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Research article

Effects of Different Potting Media on the Growth of Commercial Cacti

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Abstract: This research aims to study the appropriate growing media for the growth of cacti that can reduce production costs and promote cacti's growth. The research used four genera of cacti, i.e., *Gymnocalycium*, *Astrophytum*, *Mammillaria*, and *Echinopsis*, which were famous in the commercial market in Thailand. The experimental design was completely randomized designs (CRD) with four different growing media and three replications; T1) fermented rain tree leaves (FRTL): perlite: vermiculite: pumice: vermicompost as a control, T2) FRTL: rice husk: coconut coir: charcoal: vermicompost, T3) FRTL: rice husk ash: coconut husks chips: expanded clay: vermicompost and T4) rice husk ash: vermicompost. The plant was cultivated the plastic pot 2-inches and collected the growth for six months. The result showed that *Mammillaria* was planted in Treatment 3 gave the greatest stem diameter and the number of roots. A similar increase in stem diameter of *Echinopsis* and *Gymnocalycium* had the newest areoles. While planted in T4, as a result, the genus *Astrophytum* has increased in stem diameter, the number of new areoles, and the number of roots. In the *Gymnocalycium* also found an increase in stem diameter. Therefore, the use of cacti growing media in T3 as an appropriate for the growth of cacti. Furthermore, it can reduce the production cost of growing media about 0.72 baht per pot (33%) when compared with the commercial media (T1) in a 2-inches plastic pot.

Keywords: Cacti; Growing media; Plant growth

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1. Introduction

The cactus is a plant belonging to the family Cactaceae [1]. It is a plant that is native to the desert [2]. Cacti are slow-growing plants. The stems are succulent. Therefore, it can grow in arid places and is commonly grown as an ornamental plant. Because there flowers, stems and spines. They are unique, such as arborescent, shrubby, or creeping with a woody or succulent stem. The latter may be globular, cylindrical, or columnar [3]. Cactus spines produce by specialized structures called areoles. Areoles are an identifying feature of cacti. In addition to spines, areoles produce new flowers. Cactus flowers are beautiful and, depending on the species, are diverse in size, number, form, and color[4-6]. Thailand began to cultivate before the year 1954 with imports from abroad. Later, Thailand developed a species. Therefore, cultivation is increasingly popular [7].

Cactus needs a suitable rooting atmosphere for better growth. While traditional soils are often the problem, especially producing cacti of poor aeration and drainage. Cactus growers must find growing media suitable for

growing cacti. The optimal growing media used to produce cacti should have four basic functions: air space and water, which affect root growth and the integrity of the stem and create adequate nutrient reservoirs [8]. Now various organic ingredients like coconut coir, coconut husks chips, vermicompost, rice husk ash, rice husk are being utilized for the cactus grower and commercial purposes. Similarly the mineral potting substrates/ inorganic such as vermiculite, expanded clay, and pumice. Several studies support that soilless media management affects plant's growth and development [9]. In this case, the cactus should be grown in porous media, so that the plant media's aeration, drainage, and water-holding capacity ensure proper growth [10]. The epidemic situation of COVID-19 causing people to work from home and have more free time, so people are interested in growing more cacti [11], At the same time, cactus also has the shape, size, and ease of cactus cultivation. As a result, people are interested in growing cacti. [12]. The popular genus of cacti are *Gymnocalycium*, *Astrophytum*, *Mammillaria*, and *Echinopsis* [13].

Nowadays, there are many people who are interested in growing cacti. But the planting materials that farmers use are expensive. Causing cactus growers to find alternative materials to reduce production costs. By choosing materials that have similar properties to the materials used and that there are enough nutrients to meet the needs of the cactus. To be suitable for the growth of cacti and reduce the cost of cactus production.

2. Materials and Methods

2.1 Study area and media preparation

All experiments were actualized under plastic greenhouse conditions with 50% net shading with a temperature of 30 °C, and a light intensity of 11,530 LUX in Chonburi, Thailand. Plants were cultivated between March 2022 to September 2022. The experiment was arranged in a completely randomized design (CRD) and replicated three times with four pots per replication. The growing media included four treatments as follows: T1) fermented rain tree leave (FRTL): perlite: vermiculite: pumice: vermicompost (1: 1: 1: 1: 1) as a control, T2) FRTL: rice husk: coconut coir: charcoal: vermicompost (1: 1: 1: 1: 1), T3) FRTL: rice husk ash: coconut husks chips: expanded clay: vermicompost (1: 1: 1: 1: 1), T4) rice husk ash: vermicompost (1: 2). The planting materials in each treatment were mixed by volume. During the experiment, the cacti were not fertilized.

2.2 Plant preparation

The 6-month-old cacti seedlings were used in the experiment. The diameter size of the cacti were as follows: *Gymnocalycium* was in the size range of 1.13 – 1.93 cm and *Astrophytum* was in the size range of 0.96 – 1.55 cm, *Echinopsis* was in the size range of 1.71 – 2.94 cm, and *Mammillaria* was in the size range of 1.13 – 1.83 cm. These were planted in 2-inch plastic pots using different growing media. During the experiment, 40 ml of water was watered every 3 days and no cactus fertilization was performed during the whole experiment.

2.3 Growing media analysis

The chemical and physical properties of growing media were analyzed before and after at 6 months of planting in 4 genera of cacti. A 250 g of growing media was saturated with distilled water and stood for an hour before measured pH and electrical conductivity. The saturation extract's electrical conductivity (EC) was measured using a portable electrical conductivity meter (220 pH/EC meter). The pH of growing media was recorded by Orion research digital pH/millivolt meter with a glass electrode using buffers of pH 4.0 and 9.0 for standardizing the instrument. Growing media on physical properties were analyzed followed by the methods of Spomer [14]. The total porosity, bulk density and growing media moisture were calculated by the formula: Bulk density (g/cm^3) = (weight of pot and growing media – weight of pot)/pot volume. Total porosity (%) = {(weight of pot and growing media saturated with water – weight of pot and growing media) × 100}/pot volume. Growing media moisture (%) = (weight of water/weight of dry growing media) × 100.

2.4 Plant growth analysis and Statistical analysis

All growth parameters of the four genera of cacti were determined at 6 months after planting and were as follows: stem diameter, number of new areoles, number of roots, and root length. The collected data

were analyzed according to the completely randomized designs by Statistix 8 program, and the mean was compared by the Least Significant Difference Test (LSD) at 95%.

3. Results and Discussion

3.1 Results

3.1.1 Properties of planting material and production costs

pH value: The pH value of the growing media before planting was statistically significant difference. The mixed material in T2 had the highest pH at 7.85, while T1 had the lowest pH (7.55). After six months of planting, it was found that in the genus *Gymnocalycium*, pH values were statistically different. It was found T2 had the highest pH values at 7.85 (Table 2), while T1 had the lowest pH (7.53). In the genus *Astrophytum*, the pH of all growing media decreased when compared with before planting and was statistically different. T3 had the highest pH at 7.38, while T4 had the lowest pH (6.84). In the genus *Echinopsis*, the pH was statistically different. T3 had the highest pH at 7.63, while T4 had the lowest pH (7.19). However, the pH value was not statistically different in the genus *Mammillaria* (7.64-7.78).

Electrical Conductivity: EC (mS/cm): EC of the growing media before planting was a statistically significant difference (Table 1). The mixed material in T2 was the highest (1.02 mS/cm), while T3 had the lowest (0.54 mS/cm). After six months of planting, it was found that EC in growing media of all four genera of cacti decreased when compared with before planting. However, it showed no statistically different results. In the genus *Gymnocalycium*, the EC value was the phase of 0.51 - 0.69 mS/cm, and 0.45 - 0.54 mS/cm in the genus *Astrophytum.* The EC was in the range of 0.44 - 0.71 mS/cm in the genus *Mammillaria*, and 0.51 - 0.64 mS/cm in the genus *Echinopsis* (Table 2).

Growing media Moisture (percentage by weight): Growing media moisture of planting material before planting found that T1 and T4 had the lowest moisture content at 39.41 and 40.62 %, respectively (Table 1). After six months of planting, it was found that in the genus *Gymnocalycium*, the growing media moisture was statistically different. T4 had the lowest growing media moisture (34.65%). In the genus *Astrophytum* also was significantly different but T2 had the lowest growing media moisture (38.92%). Whereas, in the genus *Mammillaria*, there was not statistically different (37.94 - 41.63%). The genus *Echinopsis* was statistically variant. The T2 had the lowest growing media moisture (32.29%) (Table 2).

Bulk density (grams/cubic centimeter): Bulk density of growing media before planting was a statistical difference. The T2 had the lowest density at 0.46 g/cm^3 (Table 1). After six months of planting, the four treatments were not statistically different in all 4 genera of cacti. There were in ranged of 48.41 - 64.75, 55.21 - 60.71, 38.89 - 45.45, and 48.41 - 64.74 g/cm^3, respectively (Table 2).

Total porosity (%): The total porosity of the growing media before planting was significantly different. The T2 was the highest at 58.73%, but not different from T3 and T1 (54.03 and 51.73%, respectively) (Table 1). After six months of planting cacti, it was not statistically different in all 4 genera. There were in range of 48.41 - 64.75, 55.21 - 60.71, 38.89 - 45.45, and 48.41 - 64.74%, respectively (Table 2).

Table 1. Properties of growing media before planting cacti and planting a cactus and cost of growing media

Treatment	pH	EC (mS/cm)	Growing media Moisture (%)	Bulk Density (g/cm³)	Total porosity (%)	Cost (bath/2″ pot)
1	7.55[b]	0.73[b]	39.41[b]	0.57[b]	51.75[a]	2.20
2	7.85[a]	1.02[a]	55.84[a]	0.46[c]	58.73[a]	1.18
3	7.77[a]	0.54[c]	46.18[ab]	0.58[b]	54.03[a]	1.48
4	7.77[a]	0.81[b]	40.62[b]	0.70[a]	34.84[b]	2.86
%CV	0.92	8.31	17.22	8.31	10.26	
LSD$_{0.05}$	0.13	0.12	14.75	0.09	9.62	

[a, b, c] different characters in the same column are statistically different at 95% confidence level ($P \leq 0.05$)

Table 2. Properties of growing media at after 6 months of planting of all 4 genera of cacti.

Treatment	pH	EC (mS/cm)	Growing media Moisture (%)	Bulk Density (g/cm³)	Total porosity (%)
			Gymnocalycium		
1	7.53[b]	0.55	57.61[a]	0.77	53.19
2	7.85[a]	0.69	49.18[a]	0.79	48.41
3	7.83[a]	0.51	50.07[a]	0.81	64.75
4	7.79[a]	0.61	34.65[b]	0.80	58.30
%CV	1.42	15.93	12.93	16.22	17.64
LSD$_{0.05}$	0.21	ns	11.66	ns	ns
			Astrophytum		
1	7.13[a]	0.54	44.47[b]	0.71	55.21
2	7.33[a]	0.48	38.92[c]	0.74	60.71
3	7.38[a]	0.45	52.61[a]	0.80	59.49
4	6.84[b]	0.49	39.77[bc]	0.77	55.56
%CV	1.92	14.73	5.82	7.72	9.40
LSD$_{0.05}$	0.26	ns	4.82	ns	ns
			Mammillaria		
1	7.65	0.58	40.25	0.94[a]	43.11
2	7.64	0.58	37.94	0.83[ab]	45.45
3	7.66	0.44	41.63	0.93[ab]	43.18
4	7.78	0.71	40.09	0.69[b]	38.89
%CV	1.23	25.80	13.89	12.94	12.84
LSD$_{0.05}$	ns	ns	ns	0.21	ns
			Echinopsis		
1	7.29[bc]	0.53	49.83[a]	0.67[b]	53.19
2	7.45[ab]	0.51	41.45[ab]	0.66[b]	48.41
3	7.63[a]	0.55	43.88[ab]	0.82[a]	64.74
4	7.19[c]	0.64	32.29[c]	0.90[a]	58.30
%CV	1.55	15.96	8.34	8.19	17.64
LSD$_{0.05}$	0.22	ns	6.57	0.12	ns

[a, b, c] different characters in the same column are statistically different at 95% confidence level ($P \leq 0.05$)
ns = not statistically different
note: treatment 1 = FRTL: perlite: vermiculite: pumice: vermicompost (1: 1: 1: 1: 1)
treatment 2 = FRTL: rice husk: coconut coir: charcoal: vermicompost (1: 1: 1: 1: 1)
treatment 3 = FRTL: rice husk ash: coconut husks chips: expanded clay: vermicompost (1: 1: 1: 1: 1)
treatment 4 = rice husk ash: vermicompost (1: 2)

Production costs (bath/ 2 inches pot): The cost of each growing media in 2-inch pots was found that in T1 was 2.20 bath/ 2 inches pot. However, in T2 was lowest (1.18 bath), and in T3 was lower than T1 (1.48 bath). The highest cost was found in T4 that 2.86 bath (Table 1).

3.1.3 Plant growth

The experimental planting of cacti in 4 different growing media for six months showed that there was a statistically significant difference. In the genus, *Gymnocalycium* grew on T4 was the highest stem diameter (3.87 cm) while T2 had a minimum diameter (3.53 cm) (Table 3; Figure 1). In the *Astrophytum*, T4 had the largest diameter (3.05 cm) while T1 had the lowest diameter (2.65 cm). In the genus *Mammillaria*, T3 had a maximum diameter (4.33 cm), while T4 had the lowest diameter (3.88 cm). In the genus, *Echinopsis* grown on T3 was not different from growing on T1 and T4 had the largest stem diameter (4.52, 4.50, and 4.50 cm) while growing on T2 has the minimum stem diameter (3.98 cm).

Table 3. The stem diameters of all 4 genera of cacti after planting in different growing media for 6 months.

Treatment	Stem diameter (cm)			
	Gymnocalycium	*Astrophytum*	*Mammillaria*	*Echinopsis*
1	3.73^{ab}	2.65^{b}	4.17^{ab}	4.50^{a}
2	3.53^{b}	2.76^{ab}	4.01^{ab}	3.98^{b}
3	3.74^{ab}	2.87^{ab}	4.33^{a}	4.52^{a}
4	3.87^{a}	3.05^{a}	3.88^{b}	4.50^{a}
C.V.%	10.54	14.25	10.92	4.28
LSD$_{0.05}$	0.32	0.33	0.37	0.15

$^{a, b}$ different characters in the same column are statistically different at 95% confidence level ($P \leq 0.05$)

The number of new areoles of the genus *Gymnocalycium* and *Astrophytum* were significantly different. In genus *Gymnocalycium* grown on T2 was not different from growing on T3. And it had the highest number of new areoles (4.67 areoles) while planting on T4 had the lowest number of new areoles (3.67 areoles) (Table 4). The *Astrophytum* grown in T4 had the highest number of new areoles (3.58 areoles) while those grown on T2 had the lowest number of new areoles (2.33 areoles). However, the number of new areoles of the genus *Mammillaria* and *Echinopsis* was not significantly different (6.42 – 7.33 and 7.00 – 8.00 areoles, respectively).

Table 4 The number of new areoles of all 4 genera of cacti after planting in different growing media for 6 months.

Treatment	Number of new areoles			
	Gymnocalycium	*Astrophytum*	*Mammillaria*	*Echinopsis*
1	3.75^{b}	2.67^{bc}	6.50	7.42
2	4.67^{a}	2.33^{c}	6.42	8.00
3	4.67^{a}	3.08^{ab}	7.33	7.00
4	3.67^{b}	3.58^{a}	6.58	7.42
C.V.%	22.84	27.91	19.00	16.65
LSD$_{0.05}$	0.79	0.67	ns	ns

$^{a, b, c}$ different characters in the same column are statistically different at 95% confidence level ($P \leq 0.05$)

ns = not statistically different

note: treatment 1 = FRTL: perlite: vermiculite: pumice: vermicompost (1: 1: 1: 1: 1)
treatment 2 = FRTL: rice husk: coconut coir: charcoal: vermicompost (1: 1: 1: 1: 1)
treatment 3 = FRTL: rice husk ash: coconut husks chips: expanded clay: vermicompost (1: 1: 1: 1: 1)
treatment 4 = rice husk ash: vermicompost (1: 2)

The number of roots of all four genera of cacti were significantly different (Table 5; Figure 1). The genus *Gymnocalycium* grown with T1 had the highest number of roots (2.67) while T2 had the lowest number of roots (1.83). In the genus *Astrophytum* grown on T4 had the highest (2.83) while growing on T1 had the minimum number of roots (1.92). In the genus *Mammillaria* grown on T4 had the highest number of roots (9.83) while T1 had the lowest (7.50). In the genus, *Echinopsis* grown on T1 had the maximum number of roots (4.75) while T4 had the lowest (3.58).

Table 5 The number of roots of all 4 genera of cacti after planting in different growing media for 6 months.

Treatment	Number of roots			
	Gymnocalycium	*Astrophytum*	*Mammillaria*	*Echinopsis*
1	2.67^{a}	1.92^{b}	7.50^{b}	4.75^{a}
2	1.83^{c}	2.67^{a}	8.58^{ab}	4.17^{b}
3	2.08^{bc}	2.17^{b}	9.67^{a}	3.92^{bc}
4	2.17^{b}	2.83^{a}	9.83^{a}	3.58^{c}
C.V.%	18.12	16.55	28.57	10.23
$LSD_{0.05}$	0.33	0.33	2.09	0.35

^{a,b,c} different characters in the same column are statistically different at 95% confidence level ($P \leq 0.05$)

The root lengths of all four genera of cacti were significantly different (Table 6; Figure 1). The *Gymnocalycium* grown on T1 had the highest root length (6.65 cm) whereas T2 had the shortest roots length (5.28 cm)). In *Astrophytum* grown on T1 had the longest root (6.68 cm), while the T4 has the lowest roots length (5.21 cm). *Mammillaria* grown on T2 had the longest roots length (5.55 cm) while T1 had the shortest roots (4.40 cm). In *Echinopsis* planted with T3 had the highest roots length (14.46 cm) while T2 had the lowest roots length (9.63 cm).

Table 6. The root length of all 4 genera of cacti after planting in different growing media for 6 months.

Treatment	Root length (cm)			
	Gymnocalycium	*Astrophytum*	*Mammillaria*	*Echinopsis*
1	6.65^{a}	6.68^{a}	4.40^{b}	10.24^{b}
2	5.28^{b}	5.85^{bc}	5.55^{a}	9.63^{b}
3	5.43^{b}	6.05^{ab}	5.48^{a}	14.46^{a}
4	5.74^{ab}	5.21^{c}	4.70^{b}	10.67^{b}
C.V.%	19.99	13.13	9.74	23.59
$LSD_{0.05}$	0.95	0.64	0.40	2.18

^{a,b,c} different characters in the same column are statistically different at 95% confidence level ($P \leq 0.05$)

note: treatment 1 = FRTL: perlite: vermiculite: pumice: vermicompost (1: 1: 1: 1: 1)
treatment 2 = FRTL: rice husk: coconut coir: charcoal: vermicompost (1: 1: 1: 1: 1)
treatment 3 = FRTL: rice husk ash: coconut husks chips: expanded clay: vermicompost (1: 1: 1: 1: 1)
treatment 4 = rice husk ash: vermicompost (1: 2)

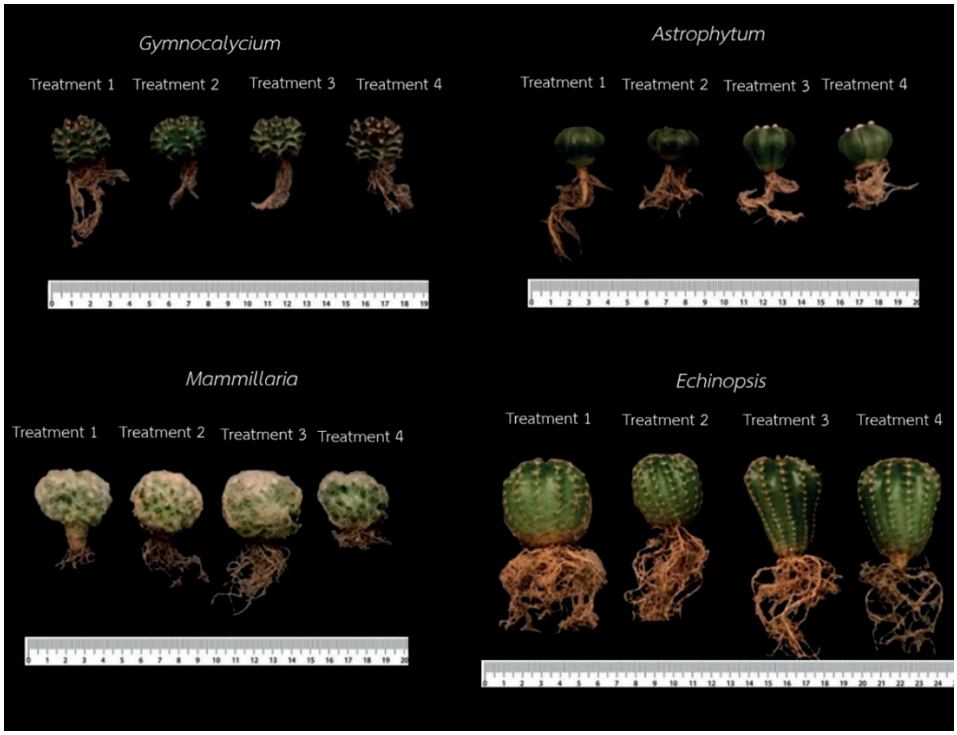

Figure 1. The stem growth of all 4 genera of cacti in 4 different growing media, namely: treatment 1) FRTL: perlite: vermiculite: pumice: vermicompost (1: 1: 1: 1: 1), treatment 2) FRTL: rice husk: coconut coir: charcoal: vermicompost (1: 1: 1: 1: 1), treatment 3) FRTL: rice husk ash: coconut husks chips: expanded clay: vermicompost (1: 1: 1: 1: 1) and treatment, and 4) rice husk ash: vermicompost (1: 2)

3.2 Discussion

The result of different growing media on the growth of 4 genera of cacti were found that T3 and T4 gave the best growth in all cacti such as stem diameter, number of roots and root length. Which were suitable for the growth of the cacti. Due to some properties of growing media were not significant difference after 6 months of planting such as follows: The pH before planting was 7.77, while after planting was in the range of 7.38 – 7.83 (T3) and 6.84 – 7.79 (T4). EC before planting was 0.54 (T3) and 0.81 (T4) mS/cm while after planting was in the range of 0.44 – 0.55 (T3) and 0.49 – 0.71 (T4). Before planting, the growing media moisture was 46.18% (T3) and 40.62% (T4), while after planting, the growing media moisture was in the range of 43.88 - 52.61% (T3) and 32.29 – 40.09% (T4). The bulk density before planting was 0.58 and 0.70 g/cm^3, while the bulk density after planting was in the range of 0.81 – 0.93 and 0.69 – 0.90 g/cm^3. The total porosity before planting was 54.03 % and 34.84% while the total porosity after planting was in the range of 43.18 – 64.75% and 38.89 – 58.30%, respectively. These properties were not different from the control treatment (T1). In the previous research reported that EC was in the range of 0.4 – 0.7 mS/cm [15], and the composition of the growing media was suitable for planting with total porosity of 50% and the rice husk ash with high porosity and low density [16]. It has enough macronutrients with 0.38% phosphorus and 1.28% potassium [17]. The FRTL have properties to help retain water and nutrients better. It contains approximately 0.5 - 0.1% nitrogen by weight [18]. Vermicompost comprises 1.15 % nitrogen, 0.38 % phosphorus, and 0.86 % potassium [19]. Coconut husks chips have good water absorption properties. It has a fibrous nature, thus allowing the growing media to be airy and loose [20]. The expanded clay can store water and nutrients [21]. Cacti were plants that prefer a low-density potting media and good drainage [10]. Their results were similar supported by Anuwong (2022), who studied the five genera of cacti grown in rice husks: vermicompost at a ratio of 1: 2 resulted in the highest height, stem diameter, number of roots and root length [22]. Although T3 and T4 gave the same results as an appropriate growth, but T3 had a lower cost than T4 and the control (T1). T3 can reduce the production cost of growing media around 0.72 baht/2-inch pot (33% of reduce cost) when compared with T1 as a commercial media.

4. Conclusions

The growth of all four genera of Cacti found that the planting material consisting of FRTL : rice husk ash: coconut husks chips: expanded clay: vermicompost had the most optimum growth in all four genera and can reduce the cost of growing media about 0.72 baht (33%) for cacti in 2-inch pot.

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