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Full Length Research Paper

Euphorbia tirucalli L. (Euphorbiaceae) – The miracle tree: Current status of available knowledge

Julius Mwine[1]* and Patrick Van Damme[2]

[1]Faculty of Agriculture, Uganda Martyrs University, Nkozi, P. O. Box 5498, Kampala, Uganda.
[2]Tropical and Subtropical Laboratory of Plant Agronomy and Ethnobotany, Faculty of Bioscience Engineering, University of Ghent, Coupure links 653, 9000 Ghent, Belgium.

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Euphorbia tirucalli **is one of the most important tree Euphorbias known worldwide for its many uses. Endemic to tropical Africa where it often grows wild, it is usually planted for boundary demarcation but also as a live fence around compounds, shrines and kraals due to its ability to withstand extreme aridity and possession of low herbivore pressure. *E. tirucalli* has white latex which is vesicant and rubifacient but also known to be a remedy against many ailments. However, most of its medicinal features are reported in folk medicine and there appears to be little medical/laboratory analysis to validate them. In this review, we attempt to explore the current knowledge status about *E. tirucalli* in relation to its classification, chemical content and functions, and the extent to which modern research has gone to validate them. It was found that although a great deal has been done to analyze its chemical composition (bark, roots and latex), and potential for biodiesel production, little is available on validation of its application for medicinal purposes, yet it continues to be used in traditional and alternative medicine on a daily basis. Empirical research is called for to achieve this.**

Key words: Ethnobotany, uses, folklore, ethnopharmacology.

INTRODUCTION

Euphorbia tirucalli L. belongs to genus *Euphorbia*, one of the 8,000 species within family Euphorbiaceae. It is a shrub or a small tree endemic to tropical areas with pencil-like branches from which it derives its vernacular name, the pencil-tree. *E. tirucalli* is generally evergreen since its stems and branches remain green all year round and are rarely fed on by herbivores. It bears white poisonous latex which may possibly account for the low herbivore pressure and medicinal features. According to agro forestry online data base (www.worldagroforestrycentre.org.), its common names in different languages include:

Amharic: Kinchib;
Arabic: Knjil;
English: Finger euphorbia, Indian spurge tree, milk bush, naked lady, pencil-tree, rubber euphorbia;
Filipin: Bali bali;
French: Arbre de Saint Sebastien, Euphorbe effile euphorbe, Garde maison, Tirucalli;
Malay: Kayu patah, Tentulang, Tulang, Tulang-tulang;
Somali: Dana;
Spanish: Alfabeto chino, Antena, Esqueleto, Palito, Aveloz;
Swahili: Mtupa mwitu, Mwasi, Utupa;
Thai: Khia cheen, Khia thian;
Ugandan: Kakoni (luganda), Oruyenje (runyankole);
Vietnamese: San h(oo) xanh, X(uw) (ow)ng c(as).

Classification

In the binomial system (USDA plants data at www.plants.usda.gov), *E. tirucalli* L. belongs to:

Kingdom: Plantae.
Division: Magnoliophyta.
Class: Magnoliopsida.

*Corresponding author. E-mail: mwinej@yahoo.com.

Plate 1. Red pencils of *E. tirucalli* specimens from US (New York State).

Order: Malpighiales.
Family: Euphorbiaceae.
Genus: *Euphorbia*.
Species: *E. tirucalli*.
Binomial name: *Euphorbia tirucalli* L.

According to the APG II system (Stevens, 2001), *E. tirucalli* L. belongs to:

Cladus: Eukaryota
Regnum: Plantae
Cladus: Angiospermae
Cladus: Eudicots
Cladus: Core eudicots
Cladus: Rosids
Cladus: Eurosids I
Ordo: Malpighiales
Familia: Euphorbiaceae
Subfamilia: Euphorbioideae
Tribus: Euphorbieae
Subtribus: Euphorbiinae
Genus: *Euphorbia*
Species: *E. tirucalli.*

The two forms of classification are independent but clearly show that *E. tirucalli* is taxonomically well understood at least up to species level. While classification from regnum to species is clear, no literature has been cited for the lower subdivisions such as subspecies, varieties and others. But referring to his 18 accessions/samples of *E. tirucalli* collected from different countries, Van Damme (2001) reports that there are some differences in vegetative structure in terms of relative dimensions of stems, leaves, general plant habit and growth rate, although no conclusive bio-chemical/molecular tests have been made to evaluate their genetic differences that would be a basis of classification. According to Van Damme (pers. comm.), differences are minor in most specimens except for the specimens from US, New York State, whose pencils/branches are yellow-red in colour while the rest are green. Our observation on these assertions at the Laboratory of Tropical and Subtropical Agronomy and Ethnobotany, University of Ghent, Belgium, revealed that some differences do exist. For example, specimens from Morocco and Senegal form thick, short and stocky whorls at branching which remain relatively closed, giving them a closed broom appearance even after opening up. On the other hand, specimens from Burundi, Kenya and Rwanda tend to form thin, elongate and more-open-at-base whorls. The former specimens show a higher canopy formation tendency than the latter. Ugandan specimens have similar appearances as those from Burundi, Kenya and Rwanda (Plates 2a and b). Also, as communicated by Van Damme earlier, young pencils of samples obtained from US (New York State) are bright yellow-red in colour and stand out from others which are green (Plate 1). It was not possible to make comparisons of the specimens in other features such as height, rate of growth, flowering, fruiting and others because the potted plants available were planted at different times. What is certain, however is that these variations are not just environmental differences since the specimens have been raised as cuttings under the same greenhouse conditions for over twenty years, yet the differences have persisted (Johan Geirnaert, greenhouse technician, pers. comm.).

This is suggestive of subdivisions within the species.

(a) (b)

Plate 2. ***E. tirucalli*** specimen from Morocco (closed-broom structure with a tendency for canopy formation (a) and *E. tirucalli* specimen from Burundi (open-broom structure with no observable tendencies for canopy formation (b).

More research is required to analyze more specimens and using proper methodologies to establish whether there is a need to subdivide the species into its lower taxonomic forms.

Plant description

Morphology of *E. tirucalli* has been extensively studied by Van Damme (1985, 1990, 2001). According to the latter author, *E. tirucalli* is an unarmed shrub or small tree that can grow 4 to 12 m high and about 15 to 20 cm in trunk diameter. Its branches are evergreen, longitudinal, succulent, about 7 mm thick and usually produced in whorls, rarely single, giving it a broom- like structure. Branches usually end in smaller pencil-like twigs, dull green to red green in colour, with fine white striations and produced in whorls of 2 to 6. Its young stem is green, photosynthetic with grooves which in fact are small canal-like structures containing stomata protected from extreme conditions. The stem stomatal frequency is estimated at 12 per mm^2 in grooves on older stem parts, while it may reach 40 per mm^2 on a smooth younger part of the stem. Older stems become rough, brown and lose their photosynthetic ability with age. Leaves are few, simple, scattered, entire, alternate, oblanceolate, about 1.3 to 2.5 cm long and 2 cm wide but broadest beyond the middle. They are present only at the tips of young branchlets. They have glandular, minute, dark brown stipules and are quickly deciduous (Van Damme, 1985, 2001) (Figure 1). According to the same author, inflorescences are stalkless and appear as yellowish heads in clusters of 2 to 6 cymes (Plate 3). The cymes produce a dense cluster of Cynthia that develop only male flowers and occasionally a few female flowers but in some plants, Cynthia are few and only female flowers develop. Cynthia have cup-shaped single sex involucres. Male involucres have bracteoles which are linear with plumose apices. Stamens are usually single per stalk and are about 4.5 mm long. Occasionally, an aborted female flower is present. In female involucres, the perianth is distinct and 3-lobed existing below a tomentose ovary which is lobular and about 0.5 mm long. The ovary is joined at the base with thickened bifid apices. Occasionally, a female flower exists within the involucres. Each involucre bears five independent nectaries that produce nectar and therefore flowers are insect-pollinated.

Fruits are glabrescent capsules on a tomentose pedicel, yellowish red when ripe and fall off easily. Seeds are ovoid, 3.5 × 2.8 mm in size, smooth, buff-speckled and with a dark brown ventral line. A caruncle exists which is about 1 mm across (Van Damme, 1985).

Figure 1. Twig of *E. tirucalli* showing position of leaves. Courtesy: Van Damme (1989).

Ecology and distribution

E. tirucalli is probably the best known and most widespread of all tree Euphorbia species (Gildenhuys, 2006). According to the same author, the plant's origin is not known but Van Damme (1989) and Schmelzer and Gurib-Fakim (2008) believe it originated from tropical East Africa and it is endemic in countries such as Angola, Eritrea, Ethiopia, Kenya, Malawi, Mauritius, Rwanda, Senegal, Sudan, Tanzania, Uganda and Zanzibar. The same authors intimate that the tree is currently widely distributed in southern Europe, Asia and the Americas having been steadily introduced due to its ornamental and medicinal features. *E. tirucalli* can survive in a wide range of habitats. Van Damme (2001) states that the plant can grow under conditions in which most crops and other trees cannot grow. They include: tropical arid areas with low rainfall, on poor eroded soils, saline soils and high altitudes up to 2000 m but cannot survive frost. Its distribution is therefore limited by low temperatures. He goes on to say that like some other Euphorbias, *E. tirucalli* combines the C3 and CAM photosynthetic pathways which could probably be the reason for its survival in hardier conditions. To clarify this, the same author explains that CAM pathway entails a higher carboxylic acid accumulation (than C3 plants) at night, raising the osmotic potential of the plant which increases its salt tolerance. Also, like other succulent plants, *E. tirucalli* stores extra water in the parenchyma and vacuoles which can be used to dilute salt ions entering the plant and as a reserve for survival in dry conditions. As a crop, *E. tirucalli* can be grown in a variety of areas since it is tolerant to a variety of conditions. Propagation is by cuttings (from any part of the shoot) which root with ease and quickly form a bush. Experiments show that *E. tirucalli* can be grown at a density of 10,000 to 20,000 plants per hectare at a spacing of 1 × 1 m whereas it coppices excellently at 20 to 30 cm height (www.hort.purdue.edu).

In many tropical areas, *E. tirucalli* grows wild often in abandoned sites of homesteads and kraals where they sometimes form thick woody vegetation tending towards a forest.

Chemical composition

E. tirucalli contains white milky latex in any part of the shoot. According to Kapaczewski (1947), the latex contains about 28% solid matter whose composition is: 21 to 27% water soluble substances, 59 to 63% resin-soluble substances and 12 to 14% rubber-like substances. The chemical composition of the different parts of the plant has been extensively studied and a variety of chemical compounds have been isolated from them. Table 1 shows some examples. This great variety of chemical substances listed reveals the complexity of *E. tirucalli* latex and may explain most of its functions. For example, low herbivore pressure, poisonous nature, pesticidal features and medicinal characteristics may all be attributed to this chemical constitution as follows:

Pests and disease

There is a tendency to believe that *E. tirucalli* has no pests and diseases because of its poisonous latex. However, a few pests including *Meloidogyne incognita* (Trivedi et al., 1986) *Cuscuta* spp. (the witch weed) (Van Damme, 2001) and *Botrytis* spp. (Yanxia et al., 2007) have been reported. The latter author notes that an infestation by *Botrytis* spp. causes the plant stem and roots to rot especially in warm and humid conditions. He

Plate 3. *E. tirucalli* efflorescence.

Table 1. Chemical diversity of *E. tirucalli* parts.

Chemical substance	Source (plant part)	Reference
4-deoxyphorbol di-ester	Latex	Kinghorn (1979)
Campesterol, Stigmasterol, Beta-sitosterol, Isofucosterol, Cycloartenol (sterols)	Stem callus	Uchida et al. (2010)
Cycloeuphordenol (triterpene)	Latex	Khan (2010)
Cyclotirucanenol (triterpene)	Latex	Khan and Ahmed (1988)
Diterpene ester	Latex	Khan and Malik (1990)
Euphol and beta-amyrin (triterpenoids)	Stem callus	Uchida et al. (2010)
Euphorbin A (polyphenol)	Stem	Yoshida and Yokoyama (1991)
Euphorcinol (pentacyclic triterpene)	Stem bark	Khan (1989)
Highly irritant euphorbia factors (not specific)	Latex	Furstenberger and Hecker (1977)
Serine proteases	Latex	Lynn and Clevett (1985)
Steroids	Latex	Nielson et al. (1979)
Taraxerane triterpene	Stem bark	Rasool (1989)
Tirucalicine (diterpene)	Latex	Khan (2010)
Tirucallin A (7) (tannin)	Stem	Yoshida and Yokoyama (1991)
Tirucallin B (11) and Euphorbin F (14) (dimers)	Stem	Yoshida and Yokoyama (1991)
Trimethylellagic acid	Latex	Chatterjee et al. (1977)

reports that a combination of *Meloidogyne* spp. and *Botrytis* spp. infestations can wipe out a whole field in a short time.

Uses of E. tirucalli

Traditional medicine: Possibly due to a great variety of chemical substances found in *E. tirucalli* tissues (Table 1), medical folklore literature of different parts of the world (especially tropical and subtropical areas where it is endemic) is tainted with its curative ability. According to Schmelzer and Gurib-Fakim (2008) and Van Damme (1989), in East Africa, latex is used against sexual impotence, warts, epilepsy, toothache, hemorrhoids, snake bites, extraction of ecto-parasites and cough among others. In Peninsular Malaysia, a poultice of the roots or stems is applied to nose ulceration, hemorrhoids

Plate 4. *E. tirucalli* potted plant as an ornamental.

and swellings. Root scrapings mixed with coconut oil are taken for stomach-ache. In India, Kumar (1999) notes that it is an unavoidable plant in most traditional homesteads and used as a remedy for ailments such as: spleen enlargement, asthma, dropsy, leprosy, biliousness, leucorrhoea, dyspepsia, jaundice, colic, tumors and bladder stones. He further says that although the latex of vesicant and rubifacient is emetic in large doses, it is purgative in small doses and applied against toothaches, earaches, rheumatism, warts, cough, neuralgia and scorpion bites. The same author points out that its branch and root decoctions are administered for colic and gastralgia while ashes are applied as caustic to open abscesses. Duke (1983) and Van Damme (1989) mention that, in Brazil, *E. tirucalli* is used against cancer, cancroids, epitheliomas, sarcomas, tumors and warts, although they argue that this has no scientific basis since the same tree is known to be co-carcinogenic. In Malabar (India) and the Moluccas, latex is used as an emetic and anti-syphilitic while in Indonesia, the root infusion is used for aching bones while a poultice of roots or leaves is used to treat nose ulcers, hemorrhoids and extraction of thorns. Wood decoctions are applied against leprosy and hands and feet paralysis following childbirth (Duke, 1983). The same author states that in Java, the plant latex is used to cure skin ailments and bone fractures.

Ornamental: *E. tirucalli* has increasingly become popular as an ornamental plant. Potted plants are placed in offices (Plate 4) and homes but can also be grown in lawns. It is preferred for its ease of maintenance and beautiful evergreen pencil-like branches which factors have increased its international trade resulting into a wide distribution in areas where it was not endemic. An extract of a report of the 17th meeting of the Convention on International Trade in Endangered Species of wild fauna and flora (CITES) plants' committee held in Geneva (Switzerland), 15 to 19 April 2006 (Table 2) shows that *E. tirucalli* trade is booming. Possibly for a similar reason, the same report classifies it as an endangered species which should be protected. However, the latter conclusion was challenged by Van Damme and the Belgian CITES committee members (Van Damme, pers. comm.). Probably in recognition of this challenge, *E. tirucalli* is presently listed among the 'least concerned' category of the International Union for Conservation of Nature (IUCN) red-list of threatened species 2010.3 (www.iucnredlist.org).

Source of energy: Duke (1983) and Calvin (1978, 1979) report that latex of *E. tirucalli* is composed of petroleum-like hydrocarbons largely C30 triterpenoids (Table 1), which on cracking yield high-octane gasoline. They estimate a crude gasoline yield between 4 and 8 barrels per hectare from an *E. tirucalli*-planted field per year; and calculated at about three dollars per barrel, it is three

Table 2. International trade figures of *E. tirucalli*.

Plant part	Source/country	2000	2001	2002	2003	2004	2005	2006
Extract (g)	Vietnam				36			
Leaves (g)	USA		4000					
Leaves (g)	Madagascar				3			
Plants	Kenya	32			12			
Plants	Belgium		23					
Plants	Brazil	4950	10000	2000	10000	10000		
Plants	Canada						204	
Plants	China			220				
Plants	USA	7481	10240	9163	20296	12935	14677	19396
Plants	Denmark							5000
Plants	Dominican Repub.	2500	1270			4200	3000	14239
Plants	Spain			165		331	80	
Plants	Haiti					108		
Plants	Netherlands	12500	6500	3000		100		
Plants	Madagascar	30			2			
Plants	Poland		1750	3040	3770	6450	17400	1100
Plants	Thailand				5			
Plants	Zambia	6		3	1		80	
Totals	All sources	27499	29788	17426	34251	34124	35441	39735

Source: CITES convention report on Euphorbias (2006).

times cheaper than normal crude oil. These postulations were validated by Calvin (1980) and although they were found to be true, extraction projects to this time have never materialized. However, *E. tirucalli* is still looked at as a potential source of biodiesel as it can produce a high biomass and grow in marginal areas unfit for production of other crops. Of late, there has been increasing attention on biodiesel production in order to reduce over-dependence on fossil fuel (Prusty, 2008). While agreeing with such a venture, Eshel et al. (2010) warn that emphasis should be put on non-food sources (such as *E. tirucalli*) to avoid hunger that can result from the use of food crops as a source of biodiesel. Associated with biodiesel production is methane and biogas generation; Rajasekaran et al. (1989) and Van Damme (1990), considering its reported high biomass production and ease with which it ferments, note that it is a potential source of methane and biogas. Sow et al. (1989) experimentally demonstrated that *E. tirucalli* produces suitable biomass for biogas generation especially through chopped material under thermophilic conditions which can yield 1.06 l/day of biogas in just 19 days. Based on estimations from research carried out near Lake Baringo (Kenya), with 80,000 plants per hectare yielding 20 dry metric tons per year, they estimated *E. tirucalli*'s potential annual methane production (with a continuous digester), at around 3,000 m^3 per year, equivalent to approximately 3,000 1 of fueloil. The same authors estimated production of about 100 metric tons of compost per year as a byproduct. Other forms of energy associated with high *E. tirucalli* biomass are fuelwood and charcoal. Van Damme (1989, 2001) names the provision of charcoal and fuelwood among its traditional uses. He further explains that the plant's ability to grow in semi-arid areas, devoid of forests, makes it one of the few alternatives for fuelwood production in such situations.

For the same reason, it has been recommended for commercial fuelwood production projects for purposes of woodlot restocking in semi-arid parts of Kenya (Mahiri, 2002). Mahiri (1998) points out that *E. tirucalli* is preferred for this purpose due to its fast growth rate, high productivity, quick acclimatizion to an area and ease with which it dries.

Source of rubber: *E. tirucalli* is reported for possessing hydrocarbon polymers that are used for manufacturing rubber substitutes. Several researchers point out that its latex is an emulsion of terpenes and resins in water which can easily be transformed into rubber at low cost (Calvin, 1979; Uzabakiliho et al., 1987; Van Damme, 1990). The same authors further report that during the Second World War, its latex was used in South Africa to develop a rubber substitute which proved unprofitable and due to high resin content, could not yield high quality rubber. Also, due to the strong fixative power of the resin, it has for long been used on the East African coast in local gum manufacture for fastening knife-blades to wood handles and spear-heads to shafts (Van Damme, 1989). In the same view, Murali (1998) notes that the resin produces comparably good wood-based glue and adhesives whereas with a few modifications, it would compete favourably with other commercial resins.

Conservation and agroforestry: Due to its favourable agronomic features such as drought resistance, *E. tirucalli* is used in semi-arid areas to carry out afforestation and re-forestation for purposes of achieving soil conservation. Van Damme (2001) in the book ‘combating desertification with plants’ points out that such plants can be used as a soil cover in places where other plants (even grasses) cannot grow. Involvement of *E. tirucalli* has been mentioned in successful reforestation and conservation programs in: Tanzania (Smith et al., 1996), Kenya (Macharia, 2004; Mahiri, 2002) and Sri Lanka (Melvani, 2009) among others. It has also featured in agroforestry programs (Jama et al., 2003; Long and Nair, 1999; Mbwambo, 2004) as a hedge plant or as an intercrop. Other related uses of *E. tirucalli* include: boundary demarcation (Kindt et al., 2006; Van Damme, 1989), live fencing around compounds and kraals (Nascimento et al., 2009; Simons et al., 2004; Van Damme, 1989), cultural connotations for example as a sign of starting a new home in Luo culture of East Africa (Mahiri, 1998) and as a windbreak in semi-arid areas (Jama et al., 2003). Simons (2004) points out that the plant plays these roles due to its latex toxicity and hence low herbivore pressure.

Pesticides: *E. tirucalli* latex has been reported to have pesticidal features against such pests as aphids (*Brevicoryne brassicae*) (Mwine and Van Damme, 2010), mosquitoes (*Aedes aegypti* and *Culex quinquefasciatus*) (Rahuman et al., 2008), micro-organisms such as bacteria (*Staphylocococcus aureus*) (Lirio et al., 1998) and molluscs (*Lymneae natalensis*) (Vassiliades, 1984) and *Biomphalaria gabrata* (Tiwari, 2006) among others. Siddiqui et al. (2003) report a dose-dependent latex toxicity to parasitic nematodes such as *Haplolaimus indicus*, *Helicotylenchus indicus* and *Tylenchus filiformis in vitro*, with increasing exposure period, although some nematodes like *Meloidogyne* spp. are known to attack the plant. The latex is also reported to be a hunters’ tool applied in local fishing and arrow poisoning in tropical Africa (Neuwinger, 2004). Piscicidal feature has been validated by Kumat (1995) and Tiwari (2006). Although the plant is generally mentioned as a pesticidal plant; scanty experimental work has been performed to confirm this.

Disuses

A number of disuses have also been mentioned. Associated with its vesicant and rubifacient features, *E. tirucalli* latex is reported to cause conjunctivitis (Hsueh et al., 2004; Joshi and Shingal, 2008; Scott and Karp, 1996; Shlamovitz et al., 2009) when it accidentally gets in contact with the eyes. Eke et al. (2000) report that symptoms range from mild epithelial keratoconjunctivitis to severe keratitis with stromal oedema, epithelial sloughing and anterior uveitis which usually heal in 2 to 7 days but can also result into permanent blindness. They advise that it should be handled with caution. Research also shows that *E. tirucalli* is co-carcinogenic. Roe (1961) observed that papillomas and malignant tumors were elicited in mice treated with acetone extracts of *Euphorbia* lattices. Mizuno (1986) reports a high incidence of Burkitt's lymphoma - a latent Epstein-Barr virus (EBV) malignancy in East Africa where *E. tirucalli* is endemic. EBV causative factors were detected in soil and drinking water (where *E. tirucalli* grows) implying that people living in such areas run a high cancer risk. The findings have been further clinically validated in rats (Fürstenberger and Hecker, 1985; Imai et al., 1994; MacNeil et al., 2003; Silva et al., 2007); some of which developed full blast lymphomas. However, folklore reports anti-cancer treatment by the latex (Cataluna and Rates, 1999), and there are scientific indications that it may modulate myelopoiesis and enhance resistance against tumor bearing (Valadares et al., 2006), both of which are suggestive of a cancer cure. *E. tirucalli* is known to be an irritant to herbivores and due to its nasty and acrid features, most herbivores learn to avoid it. Howes (1946) and Simons et al. (2004) point out that this is one of the reasons why it is a good live fencing material. Conclusively, *E. tirucalli* is a miracle tree. This is undoubtedly expressed by the vast number of uses cited. Evidently, quite a lot has been done on exploration of its chemistry and evaluation of its potential as an energy plant. However, most of the medicinal uses mentioned have been left to folklore and need validation. For example, in spite of the vast number of ailments it is reported to cure, to our knowledge, no substance of pharmaceutical importance has so far been obtained from it. Also scanty literature has been cited on validation of other functions like the reported insecticidal, nematicidal, piscicidal and molluscicidal features. This calls for more research/laboratory investigation, in order to establish scientific authenticity of these important functions and to ascertain with confidence that *E. tirucalli* is a wonder plant for modern science.

It remains a research issue whether people should continue to use *E. tirucalli* for the mentioned uses but as it were, many societies have always applied it and will continue to do so until its effects are scientifically proved dangerous. Table 2 indicates that most of the exporting countries are not countries of *E. tirucalli* endemicity which reveals how widespread and widely grown it has become.

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