertilizer 3:3:3), commercial inorganic fertilizer (Yara 16:16:16), and commercial compound fertilizer (Midori Fertilizer 6:6:6). The experiment was conducted based on Completely Randomized Block Design (RCBD) with three replications per treatments (T1: control treatment without fertilizer input; T2: organic fertilizer (3:3:3), T3: inorganic fertilizer (16:16:16), T4: biofertilizer (6:6:6), T5: organic + inorganic fertilizer (3:3:3 + 16:16:16). A total of 9 g m⁻² of nitrogen, phosphorus and potassium were applied for each treatment which split into 2 applications (Table 1). Fertilizer were applied at the first and third week after planting according nutrient requirement of plant (DOA, 2019). Plants were watered twice a day with 20L water/ bed. Water spinach were harvested after a month of planting.

<table>
<thead>
<tr>
<th>Application Timing</th>
<th>Total N Application (g N m⁻²)</th>
<th>Total Fertilizer Application, g m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
<td>T2</td>
</tr>
<tr>
<td>Week 1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Week 3</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

Note:
T1: control treatment without fertilizer input  
T2: organic fertilizer (3:3:3)  
T3: chemical fertilizer (16:16:16)  
T4: compound fertilizer (6:6:6)  
T5: organic (3:3:3) + inorganic fertilizer (16:16:16)
Data Collection

Total plant weight, root weight, root length, plant height and leaves number were measured during the harvest of water spinach. Electroconductivity (EC), pH, soil organic matter (SOM) and moisture of the soil were recorded before and after the experiment.

Plant Moisture Content

Plant samples were oven-dried at 105 °C until constant weight. The plant weight before and after drying process were recorded to determine the percentage of moisture content.

Plant Carbon and Nitrogen Content

Plant samples were dried at 80 °C for 24 hours. Then, the dried samples were ground and sieved through 20 mesh size. The carbon and nitrogen content of dried plant samples were analysed via the Dumas method by using Elementor Vario Micro Cube CHNS analyser (BS EN ISO 16948:2015).

Surface and Subsurface Soil Sampling

Surface soil (0-15 cm below ground surface) and shallow subsurface soil (15-30 cm below ground surface) sample were collected for each treatment. Gravels and roots mat near the surface were removed before the sample was collected. The composite soil samples (n=5) were collected by using an auger with 2.5 cm-diameter. Composite surface and subsurface soil samples of the same planting beds were homogenized prior to analysis.

Soil Moisture

Moisture of soil were measured by oven drying method. 10 g of soil sample were dried in oven dryer at 105°C until constant weight. The weight of soil sample before and after the drying process were measured to determine the moisture content of the soil. Percentage of soil moisture content were calculation as below (Eqn 1)

\[
\text{Eqn. 1} \quad \frac{W_1(g) - W_2(g)}{W_1(g)} \times 100
\]

where, \(W_1\): weight of moist soil, \(W_2\): weight of dry soil

Soil Organic Matter (SOM)

Dried soil samples for each treatment were ashed in a muffle furnace (Carbolite Gero ELF Model) for 24 hr at 440 °C. The weight of soil sample before and after the process were measured to determine soil organic matter of the soil. Percentage of soil organic matter were calculated as below (Eqn 2)

\[
\text{Eqn. 2} \quad \frac{W_2(g) - W_3(g)}{W_2(g)} \times 100
\]

where, \(W_2\): weight of dry soil, \(W_3\): weight of ashed soil
Soil pH and Soil Electroconductivity (EC)

Soil samples were immersed in the distilled water with ratio 1:1 for 24 hr. Then, pH of the soil was determined by using a pH meter (Mettler Toledo Seven Excellence Benchtop pH/Conductivity Meter).

Statistical Analysis

The results were evaluated with analysis of variance (ANOVA) procedures of the Statistical Packages for Social Sciences version 16 (SPSS-16). Means comparisons between treatments were performed by least significant difference (LSD) test at p<0.05.

RESULTS AND DISCUSSION

Effect of Organic, Chemical and Compound Fertilizer on Plant Growth of Water Spinach

The vegetative and plant yield parameters were recorded to evaluate the effects of different types of fertilizer on the growth and quality of water spinach. Table 2 showed plant growth of water spinach treated with different type of fertilizer.

Table 2. Average plant weight, root weight root length, plant height and leaves number of water spinach applied with different types of fertilizer

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total Weight (g)</th>
<th>Root Weight (g)</th>
<th>Root Length (cm)</th>
<th>Plant Height (cm)</th>
<th>Leaves Number (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>57.85 ± 14.34a</td>
<td>8.80 ± 2.23a</td>
<td>19.13 ± 1.11a</td>
<td>42.51 ± 1.58c</td>
<td>57.67 ± 7.51a</td>
</tr>
<tr>
<td>T2</td>
<td>58.17 ± 14.51a</td>
<td>7.91 ± 1.63a</td>
<td>18.67 ± 2.55a</td>
<td>45.37 ± 4.61bc</td>
<td>52.51 ± 6.29a</td>
</tr>
<tr>
<td>T3</td>
<td>78.03 ± 11.42a</td>
<td>8.79 ± 0.33a</td>
<td>19.96 ± 2.45a</td>
<td>49.58 ± 2.79bc</td>
<td>61.38 ± 9.90a</td>
</tr>
<tr>
<td>T4</td>
<td>66.87 ± 21.98a</td>
<td>7.86 ± 2.41a</td>
<td>16.43 ± 3.39a</td>
<td>52.82 ± 6.10a</td>
<td>50.40 ± 17.33a</td>
</tr>
<tr>
<td>T5</td>
<td>74.33 ± 4.04a</td>
<td>6.99 ± 0.06a</td>
<td>18.98 ± 0.33a</td>
<td>51.93 ± 1.10ab</td>
<td>72.04 ± 18.18a</td>
</tr>
</tbody>
</table>

Note: Mean ± S.D in the same column with different superscript represent significant difference (p<0.05).

No significant difference was observed in root weight and root length between treatments. Nevertheless, water spinach grew without fertilizer input had the highest average root weight (8.80 ± 2.23 g), although not significantly different from other groups. Meanwhile, water spinach applied with inorganic fertilizer had the highest average root length (19.96 ± 2.45 cm). There was a significant difference (p<0.05) between plant height of water spinach treated with compound fertilizer as compared to without fertilizer. The average height of plant varied from 42.51 ± 1.58 cm in T1 (without fertilizer input) to 52.818 ± 6.10 cm in T4 (compound fertilizer input). There was no significant difference (p>0.05) on the leaves number of water spinach. In average, the leaves number was found highest in water spinach treated with organic + inorganic fertilizer (72.04 ± 18.18) and lowest in compound fertilizer (50.40 ± 17.33).

According to Uddin et al. (2012), water spinach treated with organic and inorganic fertilizer resulted range of maximum height of shoot at harvest from 29.7 cm to 51.0 cm. However, the leaves number was between 11 and 18 leaves per plant. Comparable results were obtained from this experiment in which the plant height of water spinach treated with organic and inorganic fertilizer ranged from 42.51 ± 1.58 cm to 52.82 ± 6.10 cm. Both organic and inorganic fertilizers provide the necessary nutrient need by plant to growth. Moreover, the
leaves number was ranged from 52.51 ± 6.29 to 72.04 ± 18.18 pieces per plant. Plant yield has a tendency to be increased by the nutrient availability when exposed to addition of either organic or inorganic fertilizer (Kashem and Singh, 2001).

It was noticed that the application of organic and inorganic fertilizers either solely or in combination had a great influence on the vegetative growth of the water spinach. Organic fertilizer maintained the good health of the soil by slow release of adequate nutrient. Research work by Ullah et al., 2008 found the highest growth of eggplant was treated by integration of organic and inorganic fertilizer (20% cow dung + 20% mustard oil cake + 20% poultry manure + 40% NPK). Combination of organic and inorganic fertilizer may ensure continuous and rapid supplies of nutrients for plant growth.

Fig. 1. Correlation between weight of shoot and root on fertilizer treatments toward water spinach crop (A) T1: $R^2=0.672$; (B) T2:$R^2=0.799$; (C) T3:$R^2=0.442$; (D) T4:$R^2=0.779$; (E) T5:$R^2=0.804$
Figure 1 shows a strong correlation of 0.804 between weight and shoot of T5 as compared to other treatments. Weight and shoot of T2, T4 and T1 also showed high correlation of 0.799, 0.779 and 0.672, respectively. However, T3 showed poor correlation 0.442 between the weight of shoot and root. Correlation analysis measures the mutual relationship between two parameters. In this study, positive correlation between shoot and root weight were observed. The trend observed agrees with other studies which suggested that there is a persistence tendency of a positive correlation between roots and shoot (Puig et al., 2012; Silva et al., 2012; Ason et al., 2015). Generally, as root weight increases, growth of the plant also increased (Ason et al., 2015). Water limitation commonly triggered an adaptive response in plant to avoid water stress which would result in higher root growth and greater capacity to absorb water (Kozlowski and Pallardy, 2002). Sandy loamy sediment typically has a lower water holding capacity than the silt loam soil and this may account for slightly higher root weight and a lower shoot growth.

![Moisture content of Water spinach](image)

**Fig. 2.** Moisture content water spinach on different fertilization treatments

Figure 2 shows the percentage moisture content of water spinach. There are significantly difference (p<0.05) among the treatments. Water spinach T5 (87.46 ± 2.73 %) presented the highest percentage of moisture content. This is followed by T4 (85.69 ± 2.74 %), T3 (83.01 ± 2.52 %) and T1 (82.79 ± 2.73 %). Meanwhile T2 (79.68 ± 2.44 %) showed the lowest percentage of moisture content. Water spinach is known to contain high moisture within the range of 70 - 90 % (Ogle et al., 2001; Umar, et al., 2007). In this study, water spinach treated with combination of organic and inorganic compound fertilizer resulted in significantly higher moisture content. The lowest percentage of moisture was observed in water spinach treated with organic fertilizer. Study has shown organic fertilizer with slow-release nutrient increased the nutritional value of plant (Zheljazkur and Warman, 2003; Uddin et al., 2012). Uddin et al., (2012) reported dry weight of shoot and roots of water spinach increased 70-73 % when applied addition of phosphorus element in cow manure. Proper fertilizer management improves soil physical, chemical and biological properties which enhanced the soil organic matter and plant growth. Increasing of organic matter in the soil attributed to the increased in nutrient availability to the plants (Zheljazkur and Warman, 2003).

Table 3 shows effect of different types of fertilizer on carbon and nitrogen content of water spinach. There is no significant difference (p<0.05) on C content of the plant. The range of C content in the plant was 37.31 ±
The initial value of EC reading with inorganic fertilizer was more acidic as compared to organic fertilizer. Inorganic fertilizer contains urea. The initial value of soil pH before planting were classified as acidic. In this study, pH value of the soil treated with inorganic fertilizer showed significantly different values from water spinach crop. Specifically, pH value of 3.3% N (Li et al., 2010). In this experiment, the content of nitrogen was slightly higher (3.5-4.3%) which is good for plant as nitrogen was a major component of chlorophyll to assist photosynthesis process. In this study, carbon content of the water spinach was within the range of 37.71 to 38.39%. A study found that a desert shrub in Mongolia, China had carbon content of ~36% (Xu et al., 2007). Another study in semiarid Senegal also showed that the carbon content in shrub residue was around 35% (Dossa et al., 2009). Study by Talgre et al., (2017) on green plant revealed carbon content showed variation from 38% to 46%.

**Table 3.** Fertilizers on Carbon (C) and Nitrogen (N) content of water spinach

<table>
<thead>
<tr>
<th>Treatment</th>
<th>C (%)</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>37.48 ± 0.65&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.68 ± 0.53&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>38.39 ± 0.24&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.54 ± 0.42&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3</td>
<td>37.83 ± 0.57&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.28 ± 0.21&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>37.31 ± 1.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.55 ± 0.27&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T5</td>
<td>37.35 ± 0.52&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.36 ± 0.26&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: Mean ± S.D in the same columns with different superscript represent significant difference (p<0.05)

Application of organic fertilizer together with inorganic fertilizer to the water spinach crop increase the value of nitrogen content. In this case, the supply of nutrient is directly from inorganic fertilizer and indirectly from organic fertilizer. Previously, nitrogen element was found to increase the activity of apical meristem to generate shoot growth which affect the plant height growth rate (Purbajanti et al., 2019). Study by Juan et al. (2014) on carbon and nitrogen content in native vegetation of an arid land in Northwest China reported 35.5% to 55.7% C and 0.5-3.3% N (Li et al., 2010). In this experiment, the content of nitrogen was slightly higher (3.5-4.3%) which is for good plant as nitrogen was a major component of chlorophyll to assist photosynthesis process. In this study, carbon content of the water spinach was within the range of 37.71 to 38.39%. A study found that a desert shrub in Mongolia, China had carbon content of ~36% (Xu et al., 2007). Another study in semiarid Senegal also showed that the carbon content in shrub residue was around 35% (Dossa et al., 2009). Study by Talgre et al., (2017) on green plant revealed carbon content showed variation from 38% to 46%.

**Effect of Organic, Inorganic and Compound Application on Soil Properties**

**Table 4.** The pH electroconductivity, moisture, and organic matter of soil treat with organic, inorganic and compound fertilizers

<table>
<thead>
<tr>
<th>Treatment</th>
<th>pH</th>
<th>Electroconductivity (µS/cm)</th>
<th>Moisture (%)</th>
<th>Organic Matter (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>7.35 ± 0.22&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.28 ± 8.30&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.10 ± 1.79&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.22 ± 0.23&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2</td>
<td>6.96 ± 0.04&lt;sup&gt;b&lt;/sup&gt;</td>
<td>33.45 ± 2.28&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.92 ± 0.69&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.41 ± 0.47&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3</td>
<td>6.16 ± 0.14&lt;sup&gt;c&lt;/sup&gt;</td>
<td>140.67 ± 105.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.08 ± 0.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.56 ± 0.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T4</td>
<td>6.24 ± 0.04&lt;sup&gt;c&lt;/sup&gt;</td>
<td>31.73 ± 9.83&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.08 ± 0.80&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.22 ± 0.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T5</td>
<td>5.89 ± 0.12&lt;sup&gt;d&lt;/sup&gt;</td>
<td>143.32 ± 45.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.55 ± 0.53&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.93 ± 0.12&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Initial</td>
<td>5.43</td>
<td>59.05</td>
<td>14.56</td>
<td>3.41</td>
</tr>
</tbody>
</table>

Note: Mean ± S.D in the same columns with different superscript represent significant difference (p<0.05)

Table 4 shows the effect of fertilizer on soil properties of water spinach crop. The initial value indicated the data before application of fertilizer. At the end of experiment, soil pH varied significantly (p<0.05) among the treatments. The soil pH before treatment was found to be 5.43, and the pH value increased in all groups after one crop cycle. Generally, application of organic fertilizer to integrated crop of water spinach increased the soil pH higher than inorganic and compound fertilizer. On the other hand, the electroconductivity (EC) reading showed marked increase (p<0.05) in T5 (143.32 ± 45.60 µS/cm) and T3 (140.67 ± 105.06 µS/cm). Notably, the EC of soil in three other groups, including T1 (20.28 ± 8.30 µS/cm), T2 (33.45 ± 2.28 µS/cm) and T4 (31.73 ± 9.83 µS/cm) were reduced compared to the initial value of EC (59.05 µS/cm). Furthermore, soil moisture shows significantly difference (p<0.05) between the treatments. The initial value of soil moisture was 14.56%. The soil moisture level decreased at the end of crop cycle (T5: 13.55 ± 0.53%; T2: 11.92 ± 0.691%; T3: 11.08 ± 0.82%; T4: 11.08 ± 0.80%; T1: 10.10 ± 1.79%). There was no significant difference (p > 0.05) of soil organic matter between each treatment. Soil of organic matter varied from each treatment. The Initial value of soil pH before planting were classified as acidic. In this study, pH value of the soil treated with inorganic fertilizer was more acidic as compared to organic fertilizer. Inorganic fertilizer contains urea.
which can be absorbed by the plants as ammonium ion (NH$_4^+$), then hydrogen ion (H$^+$) can be released to the soil which may decrease the soil pH (Magdof et al., 1997). The nitrification of mineralized nitrogen is the main cause of soil acidification (Xu et al., 2006). Acid soil would also be reduced with addition of organic fertilizer which leads to reduction of metal phytotoxicity issue (Kashem and Singh, 2001). In addition, the increase of soil pH after one crop cycle might be due to the return of organic matters to soil. It has been suggested that plant is a separator of the alkalinity generated by N and S assimilation (Barak et al., 1997). Therefore, by returning crop residues back to the soil will reduce the soil acidification effect due to fertilizer. This is supported by Xu et al. (2006) who reported the addition of 15 g kg$^{-1}$ of plant residues increases the pH of Wodijl, Bodallin and Lancelin soils by up to 3.4 units due to decarboxylation of organic anions and ammonification of the crop residue N (Xu et al., 2006).

Generally, organic matters increase soil pH, but the effect was differs depending on the organic matter content, treatments amounts and soil properties (Han et al., 2016). Slow decomposition of organic matter allows plants to use nutrient for a longer period of time (Bhandari et al., 2002). Although this study did not analyze soil calcium carbonate, the amount of calcium carbonate that is increased by organic-content treatments after the fertilization treatments was believed to increase buffering thereby increase the soil pH (Eghball, 1999). Long term-utilization of inorganic fertilizer may have resulted in deficiencies in essential nutrients, which may lead toward deterioration of physical, chemical and biological properties of soil (Bailey et al., 2004). The present study showed the EC was markedly increased with adding of chemical fertilizer to the soil. This result is consistent with the findings by Han et al. (2016) as the highest electroconductivity was observed in the soil treated with combination of organic fertilizer with NPK. The values of organic matter for all treatment groups were in moderate percentage ranging from 1-5 % which was suitable for planting.

**CONCLUSION**

The increase of crop productivity can be achieved with right soil nutrient management which is essential for maintaining soil quality. The growth of water spinach applied with commercial organic fertilizer treatment is comparable to the inorganic fertilizer treatments. Prior to related nutrient content of plant to the soil treatments, the nutrient composition of soil and plants should be taken into consideration. This study concluded combination of organic fertilizer and inorganic fertilizer able to promote the growth of water spinach and also improve the soil condition.

**ACKNOWLEDGMENTS**

This work was supported financially by Universiti Teknologi Malaysia (IIG Grant: Q.J130000.3609.02M35, reference no: PY/2020/04188 and GUP grant: Q.K130000.2609.15J18, reference no: PY/2017/01638). We would like to thank Innovation Centre in Agritechnology for Advanced Bioprocessing (ICA) for supporting this research activity. Special thanks to Zexin Agriculture Sdn. Bhd. for sponsoring research materials. The authors express their sincere thanks to Muhammad Zahir bin Mohd Azman from Engineer team of ICA.

**REFERENCES**


Department of Agriculture. (2019). Keterangan am sayuran tempatan kangkung. Penang, Malaysia : Jabatan Pertanian negeri Pulau Pinang


How to cite this paper: