EFFECTS OF COMBINED APPLICATION OF SELECTED FOOD WASTE AS BIO-FERTILIZER ON THE GROWTH OF *Capsicum annuum* L.

Nor Lailatul Wahidah Musa[1]*, Muhammad Halim Razali[1], Nur Thabitah Shaikh Nasir[1], Nurun Nadhirah Md Isa[1], Liliwirianis Nawi[1], Sarah Laila Mohd Jan[1]

[1]Faculty of Applied Sciences
Universiti Teknologi MARA Cawangan Pahang, 26400 Bandar Tun Abdul Razak Jengka, Pahang Malaysia

**Corresponding author: lailatul@uitm.edu.my*

Abstract

Excessive use of synthetic fertilizer will cause a lot of damage to the environment. Household waste products have been proposed to replace synthetic fertilizers and be recycled into safe fertilizers for sustainable agriculture. Therefore, this study was conducted to determine the effects of a combined application of selected food waste from onion waste (OW), coffee grounds (CG), and eggshell (ES) at various ratios on the morphological growth of *Capsicum annuum* L (chili). Seedlings of *C. annuum* were treated in three different ratios of treatment (Treatment A (3OW:2CG:1ES), Treatment B (2OW:3CG:1ES), and Treatment C (1OW:2CG:3ES) for eight weeks. The seedlings were also placed under NPK fertilizer (positive control) and without fertilizer (negative control) as a comparison. Measurements of plant growth (height, stem diameter, and number of leaves) were made at frequent intervals. Treatment A ratios enhanced the growth characteristics of *C. annuum* higher than the positive control (NPK fertilizer), with a significant increase observed particularly in the height and growth rate of the number of leaves ($p \leq 0.05$). Treatments B and C were also effective in increasing the growth of *C. annuum* plants, but not as effective as treatment A. However, seedlings under treatment A showed lower growth in diameter compared to the positive control (NPK fertilizer). These results unveiled the potential of food waste as a promising biofertilizer, but further research is needed to comprehensively increase all the growth parameters with the use of enhancers.

Keyword: Biofertilizer, height growth, diameter growth, *Capsicum annuum*

Introduction

Fertilizer is one of the methods that are important for boosting plant growth and crop yield since it contains various nutrients for plants. Synthetic fertilizer helps to increase nutrient delivery and availability for plant consumption, which is a fast approach to provide plants with the necessary macronutrients and micronutrients. Synthetic fertilizer is a chemical product composed of phosphate (P), nitrogen (N), and potassium (K) components (Anggraheni, 2019) that are essential for plant growth. The increase in the use of synthetic fertilizers at the end of the 19th century paved the way for modern agricultural production (Sabry, 2015), since this fertilizer offers fast-acting, soluble, and nutrient-uptake advantages for increased crop yields. The advantages of synthetic fertilizer are that it promotes quick plant growth. This is because the nutrients in chemical fertilizer are already water-soluble thus, the effect is usually rapid and quick, and it contains all the essential nutrients that are ready for usage (Roba, 2018). However, there are many long-term impacts that can be caused by synthetic fertilizers. Excessive use of these chemical synthetic fertilizers has caused serious nonpoint source pollution of farmland and issues with the quality and safety of agricultural production (He et al., 2020), as well as water pollution, especially when the farm's drainage system is not properly distributed (Nordin et al., 2022).

In order to reduce the dependency on synthetic fertilizers, most studies began to develop organic fertilizers from organic sources such as household waste, mostly food scraps and yard waste. According to a report by the United Nations Environment Programme (2021), in 2019, 931 million tonnes of food waste were produced globally, of which 61% came from households, 26% from food services, and 13% from retail. This includes fruit and vegetable peels, coffee grounds, eggshells, and other kitchen waste. The production of biofertilizers from household trash can reduce the requirement for chemical fertilizers and minimise waste disposal issues (Ajmal et al., 2018). As organic fertilizers are often bulkier than inorganic ones, they enhance soil quality and texture, enhance soil water retention, and lessen soil erosion (Shaji et al., 2021). Papastylianou et al. (2018) reported that coffee grounds are an excellent biofertilizer and waste reduction alternative since they can be utilised to enhance soil qualities and boost plant development. Meanwhile, Wozniak et al. (2019) also reported that crushed eggshells may efficiently release calcium and other minerals, thereby enhancing soil fertility and fostering plant development.

Capsicum is a flowering plant genus in the Solanaceae family. *Capsicum annuum* L. is a semi-perennial herbaceous plant that is typically grown as an annual crop around the world. In addition, *C. annuum* is an important horticulture crop that is recognised for its pungent variations (Arora et al., 2021), and it is one of the world's most cost-effective and agricultural vegetables (Karim et al., 2021). In Malaysia, chilli is a highly significant vegetable crop and is cultivated in many different areas with a wide range of variations. Since the desire to boost output has a good effect on agriculture, this chilli species was chosen as the research sample because of its high value in agriculture. Eggshells, spent coffee grounds, and onion peels have not yet found a suitable place in sustainable production but are mainly landfilled, burdening the environment. Combining different waste products will result in a biofertilizer with a more diversified and balanced nutritional profile, which is good for the general health and development of plants. In addition, different combination of household wastes would provide different enhancements to plantations. Mixing these three types of waste, which differ in their physical and chemical properties, into a homogeneous product can be an alternative for organic-mineral fertilizers intended for crops with high nutritional requirements. The present study aimed to determine the effect of different ratios of selected organic waste (onion waste, coffee grounds, and eggshell in different ratios) on the morphological growth of *Capsicum annuum*.

Materials and Methods

This study was conducted at the nursery in UiTM Cawangan Pahang from March to April 2023. The research was designed in a Randomized Block Design (RBD), with 4 replicates for each ratio and 3 replicates for each control (positive control – NPK 15 fertilizer application and negative control – without fertilizer application), and 3 treatments: Treatment A (3OW:2CG:1ES), Treatment B (2OW:3CG:1ES), and Treatment C (1OW:2CG:3ES) (**Table 1**). The ratio for every treatment was 1:10 grammes.

Table 1 The ratios of onion waste, coffee ground and eggshell used in treatment as biofertilizer

Treatment	Ratios Onion waste (OW)	Coffee ground (CG)	Eggshell (ES)	No. of samples
Treatment A	3	2	1	4
Treatment B	2	3	1	4
Treatment C	1	2	3	4
Positive control (NPK 15 fertilizer application)	NA	NA	NA	3
Negative control (without fertilizer application)	NA	NA	NA	3

Plant Materials, Growth Conditions and Experimental Design

Capsicum annuum seeds were germinated in a germination tray at a depth of 5 cm. The germination period takes place for 30 days. The one-month-old seedlings of *C. annuum* were then transferred from the germination trays into the polybags (24 cm x 24 cm) that were filled with planting medium and planted at 5 cm depth. The plants were watered with 300 ml of water per polybag and labelled in accordance with the applied combination ratio of the biofertilizer. The plants were put in a shaded place for 5 days and acclimatized. Then, the polybag was transferred to a place where it got sufficient light and covered with paranet to reduce excessive light intensity, prevent pest interference, and prevent rainwater from penetrating the planting medium excessively. Biofertilizer treatments in accordance with each treatment were supplied in powder form to facilitate the absorption of the fertilizers by the samples and gently mixed with soil. These treatments were applied once every three days. The treatment period was carried out for 8 weeks.

Observation on the Growth Parameters

Plant growth (n = 18) was assessed twice a week for 8 weeks by regular, non-destructive measurements. Plant height (cm) was measured from the collar to the apical meristem using a standard measuring tape, while stem diameter (mm) was measured with digital callipers 5 cm from the collar of the seedlings. The number of leaves was counted twice a week for each sample. Relative height growth rate (RHGR), stem basal diameter growth rate (SDGR), and leaf growth rate were calculated every week according to Hunt (2012). $RGR = (\ln_{W2} - \ln_{W1})/(t_2 - t_1)$ where week 1 ($_{W1}$) = the height /diameter at time t_1 and week 2 ($_{W2}$) = the height /diameter at time t_2. An analysis of variance (ANOVA) at $p \leq 0.05$ was used to consider significant differences in growth characteristics for the seedlings grown in each treatment. The ANOVA was performed using the SPSS program. Differences between means ± standard error (SE) of each parameter were examined by Tukey's studentized range test at $p \leq 0.05$.

Results and Discussion

The seedlings of *C. annuum* exhibited the greatest height, diameter, and number of leaves increments under Treatment A (3OW:2CG:1ES) compared to Treatment B (2OW:3CG:1ES) and Treatment C (1OW:2CG:3ES). At the end of treatment, the height of *C. annuum* under Treatment A was 65.0 cm, which is 21%, 28%, and 20%, respectively, higher compared to seedlings under Treatment B, Treatment C, and NPK fertilizer (positive control) ($p < 0.05$) (**Table 2**) (**Figure 1**). The Height Relative Growth Rate (HRGR) of *C. annuum* seedlings under Treatment A also exhibited a significant difference between treatments ($p < 0.005$) (**Table 2**), with the highest growth rate recorded at 1.58 cm cm^{-1} day^{-1} at week 3, which is 0.33 cm cm^{-1} day^{-1} higher than the highest growth rate of *C. annuum* recorded under NPK fertilizer (**Figure 2**). The highest growth rates recorded under Treatments B and C were 1.27 cm cm^{-1} day^{-1} and 1.00 cm cm^{-1} day^{-1}, respectively, at weeks 5 and 3. The RHGR pattern showed approximately the same upward trend for all treatments until it reached its highest peak in different weeks. Treatment A growth rate rapidly increased within the first 3 weeks, and the slope started to decline over the following weeks. The relationship between absolute growth and relative growth rate among the plant samples provided some of the most elementary information for these studies. This relationship helped in understanding the growth pattern and limitations of the height growth of the plant samples. Results for this height growth parameter indicated that, when compared to the other two ratios of the prepared biofertilizers, Treatment A (3OW:2CG:1ES) was the optimal combination ratio for enhancing height.

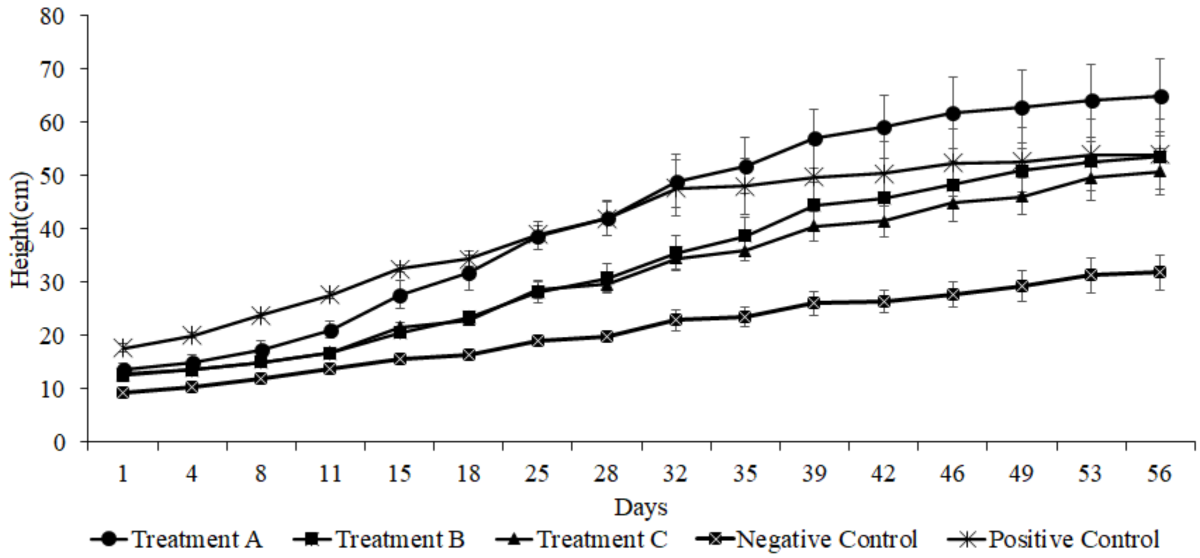

Figure 1 Absolute growth height of *C. annuum* (cm) on different treatments over 8 weeks of treatment

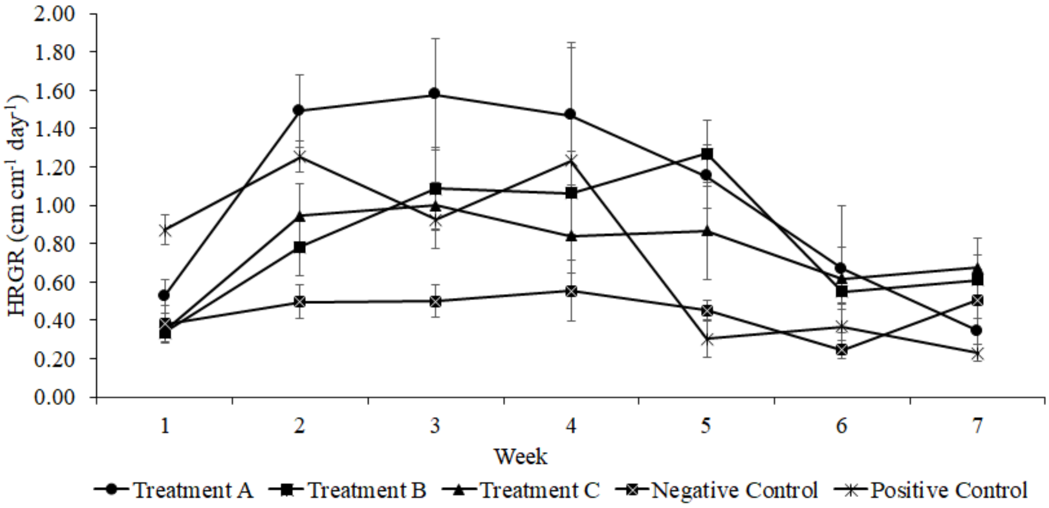

Figure 2 Weekly growth of relative difference in height of *C. annuum* during 8 weeks of treatment

The stem diameter of *C. annuum* under Treatment A after 8 weeks of treatment was 10.4 mm, which is 45% and 17% higher compared to plants under Treatment B and C, however, 18% lower compared to plants under NPK fertilizer application ($p < 0.05$) (**Table 2**) (**Figure 3**). The Diameter Relative Growth Rate (DRGR) of *C. annuum* was also statistically different ($p < 0.05$) (**Table 2**) from the ratio treatments. The highest recorded DRGR of *C. annuum* was under NPK fertilizer application which was 0.21 mm mm^{-1} day^{-1}, followed by Treatment A with 0.18 mm mm^{-1} day^{-1}, respectively, at weeks 7 and 4 (**Figure 4**). The highest stem diameter growth rate under Treatments B and C was 0.12 mm mm^{-1} day^{-1} and 0.14 mm mm^{-1} day^{-1} at weeks 5 and 3, respectively. The slope trends for DRGR under Treatment A declined after week 5, likely brought on by the plant samples beginning to blossom. According to Tepić et al. (2010), during the flowering stage, cell expansion was limited due to the allocation of nitrogen available for fruiting purposes. The fact that this treatment's growth rate was still higher than that of the other two prepared treatments suggests that this ratio combination is still the best one for promoting *C. annuum* growth.

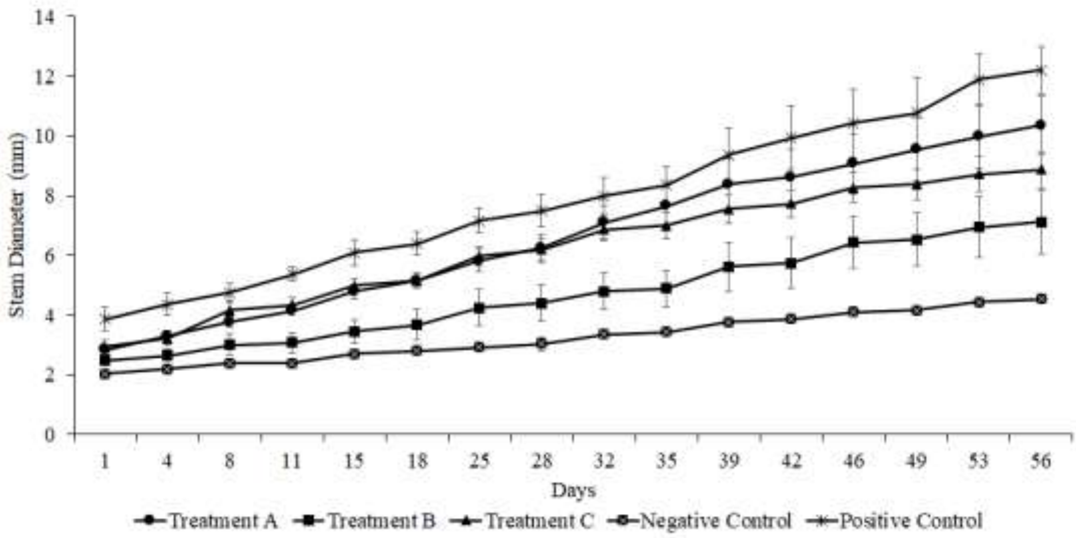

Figure 3 Absolute growth stem diameter of *C. annuum* (mm) on different treatments over 8 weeks of treatment

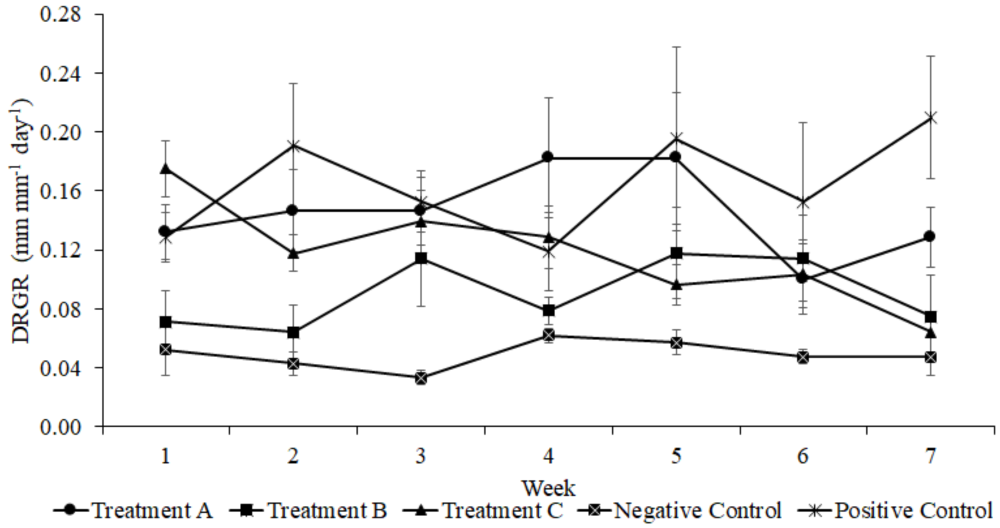

Figure 4 Weekly growth of relative difference in stem diameter of *C. annuum* during 8 weeks of treatment

Meanwhile, the number of leaves of *C. annuum* was also increased under Treatment A, with a total of 102 leaves after 8 weeks of treatment compared to Treatment B, Treatment C, and the positive control (NPK fertilizer) with 70, 81, and 92 leaves, respectively ($p < 0.05$) (**Table 2**) (**Figure 5**). In the 8 weeks of treatment, the Leaf Relative Growth Rate (LRGR) (**Figure 6**) showed a small increment from week 1 until week 3, followed by a sharp increase at weeks 4 and 5, and a continuous decrease in the RGR until the end of treatment. Plants under Treatments B and C showed the same RGR pattern, even though they did so at different week. The RGR for the number of leaves was the highest at week 5 under Treatment A, followed by the positive control (NPK fertilizer) at week 3, with a value of 2.82 no^{-1} day^{-1} and 2.48 no^{-1} day^{-1}, respectively. On the other hand, both Treatments B and C give the same highest value of LRGR, which is 1.89 no^{-1} day^{-1} at week 4. For this growth parameter, Treatment A still gives a higher production of leaves compared to the other treatments.

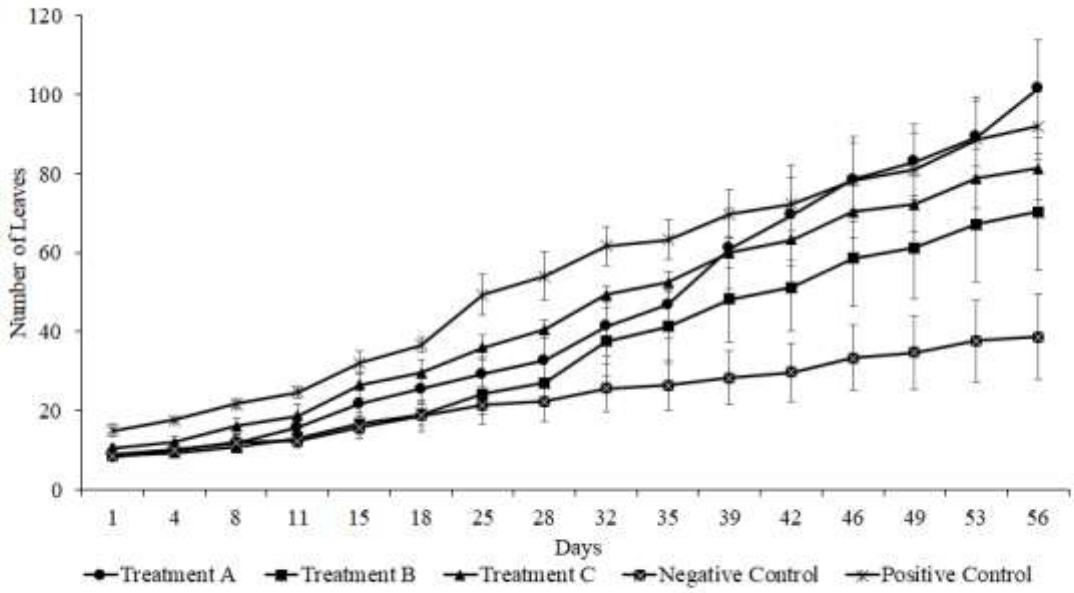

Figure 5 Absolute number of leaves growth of *C. annuum* on different treatments over 8 weeks of treatment

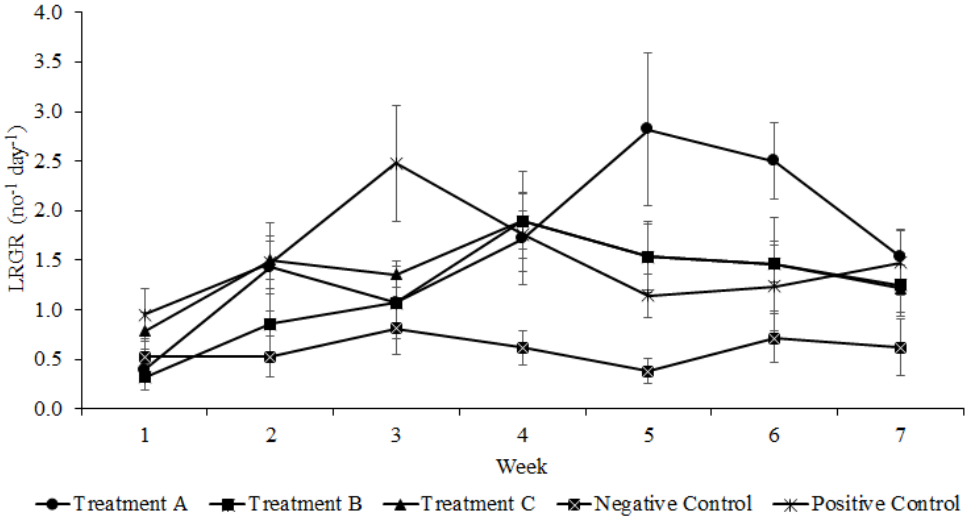

Figure 6 Weekly growth of relative difference in number of leaves of *C. annuum* during 8 weeks of treatment

Results of the analysis of variance showed that treatment A with a ratio of 3OW:2CG:1ES had a significant effect on the plant height, stem diameter, and number of leaf growth rate of *C. annuum* ($p < 0.05$) after 8 weeks of treatment compared to the other two designated treatments. The seedlings of *C. annuum* also exhibited the greatest growth increment in biomass under Treatment A compared to Treatments B and C. During the vegetative stage of *C. annuum*, the samples are actively growing the stems and need a high supply of nitrogen, phosphorus, and potassium. The designated ratio of Treatment A (3OW:2CG:1ES), which contains a high concentration of onion waste, could possibly contribute to this result. As reported by Arora and Dhaliwal (2019), onion waste contained a significant concentration of nitrogen, phosphate, potassium, calcium, magnesium, and sulphur which helped promote plant growth during the early growth phase. According to a study by Al-Aboudi et al. (2017), onion waste extract did affect the growth and production of chilli plants by significantly increasing their plant height, leaf area, and fruit output. Dananjana and Seran (2022) also reported that the high concentration of onion peel application on the cowpea plants had significantly increased the height and seed yield of these plants. When composted or used as fertilizer, onion waste may release nitrogen gradually, giving plants a consistent source of this essential mineral (Kader & Senge, 2017). According to Oliveira et al. (2022), applying the spent coffee ground to crops improves the vegetable nutritional content, enriches the soil, and speeds up plant growth. The higher availability of three macro-nutrients (nitrogen, phosphorus, and potassium) in fertilizers and their consumption can progressively enhance plant height (Sugiyanta & Kartika, 2018).

Table 2 Effects of treatments on absolute growth, relative growth rate (RGR), root length and biomass in *Capsicum annuum* L. after eight weeks of treatment

Characters	Treatment A	Treatment B	Treatment C	Positive control	Negative control
Height growth (cm)	42.5±2.5^{d}	33.2±1.9^{cb}	31.5±1.7^{b}	40.4±2.0^{cd}	20.9±1.1^{a}
HRGR cm cm^{-1} day^{-1}	1.03±0.12^{b}	0.81±0.08^{ab}	0.76±0.07^{ab}	0.74±0.12^{ab}	0.44±0.04^{a}
Diameter growth (mm)	5.56±0.30^{bc}	5.07±0.24^{b}	6.28±0.25^{c}	7.95±0.40^{d}	5.63±1.15^{a}
DRGR mm mm^{-1} day^{-1}	0.15±0.01^{cd}	0.09±0.00^{b}	0.12±0.00^{bc}	0.16±0.01^{d}	0.05±0.00^{a}
No. of leaf growth	45.4±4.1^{bc}	35.2±3.3^{ab}	45.3±3.2^{bc}	53.7±3.9^{c}	23.4±1.9^{a}
LRGR no^{-1} day^{-1}	1.64±0.21^{b}	1.20±0.14^{b}	1.39±0.11^{b}	1.50±0.15^{b}	0.60±0.08^{a}

The high number of leaves produced under Treatment A is in accordance with the report by Dananjana and Seran (2022), whereby onion peel had more potassium than other mineral nutrients, and potassium is required for the growth of cells, which may explain the increase in plant leaves. Lastly, the potassium element helps to build protein and carbohydrates as well as strengthen the plant, preventing leaves from coming off easily and providing strength to plants in the face of drought and disease (Anugrah & Safahi, 2021). On the other hand, the low stem diameter increments in Treatment A (3OW:2CG:1ES) were possibly influenced by the low concentration of eggshell compared to the high concentration of eggshell in Treatment C (1OW:2CG:3ES). According to Ganiger et al. (2013), an imbalance in the delivery of nutrients causes plants to experience changes in stem thickness as well as a variety of physiological and developmental problems..

Conclusion

Results of the analysis showed that Treatment A, which had a designated ratio of 3OW:2CG:1ES, did promote the growth of *Capsicum annuum* after 8 weeks of treatment, particularly on the plant height and growth rate of the number of leaves, compared to Treatment B (2OW:3CG:1ES), Treatment C (1OW:2CG:3ES), and the positive control (NPK fertilizer). However, Treatment A showed significantly lower growth in stem diameter than the positive control (NPK fertilizer).

Ethics Statement

The research does not require research ethics approval.

Authors Contribution

Writing – Original draft preparation, Mohd Halim Razali; Literature Review, Nur Thabitah Shaikh Nasir and Liliwirianis Nawi; Methodology, Nurun Nadhirah Md Isa and Sarah Laila Mohd Jan, Writing – Review and editing, Nor Lailatul Wahidah Musa.

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Conflict of interests

The author(s) confirm that this article content has no conflicts of interest.

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