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Effects of Eggshells as Organic Fertilizer on Growth of *Brassica juncea* (Mustard Green)

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ABSTRACT

Eggshell can be very useful as an organic fertilizer in agricultural practices as the main substance found in eggshells are calcium carbonate as well as other micronutrients which might enhance plant growth. The aim of this study was to evaluate the effects of different amounts of eggshells application toward *Brassica juncea* growth. There were 5 treatments with 3 replicates arranged in a completely randomized design (CRD) where treatments are arranged as T1 (control) without eggshell, 1 g of eggshell (T2), 5 g of eggshell (T3), 10 g of eggshell (T4) and 15 g of eggshell (T5) application. Results showed significant differences in crop growth with 11-36% increase in height, 11-70% increase in number of leaves and 26-171% increase in leaves when compared with control, where the most pronounced growth was observed in T5 (15 g of eggshell application). Significant increase was also observed in clay loam soil pH from pH 5.5 to pH 7.52 (T5) and 12-75% increase calcium content in soil but no significant difference was found in plant nutrient contents among treatments. It can be concluded that the addition of eggshells may improve the growth of *Brassica juncea* as well as soil pH and available calcium content.

Keywords: Brassica juncea, calcium, eggshell, growth, nutrient content, soil pH

INTRODUCTION

Fruits and vegetables are the commodity with high commercial value and have many benefits where vegetables are an important crop dietary component in supplying vitamins and fibres. *Brassica juncea*, from family of Brassicaceae commonly known as mustard green, brown mustard and Chinese mustard is originated from India. This species is a fast-growing vegetable rich in many nutritional compounds including

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antioxidants, proteins and minerals. Imported leafy vegetables prices specifically Brassica are still high even after COVID-19 pandemic had subsided where the price has risen up to 30% and 40% (Tan, 2021) from RM3.00 to RM9.00 due to the escalating costs of agricultural inputs, labour shortage, and irregular weather in Malaysia. Such price increment is also due to the production being lower than its consumption (Federal Agricultural Marketing Authority, 2021) leading to imports of Brassica to meet the demand. Hence, increasing the local production while lowering their imports is therefore perceived as a way to alleviate the deficiency of such vegetable supplies.

Hence, the high demand for *Brassica juncea* in the market urges farmers to make extensive attempts in increasing the supply of these vegetables, and generally this is done with higher fertilizer application rates that may be harmful for environment and ecosystem (Najarian et al., 2021). Currently, it is very much recommended to apply organic fertilizers instead of inorganic fertilizers due to the negative impact of inorganic fertilizers (Brankov et al., 2020). Various types of organic waste materials can be used as organic fertilizers such as the undervalued form of household waste, the eggshell (Anugrah et al., 2021).

Each day, huge quantities of eggshells are thrown away as organic waste globally. Eggshell waste disposal contributes to environmental problems where the smell of eggshells provides a site for flies and abrasiveness (Gaonkar & Chakraborty, 2016). As much as 250,000 tons of eggshell wastes are produced annually around the world (Verma et al., 2017). At the same time, the total consumption of eggs by Malaysians is 295 eggs per year, which is the highest rate among Asian countries as eggs are used in many recipes in Malaysia. Most of eggshell consist of calcium carbonate, a common form of calcium while the remaining comprised of proteins as well as other minerals. Moreover, as much as 95-97% of calcium carbonate are in the form of crystals, which are stabilized by the protein matrix inside the eggshell (Haroon et al., 2015). Although most eggshells are made of calcium carbonate, it is assumed that the protein matrix plays an integral role in egg strength. As eggshells contain calcium and other micronutrients, they are the most promising organic source of calcium where 90% of the nutrient is much easier to be absorbed than limestone or other coral sources (Radha & Karthikeyan, 2019). Eggshell contain healthy and balanced calcium attributed to the trace amount of other minerals simultaneously providing an important source of calcium for growing crops while at the same time also able to deter certain pests without the need for chemicals (Karne et al., 2023) since it consists of up to 93% calcium carbonate and other trace elements which make it an excellent source of organic fertilizer (Radha & Karthikeyan, 2019). Henceforth, this research was conducted to study the effects of different amounts of eggshells as an organic fertilizer on growth of *Brassica juncea* while reducing the organic wastes and promoting sustainable environmental and agricultural practices.

MATERIALS AND METHODS

Preparation of Experimental Materials

The experiment was performed in a greenhouse situated in the Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA, Jasin campus, Malacca, Malaysia (2°13'44.9"N 102°27'20.8"E). The cultivation of *Brassica juncea* took about 2 months from October 2023 until November 2023. As much as fifteen (15) healthy seeds of *Brassica juncea* of uniform in size were sown in a transplanting tray filled with peat moss and watered twice per day. The seedlings were then transplanted with one seedling per polybag when two sets of leaves had developed which was about 14 days after sowing into polybags of size 14 inch × 14 inch. The polybags were filled with topsoil taken at a nearby field in the faculty at 0–15 cm depth of a clay loam texture from Malacca series (Typic Hapludox). As much as 10 kg of topsoil were filled in each of the polybags. The watering was done manually which was provided twice per day in the morning and evening (1 L/ polybag). On the other hand, as much as 3 kg of fresh eggshells were collected, washed, and dried. Then, the eggshells were grinded to a fine powder in a mixer grinder.

Treatment Application

Each seedling was applied with 5 g NPK Green (15:15:15) at every selected period (21 DAS and 30 DAS) while the powdered eggshell treatments were surface-applied on a bi-weekly basis (8 DAS, 21 DAS, 35 DAS and 50 DAS) for 8 weeks of growth according to the treatments shown in Table 1.

Table1
Treatments used in the study

Treatment	Description
T1	Without eggshell + 5 g NPK green fertilizer per polybag
T2	1 g eggshell + 5 g NPK green fertilizer per polybag
T3	5 g eggshell + 5 g NPK green fertilizer per polybag
T4	10 g eggshell + 5 g NPK green fertilizer per polybag
T5	15 g eggshell + 5 g NPK green fertilizer per polybag

Experimental Design and Layout

This experiment followed a completely randomized (CRD) design with a total of 15 experimental units consisting of 5 treatments with 3 replications. CRD was chosen as a design for this study since the microclimate in the greenhouse was constant throughout the area where relative humidity was 80%, temperature throughout the greenhouse was 34 °C in the afternoon, sunshine was more than 5.5 hours/day with more than 17 MJ per sq m per day, while mean wind speed was measured at about 10 m/sec.

Data Collection

The plants were grown for 8 weeks (56 DAS) where during harvest, the *Brassica juncea* plants were measured in terms of plant height, number of leaves, width of leaves, soil pH, as well as soil and plant nutrient analysis. Plant height was measured from the collar of the plant at the surface of the topsoil up to the highest tip of the plant by using a measuring tape while the number of leaves per plant was measured by only counting fully open true leaves. The width of leaves was measured by determining at the widest point perpendicular to the longitudinal axis of the leaf. Soil pH was measured using a pH meter at a 1:2.5 soil-to-solution ratio (Enio et al., 2021). For soil nutrient analysis, available calcium, magnesium, and potassium were determined using ammonium acetate (NH_4OAc) (Reeza et al., 2021) while available phosphorus was determined using the method of Bray-2 (Bray & Kurtz, 1945). For plant nutrient analysis, the dry ashing method was employed (Sahrawat et al., 2002).

Statistical Analysis

Analysis of variance (ANOVA) was used to test significant differences between treatments using statistical package for social science (SPSS) (version 21) software while means of the treatments were compared using Tukey's test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Crop Morpho-Physiological Traits

The height of *Brassica juncea* at 56 DAS (at harvest) significantly increased with the increasing amount of eggshell applied, where T5 with 15 g of eggshell was significantly the highest in height with increment of 36% more compared to control (T1) as displayed in Figure 1. Similar results were also found by Anugrah et al. (2021) and Casinillo et al. (2024) where the height significantly increased as the amount of eggshells applied increased. This might be attributed by the high calcium content in eggshells which is known to trigger the establishment of seed and root hairs as well as strengthening the stems resulting in stem elongation produced from repeated cell divisions. Hence, the subsequent elongation of cells produced by the apical and intercalary meristems from shoot apical meristem (Wang & Li, 2008) thus increase the plant height. Therefore, it can be deduced that the application of eggshells may have affect the height of *Brassica juncea*.

Similar to the results in plant height, the number of leaves significantly increased as treatments were increased (Figure 2) where T5 had the maximum number of leaves with an increase up to 70% compared to control in T1 (no eggshells) which significantly had the least number of leaves. According to Saragih et al. (2016), the constitution of the eggshell comprises of 97% calcium carbonate, 3% magnesium and 3% phosphorus alongside with traces of sodium, potassium, zinc, manganese, iron, and copper. The added macro and

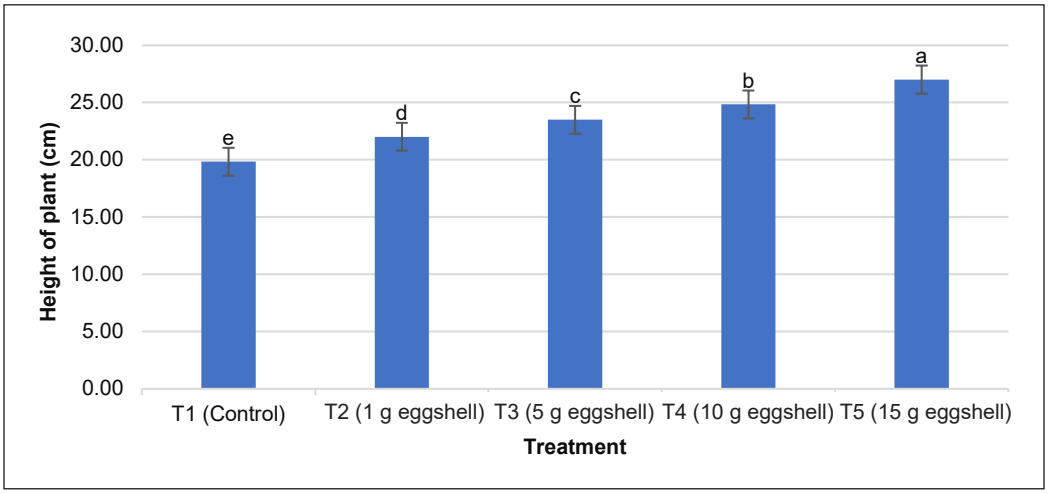

Figure 1. Mean of height of *Brassica juncea* at harvest (56 DAS). Different letters in a column is significantly different according to Tukey's test ($p \leq 0.05$)

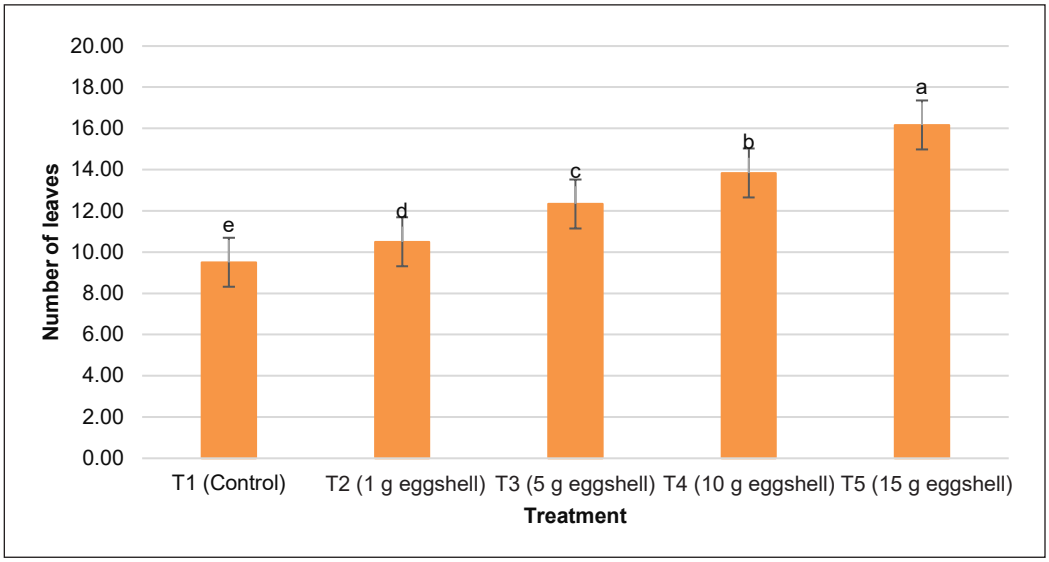

Figure 2. Mean number of leaves in *Brassica juncea* at harvest (56 DAS). Different letters in a column is significantly different according to Tukey's test ($p \leq 0.05$)

micronutrients may have contributed to increasing stem elongation as well as the number of leaves. This result is also consistent with other reports (Muyassir et al., 2022; Radha & Kartikeyan, 2019) whereby higher amounts of eggshells increase the number of leaves in *Brassica juncea* and *Phaseolus vulgaris*.

Figure 3 showed that the width of leaves significantly increased with the increasing amount of eggshells applied with increment from 26% (T2) up to 171% in T5. Such

observation is similar with the previous parameters of plant height and number of leaves in *Brassica juncea*. The width of leaves for *Brassica juncea* showed that T5 significantly had the highest width while T1 significantly had the lowest width of leaves. Similar finding was also reported by Radha and Kartikeyan (2019) where the leaf area as well as chlorophyll content, free amino acid, total protein content and total phenol increased with higher amounts of eggshells applied in cowpea (*Phaseolus vulgaris*). Studies have shown that calcium supports chlorophyll content indirectly by contributing to structural integrity, enzymatic function, and membrane stability, all of which are crucial for chlorophyll production and maintenance (Guo et al., 2023). Calcium is also an essential co-factor for several enzymes involved in the metabolism of amino acids. For instance, enzymes like *glutamate dehydrogenase* (important for amino acid synthesis) require calcium to function properly (Plaitakis et al., 2017). Adequate calcium levels can enhance the activity of these enzymes, leading to increased synthesis of amino acids, which are building blocks for proteins (Hildebrandt et al., 2015). Calcium is also involved in protein synthesis by regulating the function of ribosomes and other components of the protein synthesis machinery in the cell. It helps stabilize the structure of ribosomal subunits and influences the translation process (Schwarz & Blower, 2016). Therefore, it can be postulated that as calcium is increased, this will help plants improve on structural and enzymatic function, increasing chlorophyll content, producing enzymes important for amino acids formation and thus increasing proteins and leaf size as well. It can be deduced that the application of eggshells may be able to improve the vegetative growth by enhancing the height, number and width of the leaves of vegetables particularly *Brassica juncea*.

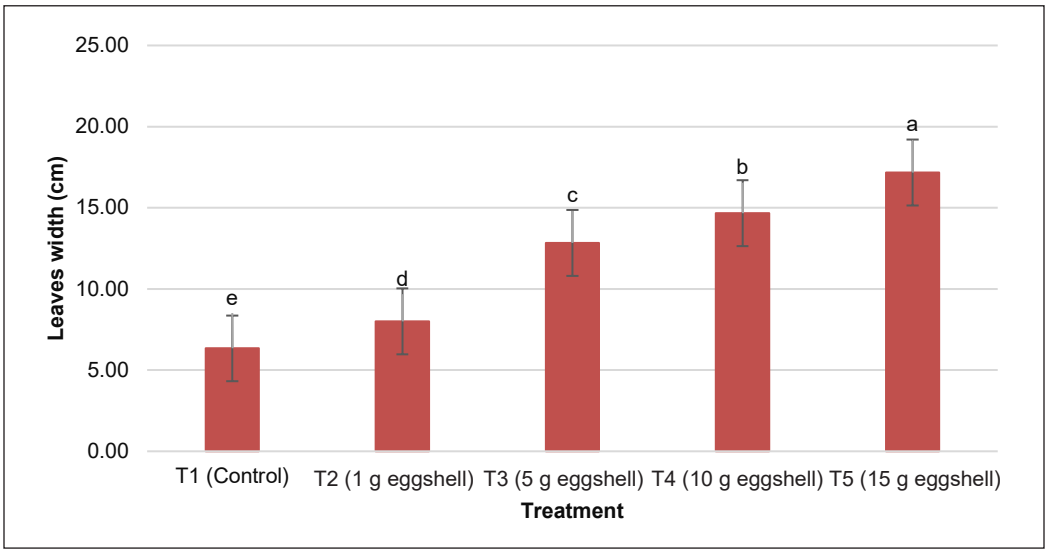

Figure 3. Mean width of leaves in *Brassica juncea* at harvest (56 DAS). Different letters in a column is significantly different according to Tukey's test ($p \leq 0.05$)

Soil pH

Significant difference in soil pH was observed in eggshell treatments as compared to control as displayed in Figure 4. The lowest soil pH was recorded at pH 5.5 for T1 whereas T5 recorded pH of 7.52 which was the highest soil pH compared to other treatments. Such increment up to 36% from the initial pH of 5.5 might be attributed to the enrichment of soil with calcium carbonate and others mineral and nutrients presence in eggshell since eggshells contain considerable amount of calcium carbonate ($CaCO_3$) which can act as an alternative to lime attributed to their high calcium content which able to neutralize the pH of acidic soils (King'Ori, 2011; Wang et al., 2023). It is well-established fact that soil pH of 6.5-7.5 is one of the good characteristics of a fertile soil having optimum physical, chemical and biological properties where all types of crops can be grown. Hence, the use of eggshell was useful in increasing soil pH from an acidic pH to neutral pH.

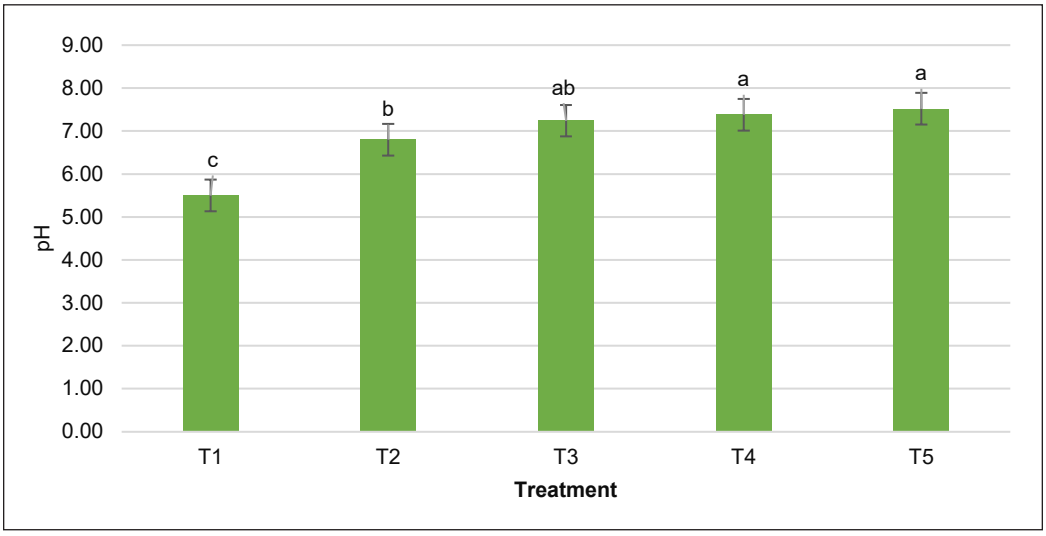

Figure 4. Mean soil pH planted with *Brassica juncea* at harvest (56 DAS). Different letters in a column is significantly different according to Tukey's test ($p \leq 0.05$) for treatments T1 (control), T2 (1 g eggshell), T3 (5 g eggshell), T4 (10 g eggshell), T5 (15 g eggshell)

Soil Nutrient Analysis

The means for soil nutrient analysis particularly phosphorus, potassium, calcium and magnesium are shown in Table 2. It was found that the calcium content was significantly the highest nutrient content, followed by phosphorus, potassium while the least was magnesium. The highest calcium content available in the soil was 3,429 mg kg^{-1} found in T5 at 15 g of eggshell application. This is to show that the application of eggshells might have contributed to the increase in available calcium in the soil. Such finding is

Table 2
Soil nutrient (P, K, Ca and Mg) at harvest (56 DAS)

Treatment	Soil available nutrient (mg kg^{-1})			
	P	K	Ca	Mg
T1(control)	814_{a}	723.9_{a}	1955_{c}	432.3_{b}
T2 (1 g eggshell)	711.43_{b}	517.2_{b}	2194_{b}	391.4_{c}
T3 (5 g eggshell)	559.4_{cd}	422.67_{c}	1875_{c}	297.27_{d}
T4 (10 g eggshell)	600.63_{c}	341.3_{d}	1585_{d}	251.23_{d}
T5 (15 g eggshell)	746.67_{b}	550.27_{b}	3429_{a}	550_{a}

Note. Different subscript within a particular nutrient (column) indicate significant difference between treatments

consistent with the report by Vu et al. (2022) whereby application of eggshells onto the soil affected pH and Ca content of the soil, where higher soil Ca was observed in higher eggshell powder rates. It can be deduced that eggshells can be a good alternative source for liming in alleviating soil acidity.

Plant Nutrient Analysis

Table 3 exhibit the mean leaf tissue nutrient analysis between treatments at harvest (56 DAS). Interestingly, only K content in *Brassica juncea* was found to be significantly different between treatments while no significant differences were found in P, Ca and Mg content in leaf tissue despite the additional increase of calcium content in the soil due to the application of the eggshells. It was also found that K is the highest nutrient content (3.3-4.0%) absorbed by the plant compared to the other nutrient (0.2-1.6%) where T1 recorded the highest K content in plant tissue (4.084 %) compared to other treatments (3.3-3.5 %). Studies done by Reeza et al. (2023) justified that plants will absorb nutrients that are needed for their growth and not according to the abundance of that particular nutrient in the soil. As such, several reports found that potassium is being highly absorbed by plants

Table 3
Leaf nutrient content (P, K, Ca and Mg) at harvest (56 DAS)

Treatment	Soil available nutrient (%)			
	P	K	Ca	Mg
T1	0.83_{ns}	4.084_{a}	1.468_{ns}	0.394_{ns}
T2	0.8372_{ns}	3.401_{b}	1.527_{ns}	0.380_{ns}
T3	0.756_{ns}	3.405_{b}	1.603_{ns}	0.355_{ns}
T4	0.6462_{ns}	3.521_{b}	1.469_{ns}	0.341_{ns}
T5	0.6016_{ns}	3.320_{b}	1.152_{ns}	0.270_{ns}

Note. Different subscript within a particular nutrient (column) indicate significant difference between treatments. ns= non-significant

compared to other nutrients (Han et al., 2016; Reeza et al., 2023; Vimala et al., 2010). In contrast, magnesium was found to be the lowest nutrient taken up by the plant regardless of the amounts of treatments applied, a similar finding in the aforementioned soil nutrient analysis. Overall, it can be deduced that the application of eggshells had no significant effect on plant nutrient content in *Brassica juncea* except K content.

Absorption of Calcium from Eggshells into Plant Tissue

The form of Ca in eggshell is in $CaCO_3$ which is not readily-available for plant uptake whereby plants absorb Ca^{2+} from the soil solution since mass flow and root interception are the principal mechanisms of Ca transport to root surface. According to Ertürk (2020), the $CaCO_3$ in eggshell needs to be decomposed and converted to Ca which is available prior to plant uptake. This implies that the form of Ca is crucial for plant nutrient uptake. By utilizing crushed eggshells, the calcium content in the soil can be enhanced along with other nutrients found in the eggshell (Faridi & Arabhosseini, 2018; Silveira et al., 2016; Taylor & Locascio, 2004;). Moreover, the benefits of using crushed eggshells is that it requires little energy for preparation, but the drawback is that it requires time for eggshell degradation and decomposition in order to provide nutrients to the plant (Mitchell, 2005; Rai et al., 2014). However, this can be alleviated by introducing liquid and foliar form or tea fertilizer.

CONCLUSION

The study confirmed that different amounts of eggshells application can affect the growth of *Brassica juncea* (green mustard) by improving plant height, number of leaves and leaves width. The application of eggshells also increased soil pH up to 36% from the initial soil pH and increased soil calcium content. However, it did not affect the majority nutrient content in the plant. Also, eggshell indeed contains macronutrient and micronutrient that are essential for plant growth. Hence, household waste such as eggshells should be used as an organic liming material and organic fertilizer to increase soil pH and the growth of crops. Further research is warranted to explore optimal timing and method of application eggshells to maximize its benefits in Brassica species.

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