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A survey of geographical distribution and host range of white mango scale, *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) in Western Ethiopia

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White mango scale (WMS) is a sucking insect which poses severe threat to mango plantation. A survey of the distribution and host range of WMS, *Aulacaspis tubercularis* was conducted in western Ethiopia from May 10, 2016 to July 15, 2016. The surveys were started from Loko village, the focus of its first record, and extended over series of mango farms in the four cardinal directions. This study showed that WMS has already spread from Loko, the focus of its first record in the four cardinal directions. It spread over the air distances of 97, 98, 92 and 43 km to the east, south, west and north directions, respectively, with high and very high levels of severity statuses in most of the localities surveyed. It was found out that mango was the only host for WMS in western Ethiopia. It is recommended that understanding the mechanism by which WMS is spread is crucial to controlling it.

Key words: Infestation, Loko, severity, survey, Wollega, distance.

INTRODUCTION

Mango, *Mangifera indica* L., is widely consumed as a fresh fruit and various forms of beverages for its high contents of sugar, protein, fats, salts and most of the vitamin types (Griesbach, 2003; Nabil et al., 2012). Mango is grown in many parts of Ethiopia, of which most of the productions come mainly from the Rift Valley, western and south western areas (Honja, 2014). Mango production in Ethiopia is at small scale level with primary purposes of family consumption and local markets; whereas, very few modern farms produce mango for fresh fruit export (Chala et al., 2014).

Mango production in Ethiopia was reported to have been constrained by a variety of insect pests and pathogens. These include the fruit fly complex, termites, thrips and various fungal diseases, among others (Hussen and Yimer, 2013; Tucho et al., 2014; Bezu et al.,

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2014).

Infestation of a new insect pest on mango was reported in 2010 from an orchard owned by Green Focus Ethiopia LTD, an Asian company located at Loko village in western Ethiopia, which was later identified at California Department of Agriculture as white mango scale (WMS), *Aulacaspis tubercularis* Newstead (Hemiptera: Diaspididae) (Dawd et al., 2012). It was stipulated that the insect could most likely be introduced to Ethiopia accidentally from Asia, with the mango seedlings imported by the aforementioned company. WMS spread from the focus of its first record to western Ethiopia and constrained mango production (Fita, 2014; Dako and Degaga, 2015).

WMS is distributed throughout the world wherever mango grows (USDA, 2007, El-Metwally et al., 2011, Ha et al., 2015). These include northern part of South America, the Caribbean, the east and west coasts of Africa, Asia, and Italy, among others. Benin, Ghana, Kenya, Madagascar, Mauritius, South Africa, Tanzania, Uganda, Zimbabwe and Zanzibar, are among 21 African countries from where WMS infestation on mango was confirmed (Germain et al., 2010; Haggag et al., 2014, Hodges and Harmon, 2016).

Infestation of WMS causes discolouration of mango fruit, leaves fall off, dieback, retarded host plant growth and death of the young mango trees (El-Metwally et al., 2011; Nabil et al*.,* 2012; Abo-Shanab, 2012). Heavy WMS infestation causes development of conspicuous pink blemishes on the fruit skin and affects export potential of the fruit and may eventually result in economic loss (USDA, 2006). Some sources indicated that infestation of WMS is not limited to mango plantation. Accordingly, Malumphy (2014) asserts that WMS is a polyphagous pest which feeds on plants belonging to 18 families. On the other hand, Borchsenius (1966) cited from Abo-Shanab (2012) said that WMS has been recorded from four plant families, namely Palmae, Lauraceae, Rutaceae, and Anacardiaceae. Erichsen and Schoeman (1992) reported that WMS was found feeding on avocado in South Africa. There has been very limited or no data on the geographical distribution of WMS in western Ethiopia, and moreover there has been no study performed on the host range of the pest in the region. Therefore, this study was conducted with the objectives of identifying host range of WMS and preparing its distribution map in western Ethiopia, which are immediate requirements for management practices of the pest.

MATERIALS AND METHODS

Study area

The surveys on geographical distribution and host range of WMS were conducted from May 10, 2016 to July 15, 2016 in four adjacent administrative zones of Oromia National Regional State in western Ethiopia. These included West Shoa, Illubabor, East and West Wollega Administrative Zones. Most of the western Ethiopian regions receive bimodal pattern of rainfall. The monthly average precipitations during the study period were 170 and 310 mm for May and July, respectively (Ethiomet, 2016). The minimum and maximum monthly temperatures were 16 and 31°C for May and July, respectively. Likewise, July had monthly minimum temperature of 15°C and a maximum monthly temperature of 28°C during the study period.

Study design and sampling procedures

Survey on the geographical distribution of WMS was started from Loko Kebele Administration, Guto Gida district of East Wollega administrative zone (09° 19.226' N and 036° 31.619' E) which was the focus where WMS was first recorded in Ethiopia. The survey was extended toward the four cardinal directions as shown in Figure 1. Since the mango farms in the study area were patchy in distribution or not continuous, farms at spots within intervals of 25 to 40 km land distance were considered for sampling. The mango trees were broadened at base and tapered upward and as a result, a total of ten leaves (4 from lower, 3 from central and 3 from upper canopies) were picked from every mango tree purposively selected from the central position within each farm. Female WMS was observed by hand lens, and its number recorded. Sampling continued as far as there were mango farms and infestation of WMS along, but terminated where there was no mango plantation or no infestation, after the land distance of about 50 km from the spot of the last sampling. However, considering a prior report on fast spread of the pest toward the west (Fita, 2014), survey continued in that direction up to a distance of about 100 km from the last spot of confirmed infestation.

For survey of alternative host of WMS, fields covered with vegetation, both natural forest and agricultural fields were purposively selected from the four administrative zones in the study area. Altitudinal variation was considered as the main reference to include as many vascular plant species as possible (Hurni, 1998; Cavieres et al., 2000; Fosaa, 2004; Habib et al., 2011). Sampling began from Loko and addressed five additional districts in the study area. During the assay, whether vascular plants other than mango were infested by WMS or not were investigated. For this purpose, 50 leaves, 10 twigs and 5 fruits (when present) found at different heights were cut from every vascular plant found within the proximity of infested mango trees and checked by hand lens for the presence/absence of WMS. Assessment diameter was broadened in all directions by 10 m successive intervals and terminated at about 100 m distance from the starting spot. Moreover, infestation of WMS of vascular plants found within the vicinity of infested mango farms were checked at roadside farms, while travelling within the study area for the survey. In the meantime, plant samples investigated for probability of infestation of WMS were collected, pressed and mounted, and taken to Addis Ababa University, Department of Plant Biology and Biodiversity Management, National Herbarium of Ethiopia for identification. During the surveys, coordinates and altitudes of each sampling site were recorded by the use of GPS.

Data analysis

Geographical distribution

ArcGIS 10.4 was used for spatial data management and mapping of WMS distribution (http://www.esri.com/arcgis). Relative frequency of WMS occurrence at each locality (mango farm) was calculated by the use of equation adopted from Kataria and Kumar (2012). This value was used to define severity index from which severity status at each farm was determined as indicated in Table 1.

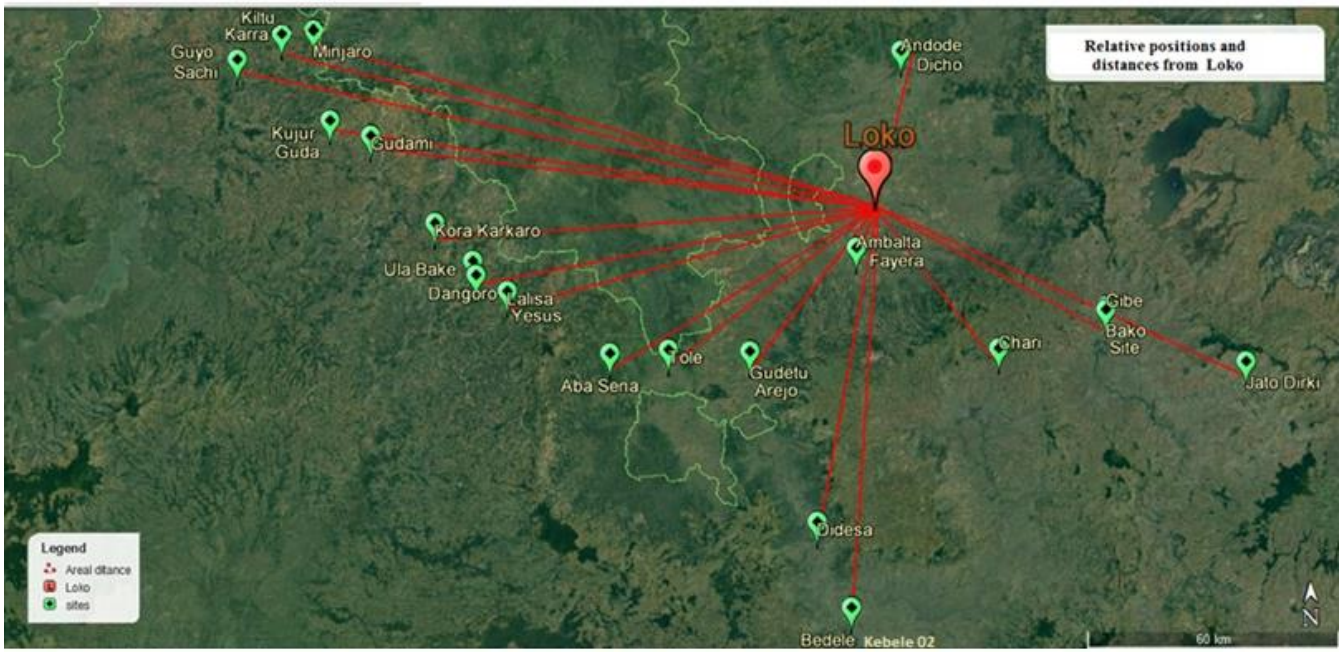

Figure 1. Spatial design of WMS distribution survey in western Ethiopia.

Table 1. Method of data summary used for determination of WMS severity status.

Relative frequency of mango scale occurrence	Severity index	Grades of severity status
0	0	No infestation
1-5	1	Mild infestation
6-10	2	High infestation
≥ 11	3	Very high infestation

$$\text{Relative frequency of WMS occurence} = \frac{\text{Number of WMS recorded per mango farm}}{\text{Total number of WMS recorded from survey area}} \text{X100}$$

Mean numbers and standard deviations were used to show the spread of mango scale within each administrative zone.

Host range

Samples of the vascular plants checked for occurrence of WMS infestation were sorted out and classified to species level. Summarized data regarding presence/absence of WMS on the plants was presented.

RESULTS

Geographical distribution

From 20 localities of the 15 districts surveyed for WMS in western Ethiopia, 13 localities found in 11 districts were confirmed to have been infested by the pest as shown in Figure 2. WMS was found already spread to the surrounding areas of Loko, up to the maximum air distances of 97, 98, 92 and 43 km to east, south, west and north directions, respectively. There was no mango farm in the east beyond Jato Dirki of Illu Gelan district and to the north in the neighbouring villages of Andode Dicho of Gida Ayana district, and as a result, survey was terminated provisorily.

The pattern of spread of WMS within each administrative zone was found to be irregular as can be seen from relative sizes of means and their standard deviations as shown in Table 2. Such irregular distribution was found to be more evident in West Wollega.

Severity status

Severity status of WMS was found to be high and very high in most of the survey localities in all the directions, except to the east where infestation was only mild as presented in Table 3. The numbers of female WMS

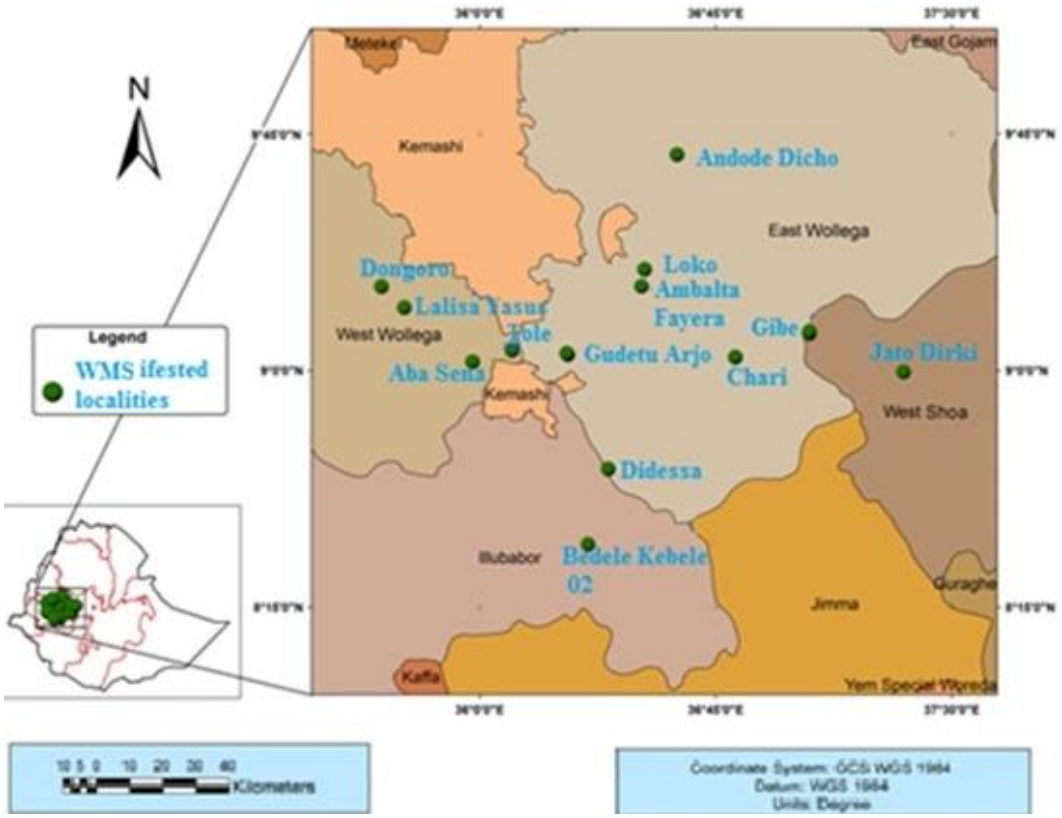

Figure 2. Distribution map of WMS in western Ethiopia.

Table 2. Mean numbers of female WMS per leaf within each administrative zone in western Ethiopia.

Administrative zone	Mean±SD
East Wollega	35.00±26.10
Illubabor	45.90 ±19.03
West Shoa	5.00±5.40
West Wollega	16.90±24.50

recorded per 10 leaves showed big differences among the localities; the maximum being 723 at Didessa locality, while the minimum was 32 at Chari locality.

Host range

A total of 120 plant samples in fields located within altitudinal gradients ranging from 1150 to 1755 m.a.s.l. were checked for WMS infestation. No WMS infestation was detected from any of the plants checked in the whole survey area. The plants were classified into 25 species and presented in Table 4.

DISCUSSION

WMS has spread from Loko, the locus of its first record in Ethiopia to all cardinal directions. Spread of WMS in south direction covered about 98 km air distance. In the west, it was recorded from Dongoro locality in Lalo Assabi district, which is found at air distance of about 92 km from Loko. However, the spread of WMS infestation didn't pass beyond 67 km air distance from Loko to the west, two years before this investigation as depicted by a survey conducted in the area (Fita, 2014). This shows that WMS is spreading very fast in western Ethiopia. It is therefore possible to realize that there are enabling environmental conditions for WMS to spread and establish its population in western Ethiopia, as far as there is mango plantation. The rate of establishment, dispersal and colonization of alien invasive species in a new habitat is likely to become tremendous when the new environment is bioclimatically favourable to the pests (Satti, 2011; Pratt et al., 2017).

Table 3. Severity status of white mango scale in western Ethiopia.

District	Locality/mango farm	Altitude (m.a.s.l)	Location		Female WMS/10 leaves	Severity index	Severity status
			North	East			
Ilu Gelan	Jato Dirki	1747	08° 59.74'	037° 20.973'	58	1	Mild
Bako Tibe	Gibe	1612	09° 07.409'	037° 03.025'	58	1	Mild
Sibu Sire	Chari	1748	09° 02.567'	036° 48.935'	32	1	Mild
Sasiga	Ambalta Fayera	1565	09° 16 .006'	036° 31.032'	418	3	Very high
Guto Gida	Loko	1375	09° 19 .226'	036° 31.619'	596	3	Very high
Gida Ayana	Andode Dicho	1483	09° 41.013'	036° 37.794'	336	2	High
Diga	Gudetu Arjo	1320	09° 03.277'	036° 16.824'	368	2	High
Dabo	Didessa	1278	08° 41.339'	036° 24.72'	723	3	Very high
Bedele	Bedele Kebele 02	1988	08° 27.001'	036° 20.863'	431	3	Very high
Gimbi	Tole	1150	09° 03.840'	036° 06.364'	425	3	Very high
Gimbi	Aba Sena	1698	09° 01.687'	035° 58.88'	311	2	High
Gimbi	Lalisa Yasus	1821	09° 11.971'	035° 45.855'	37	1	Mild
Lalo Assabi	Ula Bake	1887	09° 14.146'	035° 41.893'	0	0	No infestation
Lalo Assabi	Dongoro	1857	09° 15.957'	035° 41.524'	47	1	Mild
Boji Dirmaji	Kora Karkaro	1800	09° 20.964'	035° 36.774'	0	0	No infestation
Nedjo	Gudami	1936	09° 32.397'	035° 28.770'	0	0	No infestation
Nedjo	Kujur Guda	1713	09° 34.535'	035° 23.538'	0	0	No infestation
Kiltu Karra	Minjako	1647	09° 41.123'	035° 19.601'	0	0	No infestation
Kiltu Karra	Kiltu Karra	1635	09° 41.490'	035° 15.817'	0	0	No infestation
Manasibu	Guyo Sachi	1597	09° 42.789'	035° 11.635'	0	0	No infestation

The absence of mango farm beyond Andode Dicho to the north and Jato Dirki to the east directions restricted spread of WMS beyond these localities. Even though mechanisms by which WMS could spread in west Ethiopia was not assessed under the current study, it can be deduced that active wandering of the crawler alone cannot be a possible explanation for its dispersal over such long distances. Magsig-Castillo et al. (2010) stated that the first instar active crawlers of diaspidides can wander a distance of less than one metre before settling to establish a new population. Beardsley and Gonzalez (1975) on the other hand, stated that wind, birds, insects and other animals including man can serve as accidental dispersal carriers for armoured scale crawlers. WMS may also be dispersed through mango fruit marketing among localities in western Ethiopia. It was shown that female WMS infestation of mango fruit is at its peak when the fruit is ripe and ready for sale in western Ethiopia (Dako and Degaga, 2015), an encouraging condition for the pest to be transported with the ripe-and-ready fruit for marketing.

Distribution patterns of WMS within each administrative zone were not regular. Moreover, there were differences in severity status of the WMS among the localities, which may indicate the probable presence of factors that may affect the insect pest populations at local habitat level differently. The fact that most of the observed *very high* severity statuses were localized at relatively lower altitudes, except at Bedele Kebele 02 of Illubabor zone, may be a clue for further study in this regard.

In this study it was noted that mango plantation is the only host plant for WMS in western Ethiopia. Contrary to this finding, WMS was reported to have been infesting plants other than mango in different countries (Erichsen and Schoeman, 1992; Hodges et al., 2005; Malumphy, 2014). In line with this, Hodges and Hamon (2016) stated that plant species found under families Sapindaceae and Rutaceae served as host plants for WMS. In this study, however, *Casimiroa edulis* La Llave from Rutaceae and *Blighia unijugata* Bak from Sapindaceae were confirmed not to have been infested by the WMS across the study area. Erichsen and Schoeman (1992) listed avocado (*Persea americana* Mill.) among the fruits infested by WMS in South Africa. However, it has been confirmed by this study that avocado has not been infested by WMS, though found intercropped with mangos already infested by the pest at Chari field in Sibu Sire district of East Wollega, and in other observed roadside farms. Host plant abundance is known to positively influence host plant use, in both specialist and generalist herbivorous insects (West and Cunningham, 2002; Nobre et al., 2016). Likewise, abundance of mango plantation may be one possible explanation for the plant to have been preferred as host plant by WMS in western Ethiopia. It is indicated that western Ethiopia is one of the most known mango producing regions in the country (Ethiopian Ministry of Agriculture and Rural Developmant, 2009; Honja, 2014) and as a result, WMS crawlers could

Table 4. Vascular plants checked for WMS infestation and survey results in western Ethiopia

Coordinate		Altitude (m.a.s.l.)	Botanical Name	Family name	WMS
North	East				
09° 07.409´	037° 03.025´	1612	*Cordia africana* Lam.	Boraginaceae	Nr
09° 07.409´	037° 03.025´	1612	*Solanum incanum* L.	Solanaceae	Nr
09° 07.409´	037° 03.025´	1612	*Croton macrostachyus* Del.	Euphorbiaceae	Nr
09° 07.409´	037° 03.025´	1612	*Jacaranda mimosifolia* D. Don	Bignoniaceae	Nr
09° 02.542´	036° 48.940´	1755	*Casimiroa edulis* La Llave	Rutaceae	Nr
09° 02.567´	036° 48.935´	1748	*Persea americana* Mill.	Lauraceae	Nr
09° 02.567´	036° 48.935´	1748	*Coffea arabica* L.	Rubiaceae	Nr
09° 02.567´	036° 48.935´	1748	*Psidium guajava* L.	Myrtaceae	Nr
09° 19.226´	036° 31.619´	1375	*Carica papaya* L.	Caricaceae	Nr
09° 19.226´	036° 31.619´	1375	*Vernonia amygdalina* Del.	Asteraceae	Nr
09° 19.226´	036° 31.619´	1375	*Syzygium guineense* (Willd.) DC.	Myrtaceae	Nr
09° 19.226´	036° 31.619´	1375	*Sapium ellipticum* (Krauss) Pax	Euphorbiaceae	Nr
09° 19.226´	036° 31.619´	1375	*Trichilia dregeana* Sond.	Meliaceae	Nr
08° 41.339´	036° 24.702´	1278	*Euphorbia cotinifolia* L.	Euphorbiaceae	Nr
08° 41.339´	036° 24.702´	1278	*Lonchocarpus laxiflorus* Guill. & Perr.	Fabaceae	Nr
08° 41.339´	036° 24.702´	1278	*Senna didymobotrya* (Fresen.) Irwin and Barneby	Fabaceae	Nr
08° 41.339´	036° 24.702´	1278	*Ficus sycomorus* L.	Moraceae	Nr
08° 41.339´	036° 24.702´	1278	*Grewia mollis* A. Juss.	Tiliaceae	Nr
08° 41.339´	036° 24.702´	1278	*Piliostigma thonningii* (Schumach.) Milne-Redh.	Fabaceae	Nr
09° 03.227´	036° 16.824´	1320	*Ficus carica* L.	Moraceae	Nr
09° 03.227´	036° 16.824´	1320	*Combretum* sp.	Combretaceae	Nr
09° 03.227´	036° 16.824´	1320	*Bridelia micrantha* (Hochst.) Baill.	Euphorbiaceae	Nr
09° 03.227´	036° 16.824´	1320	*Flueggea virosa* (Willd.) Voigt.	Euphorbiaceae	Nr
09° 03.840´	036° 06.364´	1150	*Bridelia micrantha* (Hochst.) Baill.	Euphorbiaceae	Nr
09° 03.840´	036° 06.364´	1150	*Blighia unijugata* Bak.	Sapindaceae	Nr

Nr = Not recorded.

probably find mango plantation easily and settled. Studies confirmed that some phytophagous insects showed host switching between plants in relation to nutritional quality for survival, nymphal development and reproductive performances of the adults (Velasco and Walter, 1993; Mody et al., 2007). The fact that only mango was infested by WMS within farms containing other plants which were formerly reported to have been host of WMS in other countries may mean that mango is a preferred host for WMS in western Ethiopia. However, comparative analysis of nutritional quality of mango and other plants was not within the scope of the current study.

Conclusion

It is possible to see that WMS is spreading very fast and has already covered mango farms over large geographical areas in western Ethiopia, with high and very high severity status in most cases. The trend of the spread is a reminder of urgency for devising and implementing control measures.

This study concludes that mango plantation is the only host plant for WMS in western Ethiopia. Further studies are required to elucidate the reason for such single host preference of the pest in presence of other potential host plants in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests

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