

Original Research Article

Effect of vermiwash obtained from different sources (neem, rice straw and bagasse) and standardised hydroponics solution on the growth of *Colocasia esculenta* (Australian poi) in Guyana.

ABSTRACT

The chief economic activity of Guyana is agriculture. In the agricultural industries, the use of fertilizers for crop cultivation has been in common practice and has affected the crop quality over the years. The use of fertilizers accounts for about 75% of crop cultivation and quantity has basically become the major concern rather than quality. The present research carried out during 2012-13, indicated that chemical fertilizers improve quantity but not quality while organic fertilizers maintain both quantity and good quality of crops. The physico-chemical analysis of vermiwash showed the necessary elements for plant growth are present in sufficient quantity. T8 (neem + rice straw + cattle dung) followed by T9 (neem+ rice straw+ bagasse+ cattle dung) and H (chemical treatment) were the most effective treatments in hydroponics compared to C (distilled water) and T1(cattle dung) that were minimally effective. This is substantiated by 2-factor ANOVA, LSD and composite index. Plants grown using different vermiwash in comparison to hydroponically grown showed less moisture, better shoot and root growth, number of leaves, nodes and resistance to insect damage.

Key words: hydroponics, bagasse, vermiwash, earthworms, *Colocasia esculenta*

1. INTRODUCTION

The revolution of the agricultural industry has become noticeable over the past twenty years. However seventy five percent (75%) of the agricultural industries incorporate fertilizers as a necessity for production. Fertilizers use have led to the success in the production of quantity rather than quality and also distorted the organic and inorganic components of our environment. In today's society, we are faced with the challenge of effective waste management and as such we can utilize vermitechnology [1] to actively manage our organic waste disposal crises and

simultaneously utilize the products of vermitechnology as a nutrient source for modern agricultural technique.

Vermiculture is the culture of earthworms and vermicasting is the fecal matter released by the earthworms [2, 3]. Chemical fertilizers are synthetic (chemical) sources of nutrients {nitrogen (N), phosphorous (P), and potassium (K)} that help plants grow faster and healthier. Fertilizers must be formulated so that nutrients are easily absorbed by crops [4, 5]. Vermicomposting is the biological degradation and stabilization of organic waste by earthworms and microorganisms to produce vermicompost [4]. The earthworms fragment the organic waste substrates, stimulate microbial activity greatly and increase rates of mineralization. These rapidly convert the waste into humus-like substances with finer structure than thermophilic composts but possessing a greater and more diverse microbial activity [6, 7]. Vermiwash is a liquid fertilizer which is collected after it passes through a layer of soil, with earthworms in it [2, 3]. Vermiwash is composed of secretions of earthworms and micronutrients from organic breakdown as nutrients can be readily absorbed. Vermiwash, if collected properly, is a clear and transparent, pale yellow coloured fluid [2, 3]. The regular inputs of feed materials for earthworms can be in the form of agro waste, kitchen waste and nitrogen rich materials such as cattle dung, goat dung and pig manure [8].

Hydroponics is a useful technology in locations where the land areas are minimal or there are affected by excessive flooding. The process requires the use of hydroponics solution which is composition of plant nutrients in appropriate quantity is present. This research work was conducted to compare the growth of Australian poi with the use of hydroponics solution and vermiwash produced from different sources (neem, rice straw and bagasse).

2. MATERIALS AND METHODS

Vermitech units were set up at the University of Guyana (2011-2012) at the Faculty of Natural Sciences. Chemical analysis of vermiwash and other laboratory work was done at the Guyana Sugar Corporation Central Laboratory. Plants were grown at the University Of Guyana at the Faculty of Natural Sciences.

Vermiwash Units

The vermiwash unit was set up using nine buckets (size: 115 mmx115 mmx100 mm). A tap was fixed on the lower side of each bucket. About 25 cm of broken pebbles were placed at the bottom of each bucket. A 25 cm layer of coarse sand was placed after the pebbles. Water was allowed to flow through these layers to enable the settling of the basic filter unit. A 20-30 cm layer of loamy soil was placed on top of the filter bed. Earthworms were introduced into the soil for seven buckets. Cattle dung and selected organic materials in specified quantities were placed on top of the soil for the buckets with earthworms. One bucket contained cattle dung without earth worms and one with a combination of all organic materials without earthworms. Units were watered and drained at approximately every two days interval so as to keep moist. Units were monitored and additional specified quantity of organic materials was added when needed. After about six weeks, vermiwash from different treatments was harvested at needed intervals and used to grow *Colocasia esculenta*, (Australian poi). Table 1 shows the different treatments used for the experiment.

Table 1. Treatments and Abbreviations

Treatment	Symbol
Distilled water	C
Cattle dung only (300g) without earthworms	T1
Neem (25g)+ Rice straw (25g) + Bagasse (25g) + cattle dung (300 g) without earthworms	T2
Rice straw (75g) + cattle dung (300g) + earthworms (100 in number)	T3
Bagasse (75g) + cattle dung (300g) + earthworms (100 in number)	T4
Neem (75g) + cattle dung (300g) + earthworms (100 in number)	T5
Neem (37.5g) + Bagasse (37.5g) + cattle dung (300g) + earthworms (100 in number)	T6
Neem (37.5g) + Rice straw (37.5g) + cattle dung (300g) + earthworms (100 in number)	T7
Rice straw (37.5g) + Bagasse (37.5g) + cattle dung (300g) + earthworms (100 in	T8

number)

Neem (25g)+ Rice straw (25g) + Bagasse (25g)+ cattle dung (300g)+ earthworms (100 in number)

T9

Standardize hydroponic solution

H

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77 For each treatment collected, 500 ml was diluted with distilled water to five litres and used to
78 cultivate poi *Colocasia esculenta* (Australian poi) seedlings at three weeks old in a tray. Each
79 tray was drained manually at two weeks interval by carefully removing the plants and new
80 treatment of standard measurement was replaced. Initial and final solutions from all trays were
81 stored for analysis. Observations were recorded at weekly where growth parameters (shoot
82 length, number of leaves and number of nodes) were recorded. Three seedlings were placed in a
83 tray and supported by Styrofoam around the stems had sponge which allowed expansion during
84 growth. Styrofoam was used to keep the upper part of the seedling suspended in the treatments
85 while the roots were immersed. Three seedlings were placed in each tray and in duplicate giving
86 rise to twenty two trays for the nine treatments along with two trays containing distilled water
87 only and two more containing hydroponic solution. Final growth parameters (root length, fresh
88 and dry biomass) of the plants were recorded after six weeks. The Random Block Design
89 (R.B.D) was used for precision. Physico-chemical analysis of vermiwash (pH, Electrical
90 conductivity, organic carbon, nitrogen, phosphorous and potassium) were determined using
91 standard methods [9].

92 **Data analysis**

93 Data recorded were subjected to statistical tools like Student's t-test, ANOVA and LSD and
94 results were interpreted in the light of statistical justifications.

95 **3. RESULTS AND DISCUSSION**

96 **3.1 Shoot Length**

97 The results obtained showed that all the plants grown on vermiwash had significant shoot growth
98 (Table 2). The treatment with all combinations (neem, bagasse and rice straw) showed maximum
99 growth even above the commercial hydroponic treatment H. Other vermiwash treatment with
100 two combinations and with only one material had fairly constant shoot growth although they did

not exceeded treatments T9 and H respectively. The works of earthworms was proven very effective since the treatments without earthworms (T1 and T2) had poor growth of plants shoot length compared to the shoot of plants grown on vermiwash. The control treatment showed the minimum growth since nutrients were not available in sufficient quantity for the plants. The results are supported by ANOVA indicating significant impact of different treatments on shoot growth [$F_{cal} (4.17 \geq 2.03)$ for treatments and $F_{cal} (29.73 \geq 2.40)$ for time duration]. LSD analysis suggests that progression of growth is not significant in Control whereas all the other treatments show significant progression in terms of shoot growth. T-test analysis suggest that the growth in Control is not significant compared to all the other treatments. Studies show that earthworms' excreta provide plant growth hormones which promote growth and works as organic pesticides [10]. The casts of earthworm is one of the most useful and active agents in introducing changes by directly increasing the fertility and crop producing power in the soil [11].

Table 2. Shoot length over six the week period (mean $\pm$ SD) (cm)

Treatment	Weeks						Increase	t- test
	1	2	3	4	5	6		
T1	7.58 $\pm$ 0.46 ^a	7.98 $\pm$ 0.55 ^b	8.52 $\pm$ 0.37 ^c	8.88 $\pm$ 0.19 ^d	9.3 $\pm$ 0.19 ^e	9.70 $\pm$ 0.20 ^f	2.12	S
T2	7.67 $\pm$ 0.41 ^a	8.06 $\pm$ 0.32 ^b	8.28 $\pm$ 0.28 ^b	8.74 $\pm$ 0.21 ^c	9.06 $\pm$ 0.11 ^d	9.46 $\pm$ 0.11 ^e	1.79	S
T3	7.38 $\pm$ 0.39 ^a	7.76 $\pm$ 0.48 ^b	8.1 $\pm$ 0.59 ^c	8.94 $\pm$ 0.36 ^d	9.74 $\pm$ 0.31 ^e	10.34 $\pm$ 0.27 ^f	2.96	S
T4	8.05 $\pm$ 0.25 ^a	8.47 $\pm$ 0.14 ^b	8.71 $\pm$ 0.12 ^c	9.20 $\pm$ 0.17 ^d	10.0 $\pm$ 0.20 ^e	10.88 $\pm$ 0.30 ^f	2.83	S
T5	7.67 $\pm$ 0.35 ^a	7.97 $\pm$ 0.48 ^a	8.21 $\pm$ 0.66 ^a	9.17 $\pm$ 0.22 ^b	10.05 $\pm$ 0.13 ^c	10.8 $\pm$ 0.36 ^d	3.13	S
T6	7.42 $\pm$ 0.52 ^a	7.8 $\pm$ 0.59 ^b	8.25 $\pm$ 0.72 ^c	9.14 $\pm$ 0.36 ^d	10.1 $\pm$ 0.29 ^e	10.98 $\pm$ 0.19 ^f	3.56	S
T7	7.50 $\pm$ 0.33 ^a	8.03 $\pm$ 0.29 ^b	8.53 $\pm$ 0.37 ^c	9.28 $\pm$ 0.29 ^d	10.5 $\pm$ 0.69 ^e	11.75 $\pm$ 0.58 ^e	4.25	S

T8	7.33±0.53 ^a	7.6±0.62 ^a	8.12±0.84 ^b	9.55±0.54 ^c	9.97±0.29 ^c	11.07±0.46 ^c	3.74	S
T9	7.75±0.26 ^a	8.33±0.29 ^b	9.01±0.24 ^c	10.13±0.48 ^d	12.65±0.53 ^e	15.87±0.95 ^f	8.12	S
C	7.43±0.27 ^a	7.53±0.29 ^a	7.58±0.35 ^a	8.1±0.28 ^b	8.35±0.21 ^b	8.65±0.21 ^b	1.22	NS
H	7.53±0.38 ^a	7.85±0.54 ^b	8.26±0.84 ^c	9.45±0.24 ^d	12.82±0.99 ^e	14.75±0.48 ^f	7.22	S

115 **Confidence level 95%: S {Significant}, NS {Not Significant}**

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117 **3.2 No. of Leaves**

118 The combination treatment of vermiwash with all materials (T9) had maximum results for
119 number of leaves (Table 3). Although treatment T9 exceeded the others, there was fairly constant
120 growth for the other vermiwash treatment when compared to the commercial hydroponic
121 treatment (H) which was used. The leaf quality for the treatments without earthworms was poor
122 which again placed emphasis on the effectiveness of the vermiwash.

123

124 The results are supported by ANOVA indicating significant impact of different treatments on
125 number of leaves [$F_{cal} (8.89 \geq 2.03)$ for treatments and $F_{cal} (126.63 \geq 2.40)$ for time duration].
126 LSD analysis suggests that progression in number of leaves is not significant in Control whereas
127 all the other treatments show significant progression in terms of number of leaves. T-test analysis
128 suggest that the increase in number of leaves in Control is not significant compared to all the
129 other treatments. Plants grown on treatments T1, T2, H and C showed lots of leaf damage by leaf
130 miners (*Lepidoptera*) which fed on the leaf tissues. Both earthworms and its body liquid
131 (vermiwash) are scientifically proving as both 'growth promoters and protectors' for crop plants
132 [12].

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Table 3. No. of leaves over the six week period (Mean $\pm$ SD)

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Treatment	Weeks						Increase	t - test
	1	2	3	4	5	6		
T1	4.33 $\pm$ 0.82 ^a	5.5 $\pm$ 1.38 ^b	7.4 $\pm$ 0.55 ^c	7.80 $\pm$ 0.83 ^c	9.40 $\pm$ 0.55 ^d	10.2 $\pm$ 0.45 ^e	5.87	S
T2	4.33 $\pm$ 0.82 ^a	5.3 $\pm$ 0.52 ^b	6.33 $\pm$ 1.03 ^c	7.00 $\pm$ 0.70 ^c	8.80 $\pm$ 0.44 ^d	9.20 $\pm$ 0.45 ^e	4.87	S
T3	4.83 $\pm$ 0.75 ^a	5.67 $\pm$ 1.03 ^b	6.83 $\pm$ 1.60 ^c	8.8 $\pm$ 0.84 ^d	10.6 $\pm$ 0.89 ^e	13.00 $\pm$ 1.00 ^f	8.17	S
T4	5.00 $\pm$ 0.00 ^a	5.83 $\pm$ 0.75 ^b	7.33 $\pm$ 1.03 ^c	8.8 $\pm$ 1.30 ^d	11.67 $\pm$ 1.21 ^e	13.17 $\pm$ 1.47 ^f	8.17	S
T5	4.5 $\pm$ 0.55 ^a	5.33 $\pm$ 1.03 ^b	6.67 $\pm$ 1.86 ^c	10.25 $\pm$ 0.5 ^d	11.25 $\pm$ 0.95 ^e	13.5 $\pm$ 0.58 ^f	9.00	S
T6	4.67 $\pm$ 0.82 ^a	5.83 $\pm$ 0.98 ^b	7.33 $\pm$ 1.75 ^c	9.00 $\pm$ 1.87 ^d	11.4 $\pm$ 1.52 ^e	13.6 $\pm$ 1.67 ^f	8.93	S
T7	4.83 $\pm$ 0.75 ^a	6.00 $\pm$ 0.89 ^b	7.33 $\pm$ 1.37 ^c	10.0 $\pm$ 0.71 ^d	11.3 $\pm$ 1.21 ^e	13.5 $\pm$ 1.05 ^f	8.67	S
T8	4.83 $\pm$ 0.75 ^a	5.5 $\pm$ 1.22 ^b	6.8 $\pm$ 1.92 ^c	9.5 $\pm$ 0.58 ^d	11.75 $\pm$ 0.5 ^e	13.75 $\pm$ 0.96 ^f	8.92	S
T9	4.33 $\pm$ 0.52 ^a	6.67 $\pm$ 0.82 ^b	8.5 $\pm$ 1.05 ^c	10.8 $\pm$ 0.84 ^d	14.33 $\pm$ 1.21 ^e	16.33 $\pm$ 1.21 ^f	12.00	S
C	4.5 $\pm$ 0.54 ^a	4.67 $\pm$ 0.82 ^a	5.00 $\pm$ 0.89 ^a	6.50 $\pm$ 0.71 ^b	8.00 $\pm$ 0.00 ^c	8.50 $\pm$ 0.71 ^c	4.00	NS
H	5.3 $\pm$ 0.82 ^a	6.5 $\pm$ 1.22 ^b	7.00 $\pm$ 1.79 ^c	10.0 $\pm$ 0.82 ^d	12.75 $\pm$ 0.5 ^e	14.25 $\pm$ 1.5 ^f	8.95	S

141 **Confidence level 95%: S {Significant}, NS {Not Significant}**

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143 **3.3 No. of Nodes**

144 Similarly like the number of leaves and growth of shoot length, the number of nodes showed
 145 significant increase for the vermiwash treatment T9 (Table 4). The hydroponic treatment (H)
 146 showed a significant increase in the number of nodes also while the other vermiwash treatments
 147 (T6, T8) showed consistent number of nodes. Because of the readily available nutrients present

in the vermiwash, node increase was successful throughout the course of the experiment while the plants grown without the influence of earthworms showed poor results.

The results are supported by ANOVA indicating significant impact of different treatments on number of nodes [$F_{cal} (9.56 \geq 2.03)$ for treatments and $F_{cal} (106.81 \geq 2.40)$ for time duration]. LSD analysis suggests that progression in number of nodes is not significant in Control whereas all the other treatments show significant progression in terms of number of nodes. T-test analysis suggest that increase in number of nodes in Control is not significant compared to all the other treatments. Earthworms restore and improve vermiwash fertility and significantly boost crop productivity [12]. Throughout the experiment for the parameters that are being influenced by treatments of vermiwash of both combination and single treatment it can be highlighted that vermiwash are also enriched in certain metabolites and vitamins that belong to the B group or provitamin D which also help to enhance plant growth [13, 14].

Table 4. No. of nodes over the six weeks period (Mean $\pm$ SD)

Treatment	Weeks						Increase	t-test
	1	2	3	4	5	6		
T1	4.67 $\pm$ 1.03 ^a	6.83 $\pm$ 2.04 ^b	7.6 $\pm$ 0.89 ^b	9.00 $\pm$ 0.70 ^c	10.2 $\pm$ 0.55 ^d	10.2 $\pm$ 0.44 ^e	5.53	S
T2	4.67 $\pm$ 1.03 ^a	6.33 $\pm$ 1.03 ^b	6.5 $\pm$ 0.84 ^b	8.8 $\pm$ 0.45 ^c	9.00 $\pm$ 0.00 ^c	9.6 $\pm$ 1.34 ^c	4.93	S
T3	5.5 $\pm$ 0.84 ^a	7.33 $\pm$ 1.21 ^b	7.67 $\pm$ 1.03 ^b	10.2 $\pm$ 0.84 ^c	11.8 $\pm$ 1.48 ^d	13.00 $\pm$ 1.00 ^e	7.50	S
T4	5.67 $\pm$ 0.82 ^a	7.33 $\pm$ 1.02 ^b	7.83 $\pm$ 1.17 ^b	10 $\pm$ 1.41 ^c	11.67 $\pm$ 1.50 ^d	13.16 $\pm$ 1.47 ^e	7.49	S
T5	5.00 $\pm$ 0.00 ^a	6.67 $\pm$ 1.86 ^b	7.17 $\pm$ 2.32 ^b	10.5 $\pm$ 0.58 ^c	12.25 $\pm$ 0.5 ^d	14.25 $\pm$ 1.26 ^e	9.25	S
T6	5.33 $\pm$ 0.52 ^a	7.17 $\pm$ 1.47 ^b	7.67 $\pm$ 1.63 ^b	10.2 $\pm$ 0.84 ^c	11.6 $\pm$ 1.52 ^d	14.4 $\pm$ 1.95 ^e	9.07	S
T7	5.5 $\pm$ 0.84 ^a	7.00 $\pm$ 1.09 ^b	8.17 $\pm$ 1.17 ^c	10.3 $\pm$ 1.51 ^d	11.83 $\pm$ 0.98 ^e	13.83 $\pm$ 1.33 ^f	8.33	S

T8	5.17±0.75 ^a	6.50±1.87 ^b	7.8±1.64 ^c	10.75±0.96 ^d	12.5±0.58 ^e	14.75±1.5 ^f	9.58	S
T9	5.67±0.52 ^a	8.00±1.26 ^b	9.33±0.82 ^c	12±1.41 ^d	15.17±1.47 ^e	17.83±2.56 ^f	12.16	S
C	4.83±0.75 ^a	5.17±0.75 ^a	5.33±1.03 ^a	8.00±0.00 ^b	9.00±1.41 ^c	9.00±1.41 ^c	4.17	NS
H	5.83±0.91 ^a	7.00±1.79 ^b	7.67±2.16 ^c	11.25±0.5 ^d	14.5±1.29 ^e	16.75±0.96 ^f	10.92	S

Confidence level 95%: S {Significant}, NS {Not Significant}

3.4 Root Length

Plants grown on treatment T6 had the highest mean percentage increase while plants grown on treatments T8 followed by plants grown on T9, H and C had a significant increase in root growth also from initial to final where the control treatment C was not minimal for this parameter (Table 5). All treatments used in the experiment had a positive impact on root growth throughout the course of the experiment. There was significant root growth for all treatments except C. Even the plants that had poor leaves shoot and node growth showed significant root growth and this point out a major flow of nutrients going towards root growth. The increase in the growth of treated plants is because of the uptake of macro and micronutrients available [15]. T-test analysis suggest that increase in root length in Control is not significant compared to all the other treatments.

Table 5. Initial and final root length (Mean ±SD)

Treatment	Initial (cm)	Final (cm)	Increase	t-test
T1	3.10±0.65	34.06±5.81	30.96	S
T2	2.50±0.00	32.30±8.43	29.80	S
T3	2.80±0.45	55.08±21.5	52.28	S
T4	3.20±0.57	45.18±21.76	41.98	S
T5	2.70±0.27	61.85±16.49	59.15	S
T6	2.50±0.00	100.42±9.85	97.92	S
T7	2.80±0.27	69.48±19.13	66.68	S

T8	2.80±0.27	76.72±17.79	73.92	S
T9	2.90±0.22	58.40±25.58	55.50	S
C	2.90±0.65	45.75±21.28	42.75	NS
H	2.9±0.41	53.37±12.40	50.47	S

Confidence level 95%: S {Significant}, NS {Not Significant}

3.5 Chlorophyll Content

The reason which accounts for the variation in chlorophyll content random set up of plants using diffused sunlight and not direct sunlight. Light is critical for chlorophyll synthesis and because of the arrangement of the plants chlorophyll varied. However, the plants grown with vermiwash (T4) showed maximum chlorophyll content since nutrients available in vermiwash, contributed to healthier plants (Table 6). Studies revealed that 10% vermiwash has potential to be used in hydroponic culture and also exhibits superiority in growth as well as in content of photosynthetic pigments [16].

Table 6. Chlorophyll content (mg/g)

Treatment	Chlorophyll Content (mg/g)
T1	4.40
T2	2.70
T3	7.96
T4	9.57
T5	6.22
T6	6.89
T7	7.35
T8	8.16
T9	8.23
C	8.39
H	9.05

The results show that the plants grown on treatment H had poor quality due to very high moisture content (Table 7). Presently consumers no longer wish to utilize plants that have been saturated with fertilizers and pesticides and producers of agricultural products are being encouraged towards organic farming [17]. This theorem supports the theme for better quality crops and this experiment proves that most crops grown on vermiwash have maintained quality and quantity unlike the chemical treatment H used that provided quantity rather than a good quality crop.

Table 7. Percentage moisture (Mean $\pm$ SD)

Treatment	Fresh Weight (g)	Dry Weight (g)	% Moisture
T1	17.42 $\pm$ 3.53	8.49 $\pm$ 2.66	51.25
T2	13.55 $\pm$ 4.10	5.16 $\pm$ 2.94	61.94
T3	30.42 $\pm$ 7.05	16.14 $\pm$ 4.25	46.94
T4	19.79 $\pm$ 5.72	9.71 $\pm$ 4.21	50.96
T5	28.59 $\pm$ 9.09	15.93 $\pm$ 5.59	44.28
T6	24.73 $\pm$ 9.69	10.95 $\pm$ 6.53	55.72
T7	31.20 $\pm$ 9.13	17.36 $\pm$ 6.37	44.37
T8	24.53 $\pm$ 2.69	9.19 $\pm$ 1.08	62.56
T9	28.77 $\pm$ 6.09	15.93 $\pm$ 5.65	44.63
C	26.36 $\pm$ 8.52	10.62 $\pm$ 4.10	59.71
H	15.41 $\pm$ 1.63	5.06 $\pm$ 0.39	67.16

Table 8. Composite index based on plant growth parameters

Treatment	Shoot Length	Root Length	Number of Nodes	Number of Leaves	Chlorophyll	Moisture %	Total	Rank
T1	9	11	9	9	10	6	54	10
T2	10	6	10	10	11	3	50	9
T3	7	10	7	6	6	8	44	7
T4	8	9	8	8	1	7	41	6

T5	6	4	4	2	9	11	36	5
T6	5	1	5	3	8	5	27	3
T7	3	3	6	5	7	10	34	4
T8	4	2	3	4	5	2	20	1
T9	1	5	1	1	4	9	21	2
C	11	8	11	11	3	4	48	8
H	2	7	2	7	2	1	21	2

From the summary composite index (Table 8) of plant growth parameters, vermiwash showed excellent results because vermiwash improves fertility and boost crop productivity (Sinha, *et al.*, 2010). Based on 2- factor ANOVA conducted on the plant growth parameters of *Colocasia esculenta* (Australian Poi) grown in the experiment, there is a significant difference between the different treatments applied on the plant growth parameters investigated ($p \leq 0.05$). According to [2] and [10] earthworms improves physico-chemical and biological properties. The research revealed that vermiwash had favourable influence on yield parameters where high levels of bio-available nutrients in balanced form for plant can be readily obtained [10].

Table 9 below shows the nutrient status for the initial treatment given to the plants in study (*Colocasia esculenta*, *Australian poi*). Physico-chemical analysis of the vermiwash (T3, T4, T5, T6, T7, T8, and T9) shows an excellent content of the factors that contribute significantly to plant growth. Earthworms excreta (vermicast) is a nutritive ‘organic fertilizer’ rich in humus, NKP, micronutrients, beneficial soil microbes, nitrogen-fixing and phosphate solubilizing bacteria and growth hormones auxins, gibberlins and cytokinins [12].

Table 9. Physico-chemical analysis of vermiwash obtained from different sources

Treatment	pH	EC ($\mu\text{s/cm}$)	OC (%)	N (mg/l)	P(mg/l)	K(mg/l)
T1	6.22	1.87	0.20	2.90	2.36	64.61
T2	6.65	1.79	0.03	2.64	1.16	54.54
T3	7.20	7.64	0.02	3.04	0.95	254.90

T4	7.07	7.22	0.02	2.60	2.04	226.60
T5	7.30	7.71	0.03	3.96	0.91	239.20
T6	7.73	5.31	0.02	2.42	3.65	191.50
T7	7.00	5.32	0.04	4.66	0.76	208.20
T8	5.36	7.60	0.02	6.65	1.71	138.40
T9	7.22	6.48	0.03	4.59	0.96	215.30
C	6.77	0.11	0.01	4.79	0.40	3.51
H	6.5	0.98	0.03	11.2	1.08	58.00

Most of the elements pH values fluctuated around a neutral pH (7) while treatment T8 showed acidity. Electrical conductivity varied where the highest values was observed for vermiwash treatments. Organic Carbon, Phosphorus, Potassium and nitrogen varied for all treatments as the table clearly indicates that treatments of vermiwash had significant level of the physico-chemical properties investigated. The interesting fact about vermiwash is that it contains organic nitrogen that does not accumulate in food products unlike food grown on chemical fertilizers. Using vermiwash may significantly increase nitrogen content due to the presence of nitrogen fixing bacteria, which increase the nitrogen content of the soil [10, 13]. The vermiwash becomes alkaline because of high pH and micro-and macronutrients present in the vermiwash which may become essential source of nutrients that are easily available to the plants [12]. This concept sets a strong foundation for hydroponics because of the nutrient rich compounds and trace elements readily available for plants to thrive.

4. CONCLUSION

This research revealed that vermiwash is an effective treatment which can be used in hydroponics to grow plants. During this study, it was found that growth of plants using vermiwash had consistency with the growth parameters investigated. Some of the plants grown on vermiwash exceeded the growth parameters of plants grown on the commercial hydroponic solution and this indicates that organic treatment (vermiwash) maintained both quantity and quality being eco-friendly simultaneously. Also, plants grown on vermiwash exhibited resistance

to insect damage unlike plants grown on chemical treatment and treatment without earthworms. Use of vermiwash as feticide in growing plants would eliminate the use of chemical fertilizers that remains as residue in the environment. The physico-chemical properties of vermiwash had significant mineral content to support plant growth where necessary requirements (nitrogen, phosphorus and potassium) were present in significant quantities. Compared to the commercial hydroponic solution, most treatments of vermiwash showed a more significant composition of nutrients and elements available. Vermiwash was found to have outstanding properties which is an asset to organic agriculture and sets a strong foundation for hydroponics

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