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Yield and fruit morphology of selected high productive Papua nutmeg trees (*Myristica argentea* Warb.)

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Abstract. Fakfak nutmeg is also known as Papua Nutmeg, and has become one of the main income sources of local communities in Fakfak and Kaimana Districts. It produces butter nutmeg, a fat derived from the seed used in perfumery and soaps. It grows wild or semi cultivation, so the productivity is generally low. To improve productivity, it is necessary to use planting materials derived from high productive trees. The study was aimed to identify nutmeg trees with high yield, good quality of fruit, seeds and essential oils. The study was undertaken in eight locations of Fakfak district. Mother trees selection were carried out during 2013-2015. About 136 mother trees have been selected with average fruit yield 2275 ± 340 fruits tree⁻¹ and have bigger fruit and seed compared with original population. The average fruit weight 106 ± 9.6 g, fruit length 7.26 ± 0.54 cm, seed weight 13.52 ± 1.44 g, seed length 3.81 ± 0.34 cm, and mace weight > 2 g. Essential oil content of mature seeds and mace was considered low ($<5\%$). The main chemical constituents of seeds and mace essential oils were sabinen, limonen and safrol. The safrole content was higher ($> 20\%$) than standard.

1. Introduction

Fakfak nutmeg (*Myristica argentea* Warb), also known as the “Negeri” or “Papua” nutmeg, is found growing wild and also cultivated widely in Papua and Papua New Guinea [1], therefore thought to be native to Papua. According to traditional chieftain, Fakfak nutmeg has been growing before the Dutch colonialism. Nutmeg plantations were scattered along the forest in the Fakfak mountains. The spread of nutmeg in the forest was thought to be assisted by nutmeg-eating birds such as Eunggano, or so-called by farmers around as the *wapur*, *wamar* or *toun-toun*.

The Fakfak nutmeg plantation center is spread over 8 districts from total of 9 districts within the Fakfak Regency. Economic life and activities of rural communities in this region are mostly related to Papua nutmeg, therefore its known as one of the main cash crops in Fakfak and Kaimana Regencies. It is also a social crop because it is cultivated by many local people and is an economic source.

Productivity of Fakfak nutmeg is considered low, around 122-175 kg seeds ha⁻¹. Yield of fruit varies from 300-4000 fruits plant⁻¹ year⁻¹. To improve productivity and quality of Fakfak nutmeg, the regional



government and the people of Fakfak Regency have determined to expand nutmeg plantation using superior seeds-

To support the development of Fakfak nutmeg with better productivity and quality, sources of quality seeds is needed. This can be done by selection of high productivity mother trees. To select fruit-producing plants with high productivity and quality, it is necessary to consider criteria for production and quality. Furthermore there must be criteria for determining which varieties or plants to be declared as high yields, and how to calculate production. Yield can be calculated based on area and per individual plant per unit time.

The performance of plant conditions in the field varies greatly in plant age, tree size and planting density. Yields on fruit-bearing crops are products of the weight of the fruit multiplied by the number of fruits. In the field, it is often found that a high number of fruits is followed by smaller fruit sizes and vice versa. [2] found high variation in nutmeg yield among plantations in Indonesia, which may be related to inherent genetic make up or varieties, seasonal weather and cultivation practices. High variation in productivity, size, shape of fruit and seeds has also been reported in various nutmeg plantations in India [3]; [4].

According to [5] superior trees produce 2,000 fruits annually, while [6] stated that high-yielding plants produce 3000 fruits annually. Minister of Agriculture Regulation No.320/2015 for *M. fragrans*, indicated production criteria for nutmeg mother trees for seed sources is 3000 fruits. No criteria determined for *M. argentea*. Fakfak nutmeg normally produces 2000- 3500 fruits with smaller fruit size (<90 g fruit⁻¹) and 1000-2500 fruits for larger fruit size (> 90 gr fruit⁻¹). Other characteristics such as fruit weight, mace volume, pericarp thickness, kernel volume, mace dry weight, are other useful criteria to determine superior nutmeg trees. The objective of this study was identifying nutmeg trees that can be declared as high productive trees, and recommended as seeds sources.

2. Materials and method

2.1. Yield observation

The stages of the activity included selection of population, followed by selection of mother trees (MTs) and observation of yield. The selection of population and MTs were carried out within three steps. In stage I (S1), focused on inventory and selection of production centers with suitability in agro-climatic condition, easy transportation and the location is easy to reach for distribution. From total of 20 locations observed, eight populations were identified. In stage II (S2) directed towards the selection of MTs in the eight population by taking into account the maintenance of the plantation, cropping patterns, farmer responses, plant health, and yield tree⁻¹. The eight populations selected were in the West Fakfak (Werba and Wirkendik), Middle Fakfak (Mondapma and Firma), East Fakfak (Wambar and Muma Wings), and City Fakfak (Pariwari), with total number 263 trees selected. In stage III (S3) final selection followed by detail observation for yield tree⁻¹ with tree yield in accordance to Ministry of Agriculture Decree 320/2015. The total number of selected MTs were 136, the number in each population were 24 MTs in Werba – West Fakfak (Philipus/Yan Kabes), 8 + 21 MTs in Wirkendik – West Fakfak (Bertus Woy and Zackaria) , 11 MTs in Mondapma- Midle Fakfak (Bernadeta Komber), 11 MTs in Firma- Fakfak (Husein T.), 23 MTs in Wambar-East Fakfak (Udin Murry), 13 MTs in Muma Wing – Wambar – East Fakfak (Abdul Hajj. W.) and 25 MTs in Pariwari-Fakfak City (Yohanes Ginuni).

2.2. Observation on morphological characters

Detail observation on morphological characters were undertaken for characteristics of fruits, seeds and mace. Ten samples was observed for each MT and data were analyzed using Barlett test.

2.3. Chemical analysis of seeds and mace

For analysis of chemical compounds, samples were collected from only 3 populations, namely Mondapma, Firma and Pariwari. Samples for analysis were bulk seeds or mace from MTs that were selected in the same population. Quality analysis was carried out on essential oil levels using steam distillation, oleoresin levels by extraction and chemical content of essential oils using GCMS (Shimadzu). Analysis of essential oil levels was carried out in the ISMCRI laboratory uses steam distillation for 8 hours. Oleoresin extraction was carried out using ethanol 96%. Chemical compounds in essential oil were determined by GCMS conducted at the Health Laboratory belongs to the Jakarta Local Government. The GC conditions used are as follows: using a DB-5MS capillary column, an inner diameter of 0.25 mm, a film thickness of 0.25 μm , a Helium carrier gas with a pressure of 100 kpa, an injection volume of 2 μl using a split injection technique. Identification of chemical components is done by comparing the fractions of compounds detected with the National Institute of Standards and Technology (NIST) library based on LRI (Linear Retention Indices) values.

3. Results and discussion

3.1. Yield performances

The Fakfak nutmeg plant starts to bear fruit at the age of 7 years, production increases with age. High production is achieved at the age of 25 years and continues until the plants are aged 60-70 years, even more. Fruit harvest in Fakfak nutmegs was taken several times a year which is usually in March-April, June-July and November-December. Beyond these three seasons, there is a small amount of nutmeg harvest which is called the sun season harvest (dry time). The same thing happened to Banda nutmeg. On the island of Ambon flowering were occurred in 3 periods namely March-April, June-July and November-January and flowering until harvest takes about 8-10 months [7].

The range of fruit production in Fakfak nutmeg is 450 - 4750 fruits tree⁻¹. Fakfak nutmeg production varies, the average production tree⁻¹ year⁻¹ is 2000 fruits, the lowest is 300. Good plants can produce up to 4000 fruits tree⁻¹ year⁻¹ [8]. Variation in fruit yield between tree can reach 100%, therefore, the plants that will be used for seed sources are selected for high production. The criteria to select Fakfak nutmeg high production tree⁻¹ year⁻¹ is ≥ 2000 (Table 1). However, the average yield of Fakfak nutmeg selected trees is only around 2270 fruits tree⁻¹ year⁻¹ with the number of dried seeds kg⁻¹ is 110-120. Based on that, the potential production of dried seeds ha⁻¹ (100 trees) is 1890 - 2060 kg and mace production of 350 kg. This production is greater than the average Fakfak mace production in general which only reaches 200 kg ha⁻¹. The use of seeds from the selected MTs is expected to increase field crop production. The use of seeds from selected trees can increase production up to 17% [9].

3.2. Morphological characters

3.2.1. Plant habit. Plant habit of Fakfak nutmeg trees is tall and large, leaf size is long and wide, as well as the size of the fruit and seeds. Selected MTs have a plant age range from 40-70 years, plant height of 15-23 meters, trunk circumference 90-150 cm, canopy width 2.5m - 3.9 m, number of branching circles (locus) in the main trunk 11-27 and number of branches in one locus vary from 3 to 6. Leaf size is large with length 14 cm - 27cm, width 4.9 cm - 9.0 cm and petiole length 1.6 cm - 2.1 cm. Plant height can reach 25 m with a canopy width of 10-12 m, but the average plant height is 15 m [8], the shape of the crown is generally rather cylindrical. Branching plants are longer with fewer branches. The observations of [10] in Gorom, Seram island, Fakfak nutmeg or onin nutmeg has larger plant habit, leaves are longer and wider than Banda nutmeg, as well as fruit and seed size.

Table 1. Yield range of fruits from Fakfak nutmeg trees in eight population

No	Population	S1		S2		S3	
		Σ Trees	Yield range fruits tree ⁻¹	Σ Trees	Yield range fruits tree ⁻¹	Σ Trees	Yield range fruits tree ⁻¹
1	Bernadeta	150	450 - 2800	22	1000 - 2800	11	2000 - 2800
2	Husein T.	150	450 - 4000	31	800 - 4000	11	2000 - 4000
3	Udin Murry	80	500 - 2500	38	1000 -2500	23	2000 - 2500
4	Abdul Hajj. W.	60	500 - 3000	20	1000 -3200	13	2000 - 3200
5	Philipus/ Yan Kabes	150	950 - 4750	47	1000 - 3000	24	2000 - 4750
6	Bertus Woy	50	700 - 2200	20	1000 - 3000	8	2000 - 3000
7	Zackaria	150	650 -3000	30	1000 - 3000	21	2000 - 3000
8	Yohanes Ginuni	120	700 - 3000	55	1000 - 3000	25	2000 - 3000
Total		910		263		136	

Table 2. Yield performances of selected Fakfak nutmeg mother trees

No.	Population/Districts	Σ MTs	Average yield in three consecutive years (fruits tree ⁻¹ year ⁻¹)			Average in three years
			2013	2014	2015	
1	Bernadeta Komber	11	1800 – 2500 (2113 ± 217)	2075 – 2650 (2418 ± 201)	1500 -2400 (1873 ± 318)	2003 – 2483 (2135 ± 167)
2	Husein T.	11	1850 – 2550 (2120 ± 211)	2050 – 2600 (2180 ± 186)	1500 -2500 (1975 ±249)	2000 – 2550 (2092 ± 162)
3	Udin Murry	23	2050 -2550 (2128 ± 129)	2100 – 2650 (2222 ± 135)	1900 – 2500 (2052 ± 139)	2016 – 2556 (2134 ± 134)
4	Abdul Hajj. W.	13	2050 – 3280 (2452 ± 490)	2100 – 3330 (2502 ± 495)	2000 – 3230 (2402 ± 500)	2050 -3280 (2452 ± 498)
5	Philipus/ Yan Kabes	24	2050 – 3050 (2390 ± 391)	2100 – 3100 (2440 ± 385)	2000 – 3000 (2340 ± 400)	2050 – 3050 (2390 ± 409)
6	Bertus Woy	8	2100 – 2250 (2150 ± 53)	2100 – 2300 (2163 ± 74)	2000 – 2200 (2063 ± 74)	2000 – 2200 (2125 ± 66)
7	Zackaria	21	2050 – 3050 (2338 ± 402)	2100 – 3100 (2388 ± 398)	2050 – 3050 (2338 ± 400)	2050 -3050 (2390 ±420)
8	Yohanes Ginuni	25	1700 – 3850 (2447 ± 506)	2025 -3900 (2569 ± 612)	1950 – 3750 (2431 ± 620)	2008 – 3830 (2482 ± 606)
Total/Average yield		136	2267 ± 395	2360 ± 411	2184 ± 406	2275 ± 340

The Onin nutmeg harvesting time is similar to Banda nutmeg. In the island of Ambon, flowering occurs in 3 periods namely March-April, June-July and November-January and flowering until harvest takes 8-10 months [7]. The Fakfak nutmeg plants suitable in hot tropical climates with high rainfall without any apparent dry periods. Rainfall in Fakfak regency is relatively high, spreading rain almost evenly throughout the year.

3.2.2. Flowers. Flowers in nutmeg Fakfak is formed on the armpit of the leaf. The number of flowers inflorescence¹ vary from 1 to 5, but the most commonly found is one. The average age of picking ripe fruit is 9 months from flower initiation [8]. This is in accordance with farmers picking ripe fruit is around 9 months.

3.2.3. Fruits. The Fakfak nutmeg fruits are ovoid in shape with variation to lanceolate ovate. The apex of the fruit is bent like having a hook or a beak. Young fruit is green in color with smooth surface. Mature fruit turn colour from beige to brown with rough brown spots. The older the fruits, the colour becomes more brown and the fruit surface even more rough. The fruit stalk is large and long, the length of the stalk can reach 4 cm with a diameter of about 0.5 cm. Fruit weight vary from rather small (60 g) to large (125 gr). Nutmeg flesh thickness is generally around 1.5 cm. Variation in fruit shapes of Banda nutmeg in North Maluku, is large including round, oblong with small to large fruit sizes and variations in fruit apex from flat to caudate. The selected MTs, having fruit weight vary from 93 to 105 g with a fruit length of about 6.5-7.9 cm and fruit width 4.3-6.2 cm. The size of the nutmeg is generally larger than the Banda nutmeg. The size of Banda nutmeg in Sangihe is characterized with a weight of 40 - 58 g / grain, fruit length 4.51 - 4.89 cm, fruit width 3.75 - 4.29 cm and fruit flesh thickness 0.79 - 0.94 cm, seed weight 6.9 - 9.5 g / grain with a length of 1.99-2.94 cm and width 1.90-2.26 cm [11]. The results of the Barlett test on the fruit character showed that the fruit weight of the selected MTs still vary, but the fruit length and width were considered homogeneous (Table 3.).

3.2.4. Seeds and mace. The shape of Fakfak nutmeg seed is lanceolate ovate with variations on slender or rather fat, the base of the seed is wider than the tip. Weight of seeds was vary from small to large sized seeds (9-17 g). The selected MTs have fresh seeds weight 11.5 - 16.8 g. The seed length is 3.03-4.63 cm, the width of the seed is 1.86 - 2.52 cm and the weight of the fresh mace is > 1.96 - 3.31 g. The results of the Barlett test on the character of the seeds showed that the weight of the seeds and the mace weight of the selected plants were still vary, but the length and width of the seeds were considered homogeneous (Table 4).

The ratio of mace to seed in Fakfak nutmeg is around 20-25%. This is in accordance with [8] which states that the proportion of Fakfak mace and nutmeg seeds is around 4:1 or equivalent to 25%. In the field, farmers generally obtain 7 kg of dried nutmeg seeds and 1.5 kg of mace from 1000 fresh nutmeg seeds. [12] states that, in the Fakfak nutmeg the proportion of fruit flesh is 90.20%, seeds are 7.46%, shells are 1.12% and mace is 1.23%. The size of several fruit samples from MTs, those proportions were not much different. The proportion of fruit weight is 89.5%, seeds are 8.55% and mace 1.78%. In Banda nutmeg, the proportion of fruit is 77.8%, seeds are shelled 15.1 and mace 4%. Although the size of the seeds and mace of Fakfak is relatively large, the proportion of fruit is smaller than that of banda nutmeg. The mace closure of Fakfak nutmeg seeds has a distinctive appearance, in contrast to the closure of mace on the banda nutmeg, which are generally rather thin and divide into many parts, while in Fakfak nutmeg the mace is generally only divide into 3 sections. Mace is easily separated from seeds and remains intact.

Table 3. Fruit and characters of selected Fakfak nutmeg MTs and its homogeneity based on Barlett's test

No.	Populations	MTs	Fruit			Leaf	
			Weight (g)	Length (cm)	Diameter (cm)	Length (cm)	Width (cm)
1	Bernadeta	11	109,8 ± 10,4	7,37 ± 0,36	5,89 ± 0,29	20,33 ± 2,49	6,90 ± 0,91
2	Husein T.	11	108,5 ± 11,2	7,46 ± 0,19	5,85 ± 0,37	22,07 ± 2,65	7,23 ± 1,01
3	Udin Murry	23	107,2 ± 8,2	7,50 ± 0,20	5,80 ± 0,41	21,6 ± 1,5	7,41 ± 0,9
4	Abdul Hajj.	13	107,8 ± 6,4	7,35 ± 0,30	5,62 ± 0,42	20,19 ± 2,40	6,77 ± 1,04
5	Kabes brothers	24	110,4 ± 12,8	7,02 ± 0,13	5,20 ± 0,25	19,08 ± 1,79	7,19 ± 0,75
6	Bertus Woy	8	101,3 ± 3,31	6,93 ± 0,40	5,15 ± 0,36	18,9 ± 3,21	6,96 ± 0,82
7	Zackaria	21	99,7 ± 6,12	7,16 ± 0,46	5,15 ± 0,36	18,87 ± 2,46	6,78 ± 0,51
8	Yohanes Ginuni	25	108,2 ± 8,18	7,33 ± 0,24	5,08 ± 0,33	21,82 ± 2,98	6,86 ± 0,54
Barlett test value(14,067)			19,96	10,41	3,08	13,37	22,14
Notes			Heterogenous	Homogenous	Homogenous	Homogenous	Heterogenous

Table 4. Seed and mace characters and its homogeneity based on Barlett's test

No	Population/ Districts	MTs	Seed weight	Seed length	Seed diameter	Weight of mace
			(g)	(cm)	(cm)	(g)
1	Bernadeta	11	14,77 ± 1,65	4,30 ± 0,27	2,14 ± 0,11	2,84 ± 0,19
2	Husein T.	11	14,05 ± 1,34	3,77 ± 0,26	2,22 ± 0,12	2,10 ± 0,11
3	Udin Murry	23	13,3 ± 0,80	3,56 ± 0,3	2,10 ± 0,11	2,43 ± 0,40
4	Abdul Hajj.	13	13,28 ± 1,43	4,02 ± 0,32	2,10 ± 0,12	2,58 ± 0,29
5	Kabes brothers	24	14,25 ± 1,75	3,62 ± 0,24	2,13 ± 0,13	2,47 ± 0,35
6	Bertus Woy	8	12,74 ± 1,69	3,43 ± 0,27	2,19 ± 0,15	2,71 ± 0,20
7	Zackaria	21	13,58 ± 1,06	3,71 ± 0,21	2,24 ± 0,12	2,68 ± 0,31
8	Yohanes Ginuni	25	12,74 ± 0,79	3,95 ± 0,79	2,07 ± 0,19	2,57 ± 0,34
Barlett test value (14,067)			17,79	12,83	14,04	27,48
Notes			Heterogenous	Homogenous	Homogenous	Heterogenous

Drying of Fakfak nutmeg seeds generally uses fuming/smoking. The process of drying the seeds is carried out until the water content of the seeds reaches 8-10% which is marked when the shells already separated from the seeds. Drying seed takes about 10-15 days at a temperature of 35-40° C. Dry Fakfak nutmeg with shell generally meets quality standards I grade ABCD in accordance with SNI 006-2015. This was obtained because generally drying with fuming so that the process is more secure. In addition to the existence of a customary 'sashi', namely to harvest the nutmeg when the fruit conditions are already perfectly ripe fruit, so that the nutmeg (kernel) seeds produced are generally pithy, intact with smooth surface. The pattern of mace of Fakfak nutmeg is thick and divides into just a few parts so that mace can be easily separated and intact, unlike Banda nutmeg.

3.3. Chemical analysis of nutmeg seeds and mace

The content of mature seed essential oil from MTs collected from three different locations is not significantly different (Table 5.), which is around 3.55% and from mace is about 3.11- 3.45%. The color of the essential oil of the seeds or mace is distilled from clear to slightly yellowish. This acquisition is almost the same as the result of nutmeg distillation by [13] that is 2.80 - 3.38% and by [12] 3.33%. The content of Fakfak nutmeg essential oils is much lower than the essential oils of Banda nutmeg seeds. Other nutmeg species such as Wegio nutmeg (*M. fatua* Houtt.), the essential oil content of seeds is less than 1%, with the main chemical content of copaene and caryophyllene [14], not recommended for herbs but for medicinal ingredients or for perfume ingredients.

Seed oleoresin content was 14-15%, and from mace was 13.5 - 14.40%, and are not much different between locations (Table 5). These results were higher than those reported by [15] dan [16] respectively which obtained 5.98% and 7.14%, respectively. The results from extraction of fat from Fakfak nutmeg seeds is 19-27%, not much different between MTs population. Nutmeg contains trimyristin which has economic value. Trimyristin is a triglyceride fat, it can be used as a raw material for soap, cosmetics, perfumes and food additives. Trimyristin content in Fakfak nutmeg on average is 79.55% with 99.20% purity [13]. This value is relatively high when compared to trimyristin from other sources such as coconut oil (coconut oil) by 17.5%, palm kernel oil (palm kernel oil) by 14.15, and babassu oil by 19.9% [17].

Table 5. Essential oil, oleoresin and trimyristin content in Fakfak nutmeg seed and mace.

Quality parameters	Location of selected mother trees		
	Wirikapal	Mondapma	Firma
Essential oil (%) (seed)	3.55	3.91	3.29
Essential oil (%) (mace)	3.45	3.20	3.11
Oleoresin (%) (seed)	14	15	14.6
Oleoresin (%) (mace)	14.10	14.40	13.50
Trimyristin (seed)	19.62	22.31	27.18

Major uses of Fakfak nutmeg is not as spices but rather for industrial purposes, so that the chemical components are important. Essential oil analysis with GCMS obtained 20 chemical components (Table 6), but only major compounds (> 1 %) are listed. The main components identified using GCMS from Fakfak nutmeg essential oil are pinene, sabinene, limonene, terpinene, terpineol, and safrole. These results are in accordance with analysis using TLC which obtained α -pinene, limonene, terpineol, safrole, and myristicin as the main compounds [13]. The chemical contents of samples from three different population was not

significantly different, except for pinene and sabinen. On the contrary, samples from Wirikapal have higher of these two components (Table 6).

Table 6. Main chemical compounds in Fakfak nutmeg essential oils analyzed by GCMS

	Main chemical compounds (%)	Location of selected mother trees		
		Wirikapal	Mondapma	Firma
1	Pinene	4.38^a	0.58^b	0.65^b
2	Sabinene	39.04^a	7.91^b	20.51^a
3	Beta myrcene	2.93	0.10	0.91
4	Alpha terpinene	1.96	1.04	1.90
5	Alpha limonene	5.30	2.09	3.76
6	Sabinene- thujene	5.57	2.46	7.30
7	Gamma terpinene	1.29	2.05	3.34
8	p-Menth-1-en-4-ol	0.16	2.09	3.54
9	4-Terpineol	4.10	5.51	2.97
10	Safrole	20.44	43.37	40.70
11	2-dimetoxy -4-(2-propenyl) benzene	1.29	4.89	4.05
12	Myristic acid	2.04	0.80	0.65

Other major component of Fakfak nutmeg seeds is Trimyristin. Trimyristin together with myristic acid, myristicin and elimicin from Fakfak nutmeg oil reported to be active as anti-oxidant, anticonvulsant, analgesic, anti-inflammatory, anti-diabetic, anti-bacterial and anti-fungal activities[18]. Trimyristin is also used as a whitening agent for cosmetics. Trimyristin has been used in making soap. Bath soap with the active ingredient of trimyristin from nutmeg oil can be stored for long time and strongly inhibit the growth of bacteria and fungi [19]. Other important chemical component isolated from Fakfak nutmeg mace is argenteane which has a powerful antioxidant activity as vitamin E [20], and from seed oil is safrole and iso-safrole. These are used as food flavourings. However, the use of safrole is restricted. The maximum limit of safrole as flavor is 15 mg kg⁻¹ in foods containing nutmeg, whereas in seasoned meat products is 10 mg kg⁻¹ [21].

In conclusion, from the results described above, 136 high productive mother trees have been identified and selected, producing ≥ 2000 fruits tree⁻¹ year⁻¹. To meet the demand of local government and farmers for good quality seeds, the selected mother trees may be recommended as seeds sources to improve Fakfak nutmeg production.

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