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Occurrence, Distribution, and Characterization of Sweet Potato Feathery Mottle Virus (SPFMV) Infecting Sweet Potato (*Ipomoea batatas* L.,) in Leyte and Southern Leyte Provinces

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ABSTRACT

Sweet potato feathery mottle virus (SPFMV) significantly affects sweet potato production globally. However, the characterization of SPFMV isolates in Leyte and Southern Leyte has not yet been established. Thus, this research aims to determine the disease incidence and severity of SPMV in Leyte and Southern Leyte, map its distribution through GIS and assess the isolates' transmissibility using a pathogenicity test. Field surveys and collections were conducted. Disease incidence and severity were recorded, and coordinates were obtained for mapping. Distinct symptoms of SPFMV infection were observed in 29 sweet potato farms in Leyte and Southern Leyte. Typical symptoms include purple feathery mottle, chlorosis, vein clearing, purple spots, and shortening of internodes. A similar set of symptoms were also observed in Southern Leyte. The recorded SPFMV incidence ranged between 20-90%, with a severity rating of 5 to 8, meaning 16-100% of the plants exhibited clear virus symptoms. In Southern Leyte, the SPFMV incidence ranged between 10-100%, with a severity rating between 4 to 8, meaning 60-100% of the plants exhibited clear virus symptoms. The virus isolates from Leyte and Southern Leyte were pathogenic and infected the test plants when inoculated via graft transmission. The inoculated sweet potato plants exhibited symptoms typical of SPFMV infection, such as chlorotic spots, leaf curling, vein clearing, and mild to severe mottling four weeks after inoculation. The study's results may be used to draft policy recommendations like controlling the movement of planting materials from the identified SPFMV hotspots.

Keywords: sweet potato, potato feathery mottle virus (SPFMV), grafting transmission, sweet potato, purple feathery mottle, sweet potato viruses

INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is the world's sixth most essential agricultural food crop commodity (FAOSTAT 2020). In the Philippines, about 83.31 thousand hectares were planted with sweet potatoes (PSA 2021). Eastern Visayas contributed 18.5 % of the total sweet potato production, making it the country's top supplier of sweet potatoes (PSA 2021).The production of sweet potatoes is constrained by biotic factors, which causes a significant reduction in yield. Plant

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viruses are one of the critical problems in the growth and development of sweet potatoes. There are 30 plant viruses reported to cause diseases in sweet potatoes (Kwak et al 2014), and six (6) of these were reported to occur in the Philippines (Salazar & Fuentes 2000). These viruses commonly occur in mixed infections in the field (Mukasa et al 2003). Kamoteng "kulot" was often described as the symptoms of virus mixed infection in sweet potato (Vasquez et al 2008). In Leyte, the virus infection can result in approximately 64% yield reduction of sweet potato (Palomar et al 2000).

Among viruses that infect sweet potato is the sweet potato feathery mottle virus (SPFMV) (Brunt et al 1996; Vasquez et al 2008). It belongs to the genus Potyvirus, family Potyviridae (Clark & Moyer 1988), which commonly infects plants under the family Convolvulaceae. The virus is transmitted mechanically, by graft transmission (Gutierrez et al 2003) and via non-persistently borne aphids (Ateka et al 2004). Different species of aphids, such as *Aphis gossypiii*, *Aphis craccivora, Lipapis ersysimi*, and *Myzus persicae*, are known vectors of SPFMV (Muimba-Kankolongo 2018). In non-persistent transmission, the vector acquires the virus within seconds to a minute of feeding and is transmitted rapidly (there is no incubation and retention period). Occasionally, strong winds can blow them over great distances (Edwardson & Christie 1991). Sap transmission through mechanical inoculation has also been reported to cause an infection (Gutierrez et al 2003).

The disease caused by SPFMV is characterized by vein-clearing chlorotic spots in older leaves with pigmented purple borders (Moyer & Salazar 1989; Vasquez et al. 2008). It also manifested a curly appearance (Jayansinghe & Laranang 1986). In Burkina Faso, the most frequent viral symptoms observed include vein clearing, leaf distortion, curling, and chlorotic spots on older leaves (Tibiri 2020)

There are three (3) SPFMV strains based on biological and molecular properties from selected sweet potato growing areas in Luzon, Visayas, and Mindanao (Dolores et al 2012). However, the occurrence, distribution, and transmissibility of SPFMV in Leyte and Southern Leyte have yet to be well documented. The GIS mapping of the SPFMV distribution with its corresponding disease severity can give epidemiological knowledge for its management. Management of plant viruses is directed at interrupting the infection cycles (Ateka et al 2023), which entails the complete elimination of the source of inoculum that can lead to infection (Ateka et al 2023). LGUs can draft ordinances to prevent disseminating infected planting materials to neighboring municipalities. The data generated in this study will also serve as a guideline for deploying clean sweet potato planting materials.

MATERIAL AND METHODS

A. Field surveys and Virus Indexing by Symptomatology

A field survey was conducted in selected cities and municipalities of Leyte and Southern Leyte Provinces. About one to four farms in a major sweet potato growing municipality/city with at least 1 ha area and 1.5 to 4 months old sweet potato were selected as study sites. A total of 29 sweet potato farms were evaluated based on the incidence and severity of SPFMV infection. Twenty (20) sample plants were identified per farm following an X-shaped transects stretching between opposite corners of each field (Ateka et al 2004). Each sample plant was assessed for SPFMV infection. The observed symptoms in the field were compared with the SPFMV symptoms described in published references (Vasquez et al 2008). Sample vines of about 2 ft long (Gutierrez et al 2003) were collected and brought to the laboratory for pathogenicity and transmission assays.

Disease Assessment

Disease incidence (DI). The disease incidence (%) was calculated based on the formula of Mohammed et al (2016) in which the number of diseased plants were divided by the total number of sampled plants surveyed and multiplied by 100.

Disease severity (D.S). The severity of the SPFMV disease was recorded following the rating scale of McEwan et al (2015) as shown in Table 1.

Table 1. Disease severity rating scale of SPFMV on the field survey (McEwan et al 2015)

SCALE	VIRUS SYMPTOMS OBSERVATION SCALE
1	Symptoms free
2	Unclear symptoms
3	Clear virus symptoms under <5% of plants through field
4	Clear virus symptoms from 6 to 15% of plants through field
5	Clear virus symptoms from 16 to 33% of plants through field (Less than 1/3)
6	Clear virus symptoms from 34 to 66% of plants through field (Less than 2/3)
7	Clear virus symptoms from 67 to 99% of plants through field (above 2/3)
8	Clear virus symptoms at 100% of plants (no stunting)
9	Severe virus symptoms at 100% of plants (stunting, plant dying)

B. Mapping the Occurrence of SPFMV in Leyte and Southern Leyte Provinces

During the field survey, each farm's GPS coordinates and other geographical data were recorded using the GeoCam Application (Li et al. 2021). The obtained GPS coordinates, together with the other data like the SPFMV disease incidence and severity, were run using QGIS to generate the distribution map of SPFMV infection in Leyte and Southern Leyte

C. Pathogenicity of SPFMV

Sweet potato vines that exhibited SPFMV symptoms were collected from the surveyed farms and were inoculated into healthy plants to determine their pathogenicity. The test plants were obtained from the germplasm of PhilRootcrops. The pathogenicity test was carried out following the grafting method. The setup was maintained for 4 weeks to observe the symptom expression typical of SPFMV infection.

Graft transmission. A section of each symptomatic sweet potato vine was grafted using the crown-left grafting method (de Bokx 1972). Samples collected from different farms in Leyte and Southern Leyte were grafted in SP30 test plants. This was done by cutting an approximately 5 cm section containing at least 1 to 2 nodes from the test plant vine and shaping the base of the symptomatic sweet potatoes (scions) into a wedge. The apex of the test plant was cut off to create a rootstock containing approximately 4 to 5 leaves. The scion was then inserted into a 1.5 cm lateral slit in the rootstock stem. The junction of the graft was then secured using a parafilm. All grafted plant samples were kept and maintained in an insect-proof greenhouse with relative humidity below 80%. Symptoms were observed, and % transmission was recorded four (4) weeks after grafting.

RESULTS AND DISCUSSIONS

Symptoms of SPFMV Infection

A field survey for SPFMV infection was conducted between August to October 2023. For Leyte province, the areas covered in the survey were the three (3) barangays in Baybay City and one (1) barangay from Dulag. For Southern Leyte, surveys were done in one (1) barangay each in Maasin City and the municipalities of San Juan, Anahawan, Tomas Opus, Macrohon, Sogod, Bontoc, and Malitbog. Two (2) barangays were covered in the municipalities of Hinundayan and Hinunangan, respectively. From these, 580 sample sweet potato plants were assessed for SPFMV infection, 180 in Leyte and 400 in Southern Leyte.

Majority of the samples collected from the sweet potato growing areas exhibited a diverse array of symptoms characteristic of SPFMV (Fig.1). These include purple feathery mottle, chlorosis, vein clearing, chlorotic spots, purple spots, and curling with shortening of internodes. The observed symptoms were similar to the report of Palomar et al. (2000). They reported that SPFMV infections in barangays in Baybay City, Leyte, include leaf crinkling, purpling, deformation of leaves, and mottling. Similarly, in Burkina Faso, Tibiri et al. (2020) observed viral symptoms in sweet potatoes, including stunting, leaf curling, chlorotic spots, and purpling and purplish margin.

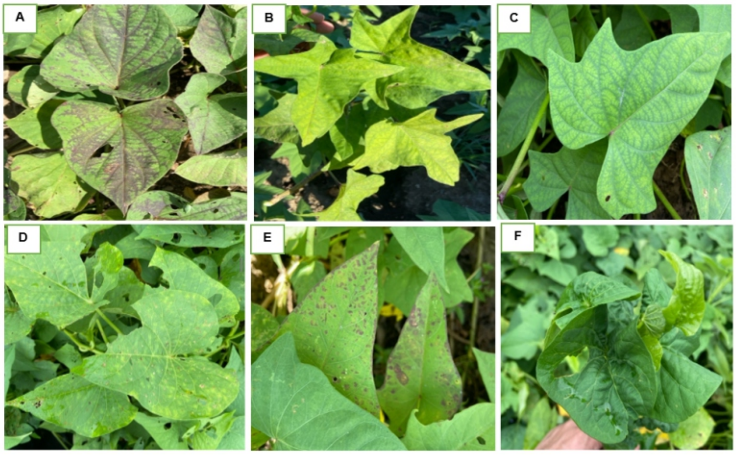

Figure 1. Typical symptoms of SPFMV observed in the surveyed farms of Leyte and Southern Leyte, Philippines. (A) purple feathery mottle, (B) chlorosis, (C) vein clearing, (D) chlorotic spots, (E) purple spots and (F) curling with shortening of internodes

Incidence and severity of SPFMV in Leyte

A total of 580 samples of sweet potato plants were assessed for SPFMV infection, 180 from Leyte and 400 from Southern Leyte. Most sweet potato farms in Leyte have an incidence range of 20-90%—the SP36 variety located in Brgy. Maganhan exhibited the lowest incidence rate of 20%. This was followed by SP30 in Brgy. Gacat, while both SP30 varieties from Brgy, Maganhan, and Brgy Rawis in Dulag recorded 30% disease incidence. The highest reported disease incidence was SP30 from sweet potato farms 7 and 8 in Brgy. Butigan. Both recorded 70 and 90% disease incidence (Table 2).

Regarding the severity of virus infection in the field, it can be noted that the SP36 variety from Brgy. Maganhan exhibited the lowest incidence. It had the least virus symptoms, ranging between 16-33% of the leaf. While the majority of the other farm sites fall within the range of disease severity rating between 6 and 7 (34-99%). Farm 2 (SP35) in Brgy. Gacat and farm 8 (SP30) in Brgy. Butigan, both located in Baybay City, recorded the highest disease severity in the field at a rating of 8. These two barangays exhibited 100% clear SPFMV symptoms with no stunting.

Table 2. Disease incidence (%) and severity of SPFMV based on visible symptoms in different sweet potato farms in Leyte

FARM	LOCATION	D.I%	D.S	VARIETY
1	Gacat, Baybay City	30	7	V2
2	Gacat, Baybay City	50	8	SP35
3	Gacat, Baybay City	60	7	SP36
4	Gacat, Baybay City	45	6	Ka-inday
5	Maganhan, Baybay City	40	6	SP30
6	Maganhan, Baybay City	20	5	SP36
7	Butigan, Baybay City	90	7	SP30
8	Butigan, Baybay City	70	8	SP30
9	Rawis, Dulag	40	6	SP30

Note: D.I% (Disease incidence %), D. (Disease severity)

Incidence and severity of SPFMV in Southern Leyte

In Southern Leyte, the percent incidence ranged from 10-100%. Brgy. Mahalo, Anahawan SP30 variety recorded the lowest disease incidence in Southern Leyte at 10% SPFMV. It was followed by SP30 in Brgy. Lunas in Maasin City, Brgy. Ambao, Hinundayan and Brgy. Utama, Hinunangan with a disease incidence of 20%. The highest virus incidence was observed in the SP35 variety in Ambao, Hinundayan, and SP30 in Sangahon, Malitbog 17. Both recorded disease incidence of 100% (Table 3).

Table 3. Disease incidence (%) and severity of SPFMV based on visible symptoms in different sweet potato farms in Southern Leyte

FARM	LOCATION	D.I(%)	D.S	VARIETY
10	Lunas, Maasin City	20	5	SP30
11	Macrohon, Kambaro 2	25	6	V2
12	Kahupian, Sogod	40	8	SP25
13	Kahupian, Sogod	30	5	SP30
14	Purok Uno Dao, Bontoc	60	8	SP36
15	Purok Uno Dao, Bontoc	30	4	SP30
16	Purok Dos Dao, Bontoc	90	8	SP30
17	Tinago, Tomas Opus	40	6	SP30
18	Sangahon, Malitbog	100	8	SP30
19	Sangahon, Malitbog	40	8	Wonder
20	Sangahon, Malitbog	50	8	SP36
21	Tahusan, Hinunangan	75	8	Wonder
22	Utama, Hinunangan	20	8	SP31
23	Utama, Hinunangan	85	7	SP30
24	An-an, Hinundayan	70	5	SP36
25	Ambao, Hinundayan	100	8	SP35
26	Ambao, Hinundayan	65	5	SP30
27	Ambao, Hinundayan	20	4	SP30
28	Mahalo, Anahawan	10	6	SP30
29	Samoje, San Juan	40	7	SP30

The 100% disease severity of the SP30 variety in Brgy Kahupian (Sogod), SP36 in Brgy. Dao (Bontoc), SP30 in Brgy. Sangahan (Malitbog), variety Wonder in Brgy. Tahusan, SP31 variety in Brgy. Utama (Hinunangan) and SP35 variety in Brgy. Ambao (Hinundayan) evident with symptoms of SPFMV in all sweet potato plants collected. Only Farm 15 with SP30 variety located in Dao, Bontoc exhibited less virus severity at 6-15% severity level.

The SPFMV incidence in the two provinces is comparable to the result of Vasquez et al. (2008). They surveyed two barangays in Tarlac and two municipalities in Bataan where sweet potato was grown commercially. All areas in Tarlac were heavily infected with SPFMV, with virus infection ranging between 40-60%.

The common varieties surveyed include SP30, SP35, SP36, V2, Wonder, and Ka Inday. It was observed that the SP30 variety had higher virus incidence for both Leyte and Southern Leyte than SP25 and SP36, with relatively lower disease incidence. Musa et al. (2022) also observed differential response per cultivar. In their experiment, they screened for SPFMV among the five cultivars. The highest mean symptoms were recorded in CV2, while the average severity score of 3 for SPFMV was recorded on CV4, CV1, CV3, and CV5 were recorded to have a mean severity score of 2. The response of the sweet potato samples surveyed for disease incidence and severity may be attributed to varietal differences. However, these varieties are still susceptible since there has yet to be a report on the screening for SPFMV-resistant sweet potatoes in Leyte and Southern Leyte.

Distribution of SPFMV in Leyte and Southern Leyte

A GIS map was generated to visualize the incidence and severity of SPFMV infections in selected farms of Leyte and Southern Leyte. The green indicates municipalities and cities where the identified sweet potato farms were located. The highlighted blue color represents the barangays with SPFMV disease incidence and severity. Additionally, the single-color circles indicates the range of disease incidence and the severity rating scale. (Fig. 2 A-B, Fig. 3 A-B).

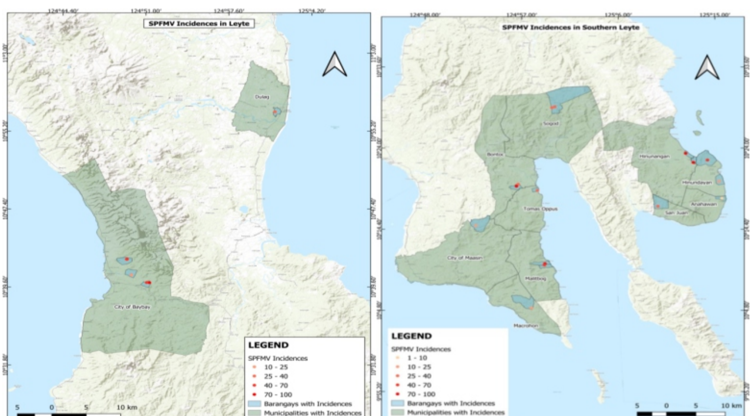

Figure 2. GIS maps of Leyte and Southern Leyte showing disease incidence of SPFMV in the identified sweet potato farms

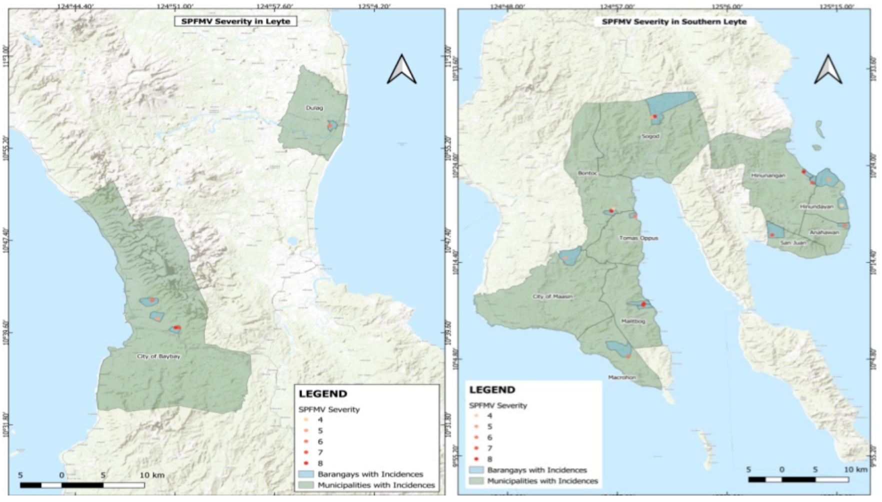

Figure 3. GIS maps of Leyte and Southern Leyte showing disease severity of SPFMV in the identified sweet potato farms

SPFMV was detected in all surveyed sweet potato farms as shown in the map. Most surveyed farms have incidence percentages between 25-40% and 40-70%. This is shown by the similarities in the color range available in the two (2) provinces (Fig. 2A and B).

The disease severity in the two (2) provinces also showed uniform distribution of severity ratings, as shown by the range of color in the map (Fig. 3A-B). In addition, it was observed that farms that showed high disease incidence and severity (Farm 7, 17, and 24) were in lower elevations compared to the other farms surveyed. The possible explanation for this may be that the higher temperature associated with lower elevation can increase the pathogen's survival and its reproduction and enhance the environment for the pathogen to grow (Halliday et al. 2021). GIS can enhance the implementation of plant disease management and epidemiology. This is done by placing epidemiological information in the same format as other farm information (Nelson et al. 1999). With this, GIS mapping was employed in this study to visualize the disease incidence and severity level of selected farms infected with SPFMV.

Pathogenicity of SPFMV

SPFMV genome is made up of a positive-sense single-stranded RNA with a 3'-terminus poly(A) tail and a protein that serves as a protein-linked genome (VPg) located in its 5'-terminus end (Wylie et al. 2017). The ssRNA of the virus is described as non-enveloped, filamentous, and flexuous in morphology (Loebenstein 2015). The collected SPFMV isolates in the major sweet potato growing farms in Leyte and Southern Leyte were pathogenic. The observed symptoms in the field were exhibited by the inoculated sweet potato plants in the greenhouse four (4) weeks after, (Fig. 4).

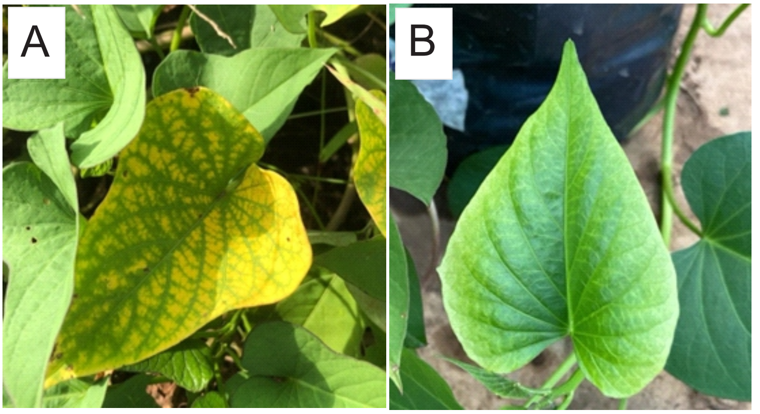

Figure 4. (A) Vein clearing and chlorosis observed in the field; (B) sweet potato plant in the greenhouse (after inoculation) showing early signs of vein clearing and chlorosis

All plant viruses cannot cause an infection through unwounded plant surfaces. Therefore, plant viruses such as SPFMV need to be introduced and deposited inside the susceptible cells of host plants by either mechanical inoculation or through grafting (Narayanasamy 2011). The results of the pathogenicity test confirmed that the collected isolates were capable of infecting new plants. The additional symptoms observed during the pathogenicity test include leaf curling, mottling, and chlorotic spots. Bednarek et al. (2021) also reported a similar result after successfully inoculating SPFMV and expressing its symptoms (4 weeks after inoculation) using an indicator plant. Mottling, chlorotic spots with yellowing, vein clearing, and curling were the common symptoms expressed by test plants using the graft-inoculation method.

Furthermore, Musa et al. (2021) reported similar symptoms, including vein clearing, mottling, and chlorotic spots in most cultivars screened for SPFMV using graft inoculation. This finding correlates with the study of Palomar et al. (2000) wherein it was reported that SPFMV symptoms include leaf size reduction, leaf crinkling, vein banding, and mild mottling. In addition, some infected grafted plants also exhibited uneven yellowing towards the midribs and even purplish margins, with sweet potato in the two provinces having similar symptoms expression associated with SPFMV

As for the degree of severity, observed symptoms in the pathogenicity test are less severe than those observed in the field. Feathery purpling mottling, purple spots, shortening of internodes, and severe mottle were noted in the SPMFV expression in the field. A possible reason was the duration of infection since the observed plants in the pathogenicity test were only four (4) weeks old. Symptoms are expected to become more severe as the duration of the infection extends. Other factors affecting the expression of symptoms include the different varietal responses, soil fertility, farm elevation, and infection from other pathogens.

CONCLUSION AND RECOMMENDATIONS

SPFMV infected sweet potato growing farms in Leyte and Southern Leyte provinces with symptoms characterized by purple feathery mottle, chlorosis, vein clearing, chlorotic spots, purple spots, and curling with shortening of internodes. Results of the GIS map showed the current hotspots of SPFMV in the two provinces surveyed. The infection was distributed at varying disease incidence ranges between 20-90% in Leyte and 10-100% in Southern Leyte. The SPFMV severity level in Leyte ranged from 5 to 8, which means 16-100% of the plants exhibited clear virus symptoms. In Southern Leyte, the severity rating fell between 4 and 8, which means 6-100% of the plants exhibited clear virus symptoms. SPFMV Isolates from Leyte and Southern Leyte were pathogenic. The local government unit should know the current status of SPFMV infections in their locality. GIS Maps of the disease incidence and severity used in this study can help formulate local ordinances for managing SPFMV infection.

Moreover, it is also recommended to buy clean planting materials from reputable nurseries and avoid the replanting of sweet potato cuttings in the identified SPFMV hotspots. Molecular characterization of SPFMV may be done to identify specific virus strains that can be used for molecular diagnostics and effective virus management.

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