

TITLE OF REPORT: INTERIM PROGRESS REPORT FOR CDFA AGREEMENT NUMBER 15-0286-SA

TITLE OF PROJECT: BROWN MARMORATED STINK BUG RISK AND IMPACTS IN WESTERN VINEYARDS

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Daane, Wiman and Walton will collaborate towards creating a feeding intensity index. Kent Daane, and Frank Zalom will conduct and coordinate regional data collection. Monica Cooper, Lucia Varela, Kent Daane, Vaughn Walton, Nik Wiman and Frank Zalom, will conduct extension outreach activity. Vaughn Walton and Nik Wiman will, conduct and coordinate, statistical analysis, reporting, paper and extension publications.

TIME PERIOD COVERED BY REPORT

The results reported here are from work conducted July 2015 to July 31, 2016.

INTRODUCTION

Brown Marmorated Stink Bug, *Halyomorpha halys* (Stål) (BMSB, Hemiptera: Pentatomidae) is becoming increasingly prevalent in Oregon and is rapidly becoming an economic concern for western vineyards (Oregon Department of Agriculture 2011, Wiman et al. 2014a, CDFA PD/GWSS Board 2015 RFA). This pest can feed on vegetative tissues, grapes, and can potentially cause contamination of the crop, leading to wine quality losses. Studies funded by a USDA-SCRI CAP grant confirmed spread and increased population levels of *H. halys* in important viticulture regions of Oregon (VMW et al. unpub.). *H. halys* was first found on the west coast in 2004 in Portland (Oregon Department of Agriculture 2011), and the pest is now common in urban and natural areas. Found on high-value specialty crops and non-economic alternate host plants alike, BMSB is increasingly causing agricultural issues for growers (Fig. 1). Since 2012, BMSB has increasingly been encountered by growers and can be found in wine grape vineyards of the Willamette Valley during the harvest period (Wiman et al. 2014a). Winemakers have recently reported finding dead BMSB in fermenting wines and infestation of winery buildings by BMSB.

Immature and adult *H. halys* feed on reproductive plant structures such as fruits, and they may also feed on vegetative tissues, such as leaves and stems, sometimes piercing through bark (Martinson et al. 2013). Fruit feeding by adult BMSB may cause direct crop loss due to berry necrosis (VMW, SCRI CAP grant report 2013). Berry feeding may also result in secondary pathogen infection and provide entry points for spoilage bacteria. Vectoring and facilitation of pathogen proliferation by BMSB is not unrealistic because true bugs (Heteroptera) such as BMSB share feeding behaviors with homopterans implicated as disease vectors in vineyards (Cilia et al 2012, Daugherty 1967, Mitchell 2004, Wiman et al 2014a). BMSB itself is a demonstrated vector of at least one phytoplasma disease (Hiruki 1999, Weintraub and Beanland 2006), while leaf-footed bugs (Heteroptera: Coreidae) and other pentatomids have also been implicated in transmission of pistachio stigmatomycosis (Michailides et al 1998). It is clear that BMSB feeding intensity and associated pathogen infection is directly related to temperature (Wiman et al. 2014b), potentially making this pest more damaging in western production regions than on the east coast.

Brown marmorated stink bug can develop on a wide range of host crops, meaning that it can find refuge or reproduce on non-crop hosts and then spread to cultivated crops such as wine grapes (Nielsen et al. 2008, Nielsen and Hamilton 2009, Leskey et al. 2012a, 2012b, Pfeiffer et al. 2012, VMW SCRI CAP report 2014). However, unlike other pentatomids, BMSB are also capable of completing development on crop plants. As a result, crop damage from nymphs is more common than it is for other stinkbugs. In the Willamette Valley, wine grapes are among the last crops to be harvested and this may increase the potential for late-season infestation and damage by BMSB.

Contamination of grape clusters by BMSB at harvest is a major concern. Adult BMSB have been observed to lodge themselves between the grapes during harvest. Work funded by USDA NWCSFR is evaluating physical removal of BMSB from clusters, as well as removal by chemical cleanup sprays, blowers and electronic sorters. However, some BMSB may remain in grape clusters and release defensive compounds during processing, causing taint in finished wine (E. Tomasino pers comm.). These taints are persistent, and may result in major market losses. Work conducted on Pinot noir has shown that trans-2-decenal, a defense compound produced by BMSB, is a contaminant present in wine that is processed with BMSB.

As in Oregon, many important wine grape growing regions of California are in close proximity to major urban centers where BMSB populations tend to increase and become sources for further spread. Little is known about BMSB seasonal phenology, voltinism, and distribution in these environments. Oregon research has documented rapid colonization and significant increases in populations between seasons, in part because two full generations of BMSB are occurring (NGW, unpublished). In Oregon, BMSB has dispersed from Portland to northern Willamette Valley vineyards within a short period. It is important to survey the wine grape growing regions of Napa, Sonoma, and Lodi because these regions are geographically close to San Francisco and Sacramento, both areas with known BMSB infestation.

Feeding intensity of different life stages of BMSB in vineyards has not been fully determined. To date, most studies have focused on adults, even though nymphs are potentially more damaging. When BMSB egg masses are laid in vineyards, the nymphs are more confined to feed on the vines than the adults, which may fly back and forth between vineyards and borders. Thus, the feeding damage from nymphs may be more concentrated as the nymphs disperse from egg masses to feed on the host plant. No information is available, however, on the impact and severity of feeding by nymphs on grape berries and vines. Spatial distribution of BMSB in vineyards and feeding intensity may reflect environmental suitability. An observation from orchard crops is that the worst BMSB damage tends to occur on the borders (Joseph et al. 2014). Similarly, vineyard borders appear to be more susceptible to BMSB infiltration from surrounding vegetation (VMW, SCRI CAP report 2014). Grapevines located close to vineyard borders may provide a better environment for the bugs due to microclimate effects of shading by surrounding vegetation. The observation that insect-vectored pathogen problems in vineyards also tend to begin at field margins (VMW, SCRI CAP report 2013) suggests spatial overlap with BMSB and raises additional concerns.

This proposed study will help to determine the potential for BMSB to cause direct damage to wine grape crops, as well as indirect damage through facilitation and vectoring of spoilage bacteria or vine diseases. Controlled damage studies to assess direct feeding damage by BMSB have been conducted in Oregon (OSU) and New Jersey (Rutgers). These studies showed an increasing number of stylet sheaths in grape berries as the numbers of BMSB test populations increased. Increased numbers of stylet sheaths were associated with decreases of berry counts, premature raisening, and increased berry necrosis but this work focused on adult feeding and was conducted for one-week periods only (VMW, SCRI CAP report 2013). Direct crop impact may be more pronounced under more optimal temperature regimes with different varieties, and with longer feeding periods by nymphs to more realistically simulate crop infestation by reproductive BMSB, as is found in vineyards in Oregon and presumably California.

OBJECTIVES

1. Survey key Oregon and California viticulture areas for BMSB presence.
2. Determine BMSB temperature-related field feeding intensity, impact and regional risk index.
3. Provide Extension for identification, distribution, and importance of Brown Marmorated Stink Bug in western vineyards.

DESCRIPTION OF ACTIVITIES CONDUCTED TO ACCOMPLISH EACH OBJECTIVE AND RESULTS FOR EACH OBJECTIVE

1. Survey key Oregon and California viticulture areas for BMSB presence.

Methods. Surveys focused on high-risk regions containing vineyards and wineries in close proximity to high traffic areas such as highways, urban centers, throughways and railroad lines. Initial beat sheet sampling in the aforementioned areas and in California included Sonoma, Napa and Lodi. Pheromone-baited pyramid traps (Khrimian et al. 2014) were used in conjunction with monitoring using beat sheets. The BMSB pheromone traps were placed in the center of each row selected for beat sheet sampling. BMSB were additionally sampled from study vineyards using beat sheet sampling every two weeks starting in August from two rows, once on the vineyard edge and once in the center of the same block. Our goal was to start surveys of California vineyard regions before the reported movement of BMSB into commercial vineyards. The vineyard regions sampled were California's north coast wine grape region (Mendocino, Napa and Sonoma counties), Lodi-Woodbridge wine grape region, and San Joaquin Valley (Fresno County). All vineyard surveys were conducted in concert with other ongoing studies, with outreach to participating farmers on BMSB description and potential presence. At each site, about 100 vines were visually sampled every 2–4 weeks. Specifically, in Mendocino County, 6 vineyard sites around Ukiah and Hopland (4 Chardonnay, 1 Merlot, 1 Grenache) were sampled as part of a leafhopper project. In Napa County, seven vineyard sites (2 Cabernet Sauvignon near St. Helena, 1 Cabernet Sauvignon near Oakville, 1 Chardonnay near Yountville, 1 Merlot near Carneros and 1 Pinot Noir and 1 Chardonnay near Carneros) were sampled as part of a red blotch or vine mealybug study. In Stanislaus and Stockton counties (Lodi Woodbridge wine grape region) three vineyards were sampled (1 Cabernet Sauvignon, 1 Pinot Noir, 1 Chardonnay) and in Fresno County five table grape blocks (2 Thompson seedless, 3 flame seedless were sampled). An additional sampling protocol was followed in three vineyard blocks in Sacramento, Yolo and Amador counties for all Hemipteran insects, but have yet to find any BMSB at any of these sites. Sampling at these sites has been conducted by visual observations and sweeping of grape foliage and other vegetation present in and adjacent to the vineyards. To date, no BMSB were found during these field visits in California.

Sampling in Oregon included seven vineyards in the northern Willamette Valley. There were no clear differences in between sampling sites and data from all vineyards were pooled for the 2015 season.

This was the third year of sampling in these vineyards and data is presented as BMSB per pyramid trap over a two-week period (Fig. 1)

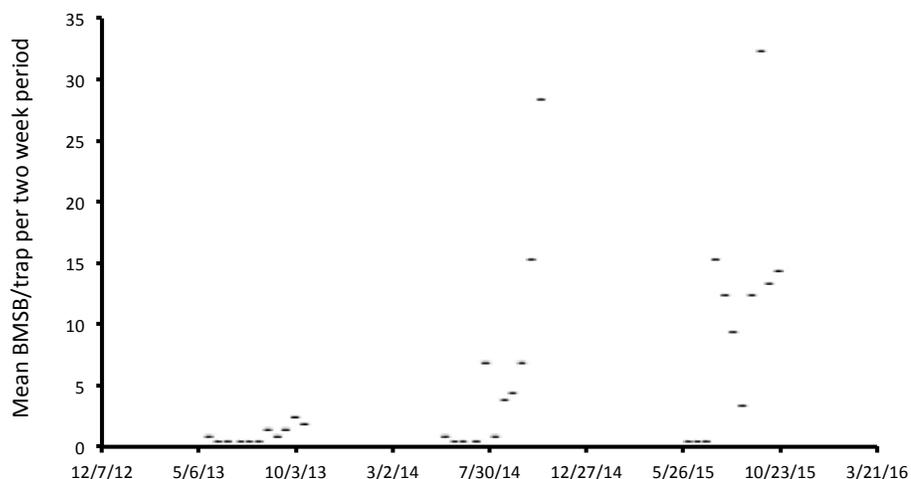


Figure 1. Number of BMSB per trap per two-week period in the Willamette Valley, Oregon during 2013-2015. Traps were placed in seven vineyards in the northern Willamette Valley.

Results. In all of the seven locations, BMSB was found in low numbers during the early part of summer in Oregon. The number of BMSB per trap and increased to ca. 30 BMSB per trap per two-week period during September through October of 2014 and 2015. The total cumulative number of BMSB trapped per trap during the whole increased from 34 (2013) to 101 (2015) BMSB per trap collected during the season.

In California, at the UC Berkeley lab (Daane Lab) starting in October, we began monitoring the farms and gardens by utilizing traps containing aggregation pheromones, as well as sweep net collections of the landscape. In Fresno County, we have sampled five Hmong farming operations, each about 3-7 acres in size. Sampling consisted of utilizing a d-vac to collect insects from three different crops (egg plant, long beans, peppers, tomatoes, peas, bitter melon, squash) at each site ever other week. From these samples, no BMSB were found, but Say’s stink bug (*Chlorochroa sayi*) and Bagrada bug (*Bagrada hilaris*) were collected.

UC Davis (Zalom Laboratory) BMSB sampling was initiated in Fall 2015 by making visual observations and collections of stink bugs from community gardens and vineyards in Sacramento, Yolo, San Joaquin and Amador counties. BMSB have previously been captured in the cities of Sacramento, Davis (Yolo county) and Stockton (San Joaquin county), but none have been captured in agricultural situations to date. We continued more intensive sampling of community gardens in Sacramento and Davis, and have also sampled community gardens in Galt (Sacramento county) and Lodi (San Joaquin county). Six species of stink bugs were collected from these gardens including *Eushistus conspersus*, *Thyanta pallidovirens*, *Chlorochroa uhleri*, *Chlorochroa ligata*, *Murgantia histrionica*, and *Nezara viridula*, but BMSB was only found in community gardens in Sacramento where it was also observed feeding on grapes that were growing there. We have yet to sample gardens elsewhere in these counties, but we have met with University of California Cooperative Extension Farm Advisor Dr. Jhalendra Rijal to discuss plans for collaboratively sampling community gardens and landscape plantings in the vicinity of previous finds in Stockton and Modesto (Stanislaus county) in the coming year. We intend to use findings of BMSB breeding populations at such sites as an indicator of where we might target sampling in nearby vineyards. The Zalom lab has obtained a permit to maintain a BMSB colony that we initiated during 2015 with bugs collected from community gardens in Sacramento, and is presently using the colony in various behavior and control studies.

2. Determine BMSB temperature-related field feeding intensity, impact and regional risk index.

Methods. Feeding intensity. In Oregon, we deployed refined portable electronic feeding monitors (Wiman et al. 2014b) August 21, 2015 for a one-month period in order to determine in-vineyard feeding intensity. Portable feeding monitors consisting of an open circuit enclosed onto a section of the grape vine will be located within 20 meters of the pheromone traps. Four electronic feeding monitors were placed in each of the two rows in a partially shaded vineyard border, and a fully sun-exposed location within the center of each vineyard. Each feeding monitor was used to determine feeding frequency, duration and time. Each portable feeding monitor logged feeding for five individual BMSB. The insects were replaced once per week. The relative risk and intensity of BMSB feeding damage were determined by creating a feeding index of insect-days (Ruppel 1983) for each of the vineyard regions using standard methods as described by Wiman et al. (2014b). Additionally, these feeding patterns were verified by counting the number of stylet sheaths and plant damage within the monitored feeding area. Data from this work is currently being analyzed.

Feeding impact. Feeding exclusion sleeves (48.0 cm x 39.5 cm, Premier Paint Roller, Richmond Hill, NY, item 60597) were placed over wine grape clusters in a commercial vineyard with known BMSB infestation in the northern Willamette Valley. The trial was maintained for a four-week period from August 21 to September 21, 2015. There were four treatments: 1) no BMSB; 2) a partial egg mass with 10 hatching eggs; 3) three BMSB nymphs; 4) three adult BMSB. All treatments were enclosed in a single sleeve on vines for four weeks. Ten replicates of each treatment were established in a randomized block design. Forty sleeves (ten of each treatment) were placed in a partially shaded vineyard border row, and forty sleeves were placed in a fully sun-exposed vineyard row in each vineyard (80 sleeves total). BMSB insects were exposed to clusters within a sleeve for four weeks during the period when BMSB are typically found in vineyards in the Willamette Valley. Dead insects were replaced every week with BMSB of the same life stage during the exposure period. At the end of the experimental period, all clusters were removed and taken to the laboratory for further inspection. Feeding activity of BMSB were determined by counting the number of stylet sheaths per berry. Additional key quality parameters were determined, including berry weight, pH, sugar, raisining, cracking and presence or absence of spoilage bacteria such as botrytis using the slip-skin method (Crisosto et al. 2002). These data together with weather data (five dataloggers per vineyard location), feeding intensity and direct impact on crop can be used to develop a relative risk model for BMSB damage in different vineyard regions (Ruppel 1983, Froissart et al. 2010, Wiman et al. 2014a, 2014b). The key cluster data is currently being analyzed.

Results. During 2015, there were significantly higher temperatures recorded in locations that received higher sun exposure levels (Fig. 2a, b). Mean temperatures during the experimental period ranged from 12.3-23.8°C during the experimental period. Temperature differences were as wide as 28.2 to 23.5°C on days when there were full sun exposure to virtually indistinguishable on cloudy days. During 2015 there were significantly higher levels of stylet sheaths between sunny and shady locations in vines ($F_{1, 4074}=45.079$, $p=0.001$; Fig. 3), and there were higher levels of stylet sheaths in treatments with adults compared to immature BMSB life stages. In order to determine if there were differences in BMSB feeding days (Insect days, Ruppel 1983) between sunny and shaded locations, we determined the mortality rates over the four-week period of the feeding trial. There were however no clear differences in cumulative mortality rates between locations that BMSB were placed on vines (Figure 4).

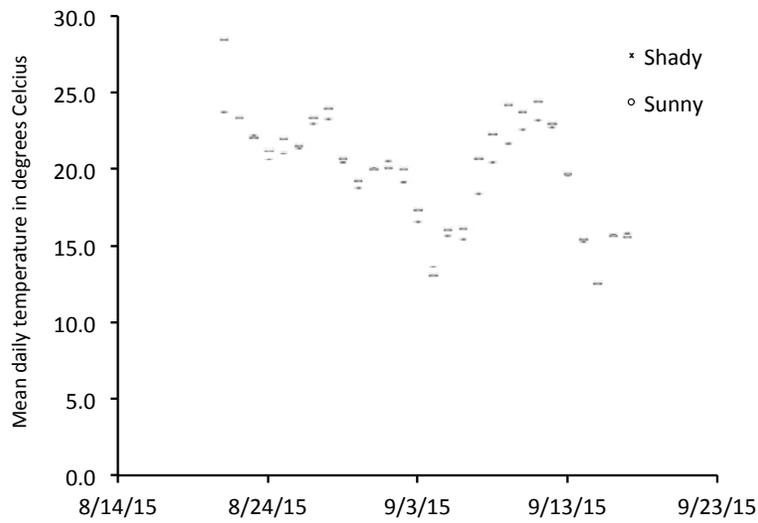


Figure 2a. Mean daily recorded temperatures from each of shady and sun-exposed locations on vines in the Willamette Valley during 2015.

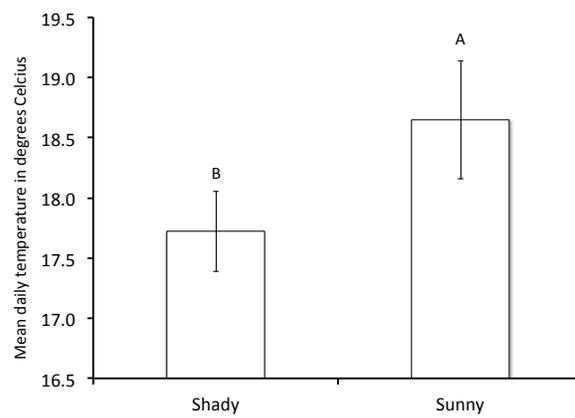


Figure 2b. Mean temperatures recorded in each of two sun-exposed locations on vines in the Willamette Valley during 2015. Significantly different letters indicates different temperatures.

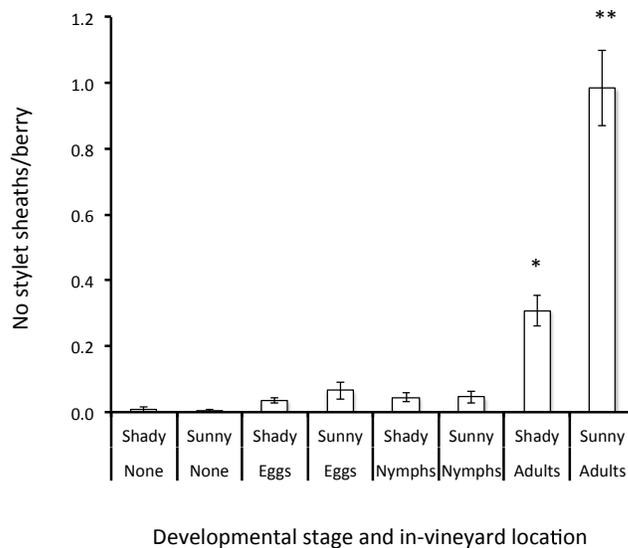


Figure 3. Number of stylet sheaths per berry in the Willamette Valley, Oregon during 2015. Bars with no, one and two asterisks (*) are significantly different from other bars.

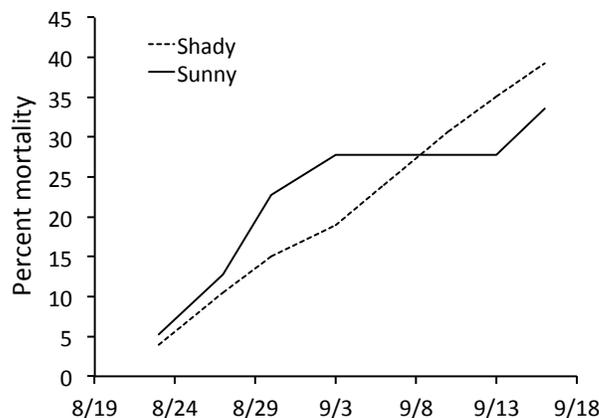


Figure 4. Percent mortality rate of BMSB in sunny and shaded locations in vines in the Willamette Valley, Oregon during 2015.

3. Provide Extension for identification, distribution, and importance of Brown Marmorated Stink Bug in western vineyards.

Methods. Because BMSB may first be seen in small organic gardens and ornamental trees, we also began outreach or surveys of small organic farms (Napa and Sonoma counties) and Southeast Asian vegetable farms (Fresno County). In the north coast region, we have partnered with Master Gardener groups in Napa and Sonoma to gain access to home gardens in which we may find desirable host source plants. Additionally, contacts have been made, in partnership with the Napa Agricultural Commissioner, allowing us access to survey and sample small-diversified farms. No BMSB have yet to be found at these sites.

Results. In Oregon, we presented results of earlier and work for this grant to growers in five locations, McMinnville, Oregon (63 attendees), Milton Freewater, Oregon, (30 attendees), Roseburg, Oregon, (50 attendees), Medford, Oregon, (48 attendees) and Rickreal Oregon (211 attendees). Several extension meetings were held in the San Joaquin Valley and coastal winegrape regions as represented by the sampled regions mentioned above.

Conclusions. In California’s north coast wine grape region, Lodi-Woodbridge wine grape region, and San Joaquin Valley (Fresno County), vineyards and small vegetable farms no BMSB were found. While this is only the initial study, BMSB have been found in the Lodi Woodbridge region in ornamental trees, but have yet to be

found near the vineyards sampled. In Oregon, BMSB were found in increasing numbers from 2013-2015 in each of the seven vineyards sampled. There were increasing website reports from winegrape growers. There is increasing concern about the higher levels of BMSB populations in Oregon vineyards. Our feeding trials show elevated levels of feeding in clusters that were more exposed to sun during the experimental period. Adults resulted in higher levels of stylet sheaths compared to the other life stages exposed to clusters

PUBLICATIONS PRODUCED AND PENDING AND PRESENTATIONS MADE

No publications were produced to date.

Extension talks. In Oregon, we presented results of earlier and work for this grant to growers in five locations, McMinnville, Oregon (63 attendees), Milton Freewater, Oregon, (30 attendees), Roseburg, Oregon, (50 attendees), Medford, Oregon, (48 attendees) and Rickreal Oregon (211 attendees). Several extension meetings were held in the San Joaquin Valley and coastal winegrape regions as represented by the sampled regions mentioned above.

RESEARCH RELEVANCE STATEMENT

The research needs to continue, as it appears as if BMSB is spreading in California vineyards. BMSB is now being found in increasing numbers and is becoming more widespread in many winegrape growing regions. The impact of BMSB in winegrapes needs additional characterization in order to minimize future risk.

LAYPERSON SUMMARY OF PROJECT ACCOMPLISHMENTS

Brown Marmorated Stink Bug was found in large and increasing numbers in vineyards in Oregon. In California, it has been found in areas closely bordering vineyards, but BMSB has yet to be found in any California vineyards. It appears as if increased temperatures on vines results in increased feeding activity levels of BMSB. It appears as if adult life stages exposed to clusters result in elevated levels of feeding activity on clusters compared to immature life stages.

STATUS OF FUNDS

Initial administrative problems with subcontract funds have resulted in a delay in payment to UC scientists. These problems have been resolved. We foresee no problems or delays of funds disbursed from OSU to UC during 2016. Funds were used as allocated in the previous budget year.

SUMMARY AND STATUS OF INTELLECTUAL PROPERTY

Not applicable

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