Grapevine Fanleaf Virus (GFLV) Distribution in North-Central Algeria's Wine-Growing Regions

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Abstract

Grapevine fanleaf virus (GFLV) is one of the most damaging viruses to grapevine around the world, causing infected vine less productive and less vigorous. The study investigated the detection and distribution of GFLV in five principal wine-producing regions of north-central Algeria: Algiers, Blida, Tipaza, Médéa, and Boumerdès. During the 2020-2024 wine seasons, 400 vine samples were collected from both symptomatic and asymptomatic vines. The Double-Antibody Sandwich Enzyme-Linked Immuno Sorbent Assay (DAS-ELISA) serological technique was used to detect the GFLV virus. The results showed a varying incidence of GFLV based on the regions investigated. Of the 400 samples analyzed, the DAS-ELISA serological technique showed an infection rate of 46.5%, the highest infection rate reported in Boumerdes with 53.76%, followed by the Médéa region with an infection rate of 40.32%. Stunted growth and flower aboration were the most discriminating symptoms of the virus in vineyards. The 1103 Paulsen rootstock and Dattier de Beyrouth grape varieties were observed to be the most sensitive to the GFLV virus. The regional distribution implies a large yet diverse presence of the virus suggesting many sources of infection and potential vector activity. These results illustrate the necessity to strengthen management strategies and restrict the progression of the GFLV in Algerian vineyards.

Keywords: GFLV, DAS-ELISA, infection rate, discriminating symptoms

Introduction

The vine (*Vitis vinifera*) is globally distributed, spanning an area exceeding 7.25 million hectares and yielding approximately 70.8 million tons of grapes. Since 2017, the total area of vineyards worldwide appears to have stabilized. Notably, the Algerian vineyard comprises 0.9% of this global area, totaling over 68,000 hectares (OIV, 2022).

Grapes harbor the highest number of documented viruses among all perennial crops. Research studies by Martelli (2014), Yepes et al. (2018), and Fuchs (2020) reported the vine as a host for numerous viruses, with over 90 viruses and viroids identified in grapevines. Some of these viruses significantly impact grape production worldwide. Infectious degeneration of the vine is a longstanding disease that is widespread and highly damaging to vineyards globally, leading to yield losses of up to 80% (Martelli and Boudon-Padieu, 2006). This disease results from a viral complex consisting of various nepoviruses, including grapevine fanleaf virus (GFLV), tomato ringspot virus (ToRSV), blueberry mottle virus (BLMoV), cress mosaic virus (ArMV), and tobacco ringspot virus (TRSV) (Martelli, 2014; Schmitt-Keichinger et al., 2017). The impact of this viral complex varies depending on grape varieties, the specific viruses present and prevailing climatic conditions (Martelli, 2014).

The primary cause of infectious dieback of grapevines is the grapevine fanleaf virus (GFLV), a nepovirus transmitted by the ectoparasitic nematode *Xiphinema index* (Pinck et al., 1988). Grapevine fanleaf virus belongs to the *Secoviridae* family, classified within the supergroup of picorna-like viruses (Andret-Link and Fuchs, 2005). Its detrimental effects result in substantial losses and a shortened productive lifespan of vineyards, as it induces progressive degeneration that can ultimately lead to death of plants (Mannini and Digiaro, 2017; Yobrègat et al., 2020).

In this context, it is necessary to address the significant challenge posed by GFLV in Algerian vineyards. On one hand, there is a restriction on the use of practically all "nematicidal" substances traditionally applied to control nematode vector populations, coupled with the absence of suitable technical solutions to battle this disease. On the other hand, there is a significant lack of comprehensive awareness regarding the health status of vineyards despite reports of severe infections of grapevine fanleaf virus (GFLV) in different grapevine varieties across the country. These cases have been documented in regions such as Mitidja, Tipaza, and Médéa by BenFreha Zemouli (1983), Martelli (1985), Melouk (2002), Tabouche (2005), and Tahirine (2020), as well as in the western Mascara region on the *Ahmer bouamer* grape variety and in the Ben Chicao region by Hadji (1991) and Morsli (1995).

The symptoms caused by the triplex interaction, GFLV-Grapevine-*Xiphinema index*, vary greatly in vineyards around the world, according to the available bibliography.To further our comprehension of this interaction involving the development of symptom expression and DAS-ELISA approach, as well as to ascertain the health state of Algerian's vineyards, this study was conducted in five wine-growing regions in northern central Algeria, specifically Médéa, Tipaza, Blida, Algiers, and Boumerdes, during the period from 2020 to 2024. The 27 vineyards examined were planted with various rootstocks and grape varieties, including Dattier Beyrouth, Muscat of Alexandria, Muscat Italia, Gros Noir, Ahmer Bouamer, Cardinal, Dabouki, Red Globe, and Alphonse Lavallée. The initial phase of the study focused on studying symptom manifestation across different vineyards and grape varieties. In the second phase, the infection rates of wine-growing regions, grape varieties, and rootstocks were evaluated using the DAS-ELISA method to assess their susceptibility to GFLV infection.

Materials and Methods

Study period and vineyard sites

During the period spanning from 2020 to 2024, a total of 27 vineyards were surveyed across five regions of northern central Algeria (Fig. 1). These vineyards were chosen at random and belonging to renowned wine regions.

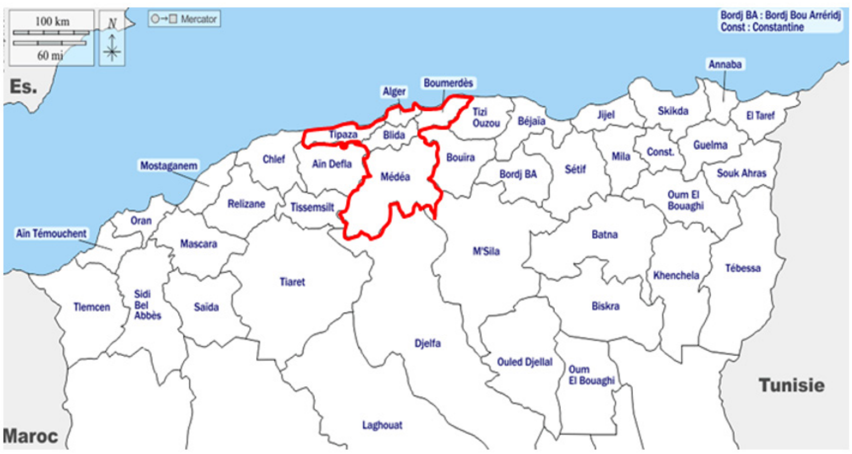

Figure 1 Location of the wine-growing regions explored in the map of centre-northern Algeria. These regions, with a significant production of grapes, marked by red, are: Algiers, Blida, Tipaza, Boumerdes and Médéa

They were also chosen on reports of viral diseases from interviews with winegrowers, reports from agricultural institutions and ongoing university research. Specifically, this included five vineyards in Médéa, five in Algiers, four in Blida, two in Tipaza, and eleven in Boumerdes. These vineyards were chosen randomly and featured a diverse array of nine grape varieties: Dattier Beyrouth, Ahmer Bouamer, Muscat Italia, Muscat Alexandrie, Alphonse laVallée, Cardinal, Gros Noir, Dabouki, and Red Globe (Table 1).

Symptom Scoring

The recording of symptoms during the vineyard monitoring period was carried out following the study of Martin et al. (2021). Leaf discoloration, including yellowing, variegation, mottling, mosaic, and vein banding, was visually estimated in June and scored from 0 to 4 (0: no discoloration; 1: 1–25%,2:25–50%, 3: 50–75%, and 4: 75–100% of the leaves showing discoloration). Leaf deformation corresponding to a fan-like aspect, asymmetric blades, or small leaves was scored in June from 0 to 4 (0: no deformation; 1: 1–25%, 2: 25–50%,3:50–75%, and 4: 75–100% of the leaves showing deformation). Development abnormalities, including double nodes, abnormal bifurcations, fasciation, and zigzagging of the shoots, were estimated in June and scored from 0 to 4 (0: no abnormality;

TABLE 1

Comprehensive summary of all surveyed vineyards, detailing their respective grape varieties, locations, ages, and rootstocks

Region	Site	Grape variety	Area (Ha)	Age	Rootstock
Médéa	Beni Chicao 1	DattierBeyrouth	0.5	32	SO_4
	Beni Chicao 2	Ahmer Bouamer	2	15	SO_4
	Beni Chicao 3	Muscat italia	1	26	SO_4
	Beni Chicao 4	Muscat Alexandrie	0.5	26	SO_4
	Beni Chicao 5	Alphonse vallée	1	15	SO_4
Algiers	Tessala el Merdja 1	Cardinal	1.5	29	110 Richter
	Tessala el Merdja 2	DattierBeyrouth	1.5	29	110 Richter
	Souidania	Gros noir	3	30	SO_4
	Ain Benian 1	Cardinal	3	30	SO_4
	Ain Benian 2	Gros noir	3	30	SO_4
Blida	Meftah	Cardinal	3	25	SO_4
	El Afroune 1	DattierBeyrouth	4.5	25	99 Richter
	El Afroune 2	Cardinal	4.5	25	99 Richter
	Mouzaia	Cardinal	3	25	SO_4
Tipaza	Ahmer El Ain 1	Gros noir	10	30	SO_4
	Ahmer El Ain 2	DattierBeyrouth	8	32	SO_4
Boumerdes	Baghlia 1	Cardinal	2	20	41 B
	Baghlia 2	Muscat	1	30	41 B
	Baghlia 3	Dabouki	3	15	110 Richter
	Zemmouri 1	Dabouki	2	19	1103 P
	Zemmouri 2	Red Globe	3	09	1103 P
	Lagatha 1	Dabouki	1.3	08	99 Richter
	Lagatha 2	Red Globe	1	08	99 Richter
	Lagatha 3	Dabouki	1.4	04	99 Richter
	Naceria	Cardinal	1	17	41 B
	Lagatha 4	Dabouki	6	20	1103 Paulsen
	Lagatha 5	Muscat	6	20	1103 Paulsen

1 to 4: 1–25%, 25–50%, 50–75%, and 75–100% of the leaves showing abnormalities). Stunting was evaluated in June from 0 to 4 (0: no stunting; 1: low; 2: medium; 3: strong; and 4: very strong). The control plant development served as a reference (no stunting), and the training wires were used to estimate the height of the plants. Color (flower abortion) was scored in July from 0 to 3 (0: no color; 1: low; 2: medium; and 3: strong).

Sampling method

To collect samples, the characteristic symptoms that indicate a possible infection, such as shortened internodes, bifurcations, flattened branches, and alterations in leaf morphology, including reduction, distortion, and discolouration were observed. Field monitoring began at stage F, characterized by the appearance of rudimentary clusters atop shoots, often with four to six spreading leaves visible. Sampling was conducted during stages H and I, corresponding to the separation of flower buds and the start of bloom, respectively. The sampling approach for each surveyed site was deliberate and targeted, driven by good reasoning.

Immunological screening of the disease with the DAS-ELISA technique

In this study, DAS-ELISA technique was used. The serum used is a BIOREBA AG® Kit. All samples taken from the field were weighed individually, and 1.0 g of fresh leaves was crushed separately using a grinder in 5.0 mL of a special "vine" extraction buffer solution in extraction bags. After reading the plates, samples with OD greater than two (2) times the OD of the negative control were considered positive and with OD less than (2) times the OD of the negative control were considered negative (healthy). The infection rate (I) was expressed by the percentage (%) of infected plants (ni) compared to the total number of plants tested (N). To calculate the rate of infection, the following formula was used:

$$I\% = (\Sigma ni / N) \times 100$$

Statistical analysis of results

The results of symptoms collected and serological tests acquired were processed in the form of tables in the Excel 2007 software, and then statistical tests were carried out with IBM SPSS Statistics V 26. The Multiple Correspondence Factorial Analysis test (MCFA) was used to develop affinity groups for the results of the symptoms observed in the field throughout the study period.

Results

Symptoms observed in different vineyards surveyed

During the period (March-October), two distinctive syndromes were observed across the 27 vineyards surveyed and these included deformity of leaves, shoots, and clusters, along with variations in leaf pigmentation. On the shoots, many symptoms were obvious, including shortening and distortion of the internodes, double nodes, fasciation, bifurcation, and zigzag growth. Additionally, symptoms observed on the leaves were distortion and indentation of the blade. Alterations in leaf pigmentation were characterized by whole and partial yellowing, leaf mosaic, reticulate and secondary variegation, as well as ordinary variations (Fig. 2).

Throughout the monitoring time which covered from 2020 to 2024, the phenotypic characteristics of vineyards recorded include leaf discolouration, leaf and shoot deformation, different anomalies, inhibited vine growth, and bunch curdling. The study

Figure 2 The most common symptoms in prospected vineyards. Flattening of the vine branch (A). Bifurcation symptoms (B). Stunted growth and yellowing of leaves (C, D). Variegation and mosaic of leaves (E). Partial and total yellowing of leaves (F, G). Leaf deformation (H). Color of grapes (I, J). Flattening, bifurcation of vine branches (K)

revealed a significant diversity in symptom manifestation and severity across different vineyards, regions, and grapevine varieties. Most of the grapevine varieties surveyed had an average age of 26 years. However, a significant exception was the Dabouki grape variety in the Lagatha region, which was only 4 years old. Despite its relative youth, this vineyard revealed particularly severe symptoms indicating of infection by the GFLV virus.

The statistical result of symptom ratings utilizing FACM (Factorial Analysis of Multiple Correspondences) exposes various significant results. Firstly, the test exhibits good reliability, with an average Cronbach's Alpha of 79.2 %. Additionally, 54.6 % of the data are included inside the two axes of values (Table. 2).

In the present study, the most common

TABLE 2

Summary of typical GFLV symptom patterns identified from the 27 prospected vineyards occupied by 9 different grape varieties during the period 2020/2024. The analyzed data set is represented with two axes where the first axis summarizes 85 % of the analyzed data and the second axis summarizes 79.2% of the analyzed

Model Summary

Dimension	Cronbach's Alpha	Variance Accounted For	
		Total (Eigenvalue)	Inertia
1	.850	3.122	.624
2	.716	2.343	.469
Total		5.464	1.093
Mean	.792[a]	2.732	.546

a. Mean Cronbach's Alpha is based on the mean Eigenvalue symptoms were growth retardation and drooping which are the most discerning markers, followed closely by abnormalities. Conversely, discoloration and leaf deformation symptoms exhibit poorer discriminating value in identifying GFLV infection. These insights provide enormous aid for consideration and prioritizing symptom observation, and assessment processes in vineyard disease control (Fig. 3).

As illustrated in Table 3, significant correlations among various symptoms, particularly abnomalities and stunting, were noted. The abnormalities displayed correlations with deformation, stunting and color at proportions of 69.3%, 63.2 % and 54.8 %, respectively. Furthermore, stunting symptoms exhibited a notable correlation of 57.8 % with the symptom of flower abortion (color). These correlations shed light on the interconnected nature of symptoms associated with GFLV infection, providing insights crucial for understanding disease progression and management strategies.

The distribution of symptoms across different vineyards and grape varieties is illustrated in two double plots on Fig. 4-5, and represent distinct groups of symptoms. The first group,

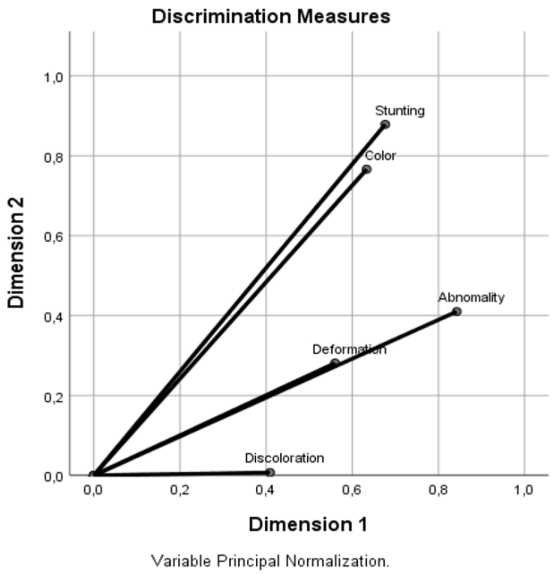

Figure 3 Measures of discrimination of groups of symptoms observed in the 27 vineyards and 9 grape varieties during the period 2020/2024

TABLE 3

Transformed variables of correlations of the expression symptom groups

Correlations Transformed Variables					
Dimension: 1					
	Abnomality	**Discoloration**	**Deformation**	**Stunting**	**Color**
Abnomality	1.000	.449	.693	.632	.547
Discoloration	.449	1.000	.289	.416	.304
Deformation[a]	.693	.289	1.000	.442	.304
Stunting[a]	.632	.416	.442	1.000	.578
Color[a]	.547	.304	.304	.578	1.000
Dimension	1	2	3	4	5
Eigenvalue	2.899	.758	.720	.390	.233

a. Missing values were imputed with the mode of the quantified variable

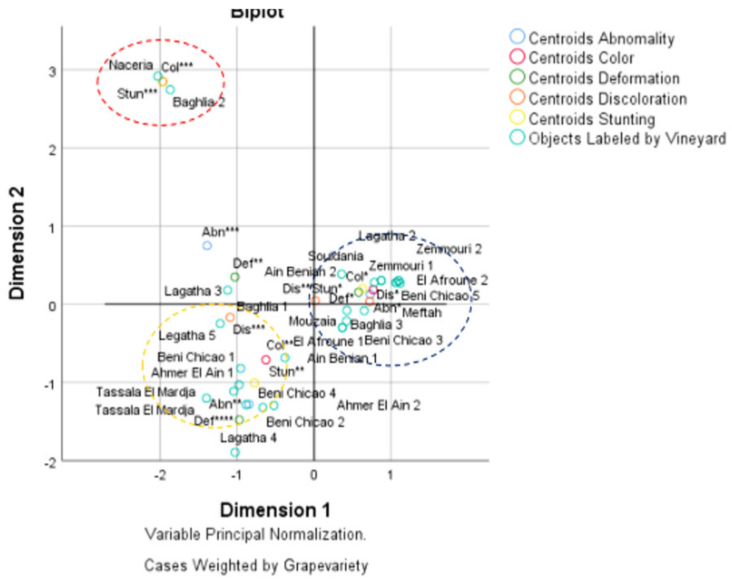

Figure 4 MBiplot of symptoms observed during the 2020/2024 period on all vineyards with centroids of abnormality, color, deformation, discoloration and stunting. *(Col: Color, Stun: stunting, Def: deformation, Abn: Abnomality and Dis: discoloration. Symptoms coring: * 0-25%, ** 25-50%, *** 50-75% and**** 75-100%)*

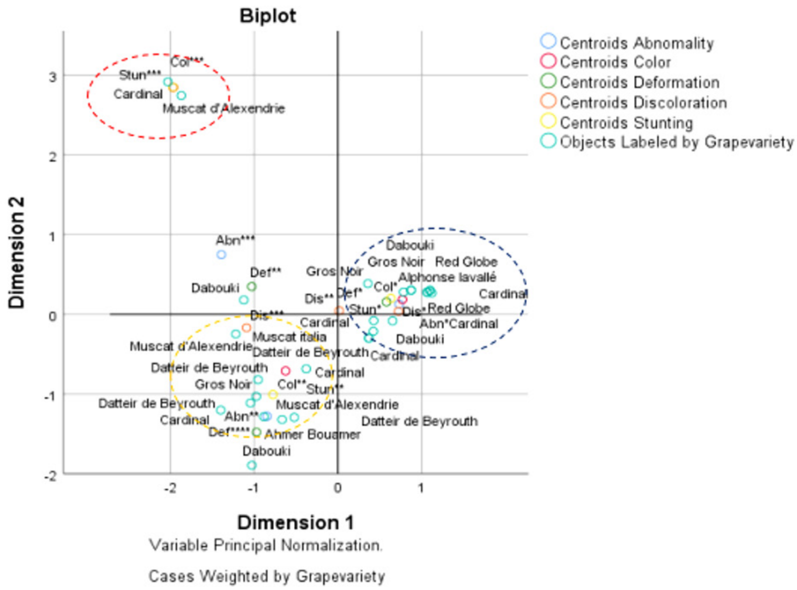

Figure 5 Biplot of symptoms observed during the 2020/2024 period on all grape varieties with centroids of abnormality, color, deformation, discoloration and stunting. *(Col: Color, Stun: stunting, Def: deformation, Abn: Abnomality and Dis: discoloration. Symptoms coring: * 0-25%, ** 25-50%, *** 50-75% and **** 75-100%)*

denoted by the blue circle, exhibits moderate levels of deformations, anomalies, stunting and discoloration (0-25%), accompanied by a low level of flower abortion. Vineyards within this group include Tessala El Mardja 1 and 2, Ahmer El Ain 1, Béni Chicao 3 and 5, A in Benian 1 and 2, Lagatha 3 and 5, primarily occupied by Dabouki, Cardinal, Alphonse Vallé, Dattier Beyrouth, Gros Noir and Muscat Alexandrie grape varieties.

In contrast, the yellow circle represents a second group characterized by minimal flower abortion (minimal level); stunting, and abnomalies (25 to 50%), along with intensity leaf discolorations and deformation (50 to 75%). Vineyards in this category include El Afroune 1 and 2, Baghlia 3, Béni Chicao 1,2 and 4, Zemmouri 1 and 2, Lagatha 2, Meftah, Souidania, Mouzaia, Ahmer El Ain 2, Baghlia 3 and Legatha 2; featuring grape varieties such as DattierBeyrouth, Cardinal, Gros Noir, Dabouki, Red Globe, Muscat Alexandrie and Muscat Italia. Lastly, the red circle signifies the most severe symptom grouping, with pronounced growth retardation (stunting: 50 to 75%), and heavy flower abortion (level 3). This group is represented by only two vineyards: Baghlia 2 and Naceria both located near Boumerdes and occupied by Muscat Alexandrie and *Cardinal* grape varieties.

Immunological detection of GFLV with the DAS-ELISA technique

The infection rate of vineyards and region

Concerning the DAS-ELISA serological analysis results of 400 samples collected from 27 vineyards and nine grape varieties 186 samples showed positive reactions to specific DAS-ELISA test, which corresponds to an infection rate of 46.5%, and 214 samples had a response negative on the test, which represents a rate of 53.5% (Table 4).

Analysis of the distribution of positive GFLV

TABLE 4

Quantity of samples, positive and negative tests categorized by vine-growing regions and grape varieties

Wilaya	Site	Grape variety	Samples	Test$^+$	Test$^-$
Médéa	Beni Chicao 1	*DattierBeyrouth*	40	36	4
	Beni Chicao 2	*Ahmer Bouamer*	20	12	8
	Beni Chicao 3	*Muscat italia*	20	7	7
	Beni Chicao 4	*Muscat Alexandrie*	18	10	8
	Beni Chicao 5	*Alphonse vallée*	18	10	8
Algiers	TessalaelMerdja 1	*Cardinal*	18	0	18
	TessalaelMerdja 2	*DattierBeyrouth*	19	1	18
	Souidania	*Gros noir*	16	0	16
	Ain Benian 1	*Cardinal*	10	0	10
	Ain Benian 2	*Gros noir*	12	0	12
Blida	Meftah	*Cardinal*	10	4	6
	El Afroune 1	*DattierBeyrouth*	8	0	8
	El Afroune 2	*Cardinal*	8	0	8
	Mouzaia	*Cardinal*	8	0	8
Tipaza	Ahmer El Ain 1	*Gros noir*	10	2	8
	Ahmer El Ain 2	*DattierBeyrouth*	10	4	6
Boumerdes	Baghlia 1	*Cardinal*	10	5	5
	Baghlia 2	*Muscat*	17	12	5
	Baghlia 3	*Dabouki*	10	3	7
	Zemmouri 1	*Dabouki*	18	12	8
	Zemmouri 2	*Red Globe*	14	7	7
	Lagatha 1	*Dabouki*	16	8	8
	Lagatha 2	*Red Globe*	14	8	6
	Lagatha 3	*Dabouki*	18	14	4
	Naceria	*Cardinal*	12	8	4
	Lagatha 4	*Dabouki*	14	12	2
	Lagatha 5	*Muscat Alexandrie*	12	11	1
		Total	400	186 (46.5%)	214 (53.5%)

tests throughout the five wine-growing regions of north-central Algeria demonstrated a considerable geographical variation. The Boumerdès region had the highest infection rate of53.76%, followed by Médéa (40.32%). In comparison, the regions of Blida (2.15%), Tipaza (3.22%), and Algiers (0.53%) had much lower rates (Fig. 6).

Distribution of positive tests across vineyards

The samples that reacted positively to the DAS-ELISA test belong to the Béni Chicao 1 vineyards, with 36 positive reactions, followed by the Lagatha 3 vineyard, with 14 positive samples (Fig. 7).

In the Béni Chicao 2, Baghlia 2, Legatha 4 and Zemmouri 1 vineyards twelve positive reactions were found on each site. Eleven positive reactions were obtained in Legatha 5 vineyards. Ten positive reactions were obtained for the Béni Chicao 4 and 5 vineyards. For the Lagatha 1 and 2, as well as Naceria vineyards, eight positive reactions were recorded in each vineyard. The two vineyards of Béni Chicao 3 and Zemmouri 2

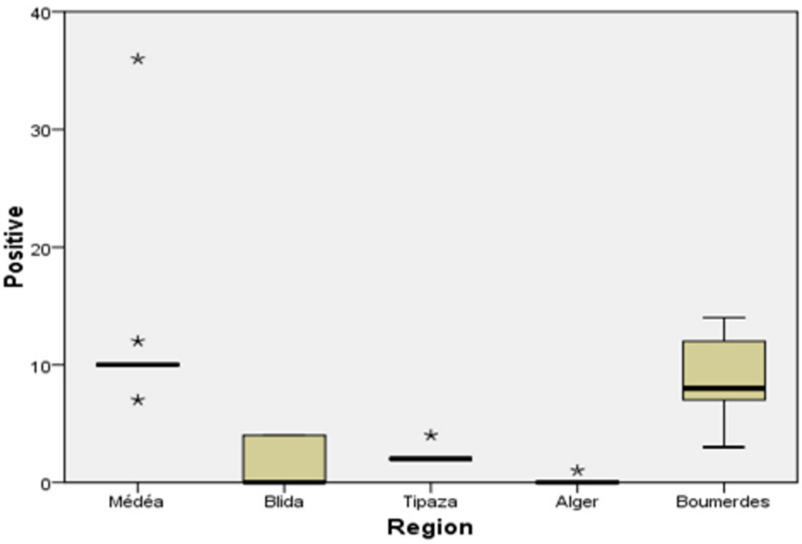

Figure 6 Infection rates of Grapevine fanleaf virus (GFLV) across the five wine-growing region

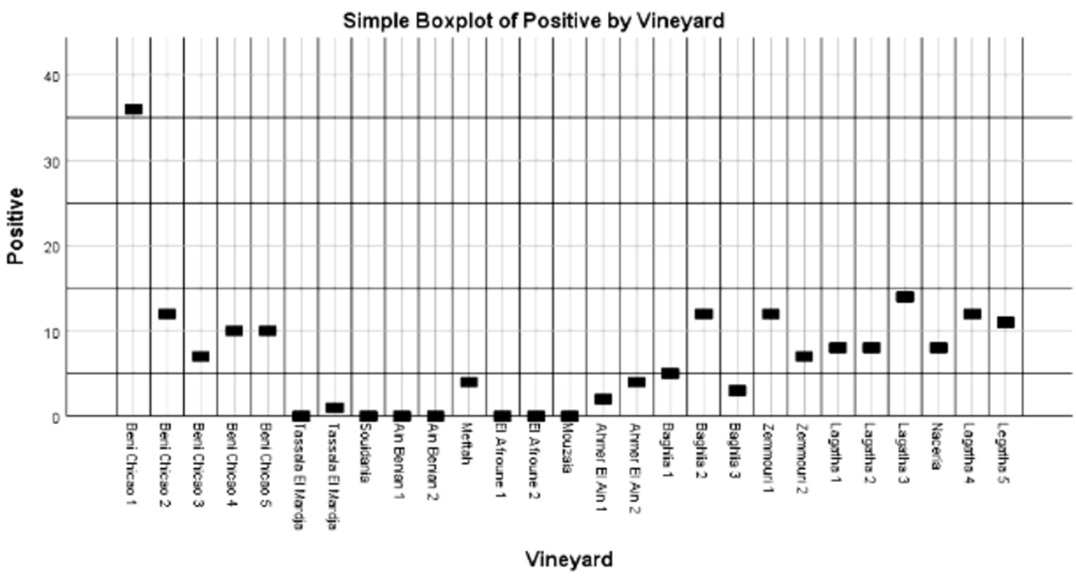

Figure 7 Simple box plot representing the distribution of positive tests detected by the DAS-ELISA serological method on the vineyards

were recorded seven positive reactions. Five positive results were reported at the Baghlia 1 vineyard. The Meftah and Ahmer El Ain 2 vineyards recorded four positive results. For the Baghlia 3, Ahmer El Ain 1 and Tassala El Mardja 1 vineyards, they recorded 3, 2 and 1 positive reaction, respectively. No positive reactions were detected in Mouzaia, El Afroune 1 and 2, Ain Benian 1 and 2, Tassala El Mardja 1, and Souidania vineyards.

Distribution of infection rates across grape varieties

According to the number of samples tested in relation to the number of tests revealed positive, the Dattier Beyrouth recorded the highest infection rate of 25.15% followed by the Dabouki grape variety with 22.70% rate of infection. The Muscat Alexandrie grape variety recorded an infection rate of 13.50%, followed by the Cardinal grape variety with an infection rate of 10.43%. For the Red Globe, Ahmer Bouamer, Alphonse lavallé and Muscat italia grape varieties, they respectively recorded an infection rate of 9.20%, 7.36%, 6.13% and 4.29%. The Gros Noir grape variety recorded the lowest infection rate with 1.23% (Fig. 8).

Distribution of infection rate across rootstocks

The distribution of the infection rate by the rootstocks of the grape varieties are presented in Fig. 9. With a rate of 32.82%, the most infected rootstock was the 1103 Paulsen.

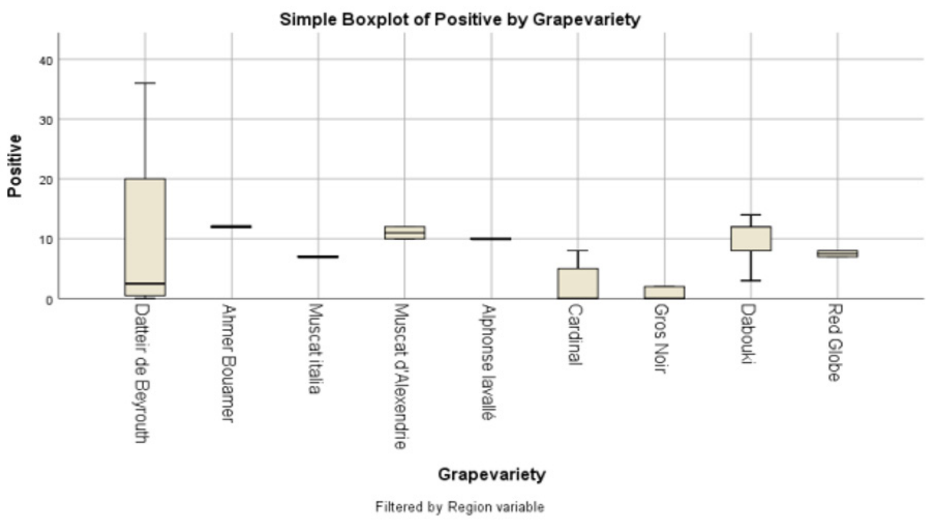

Figure 8 Simple box plot illustrating the distribution of the positives tests for different grape varieties carried out using the DAS-ELISA serological technique

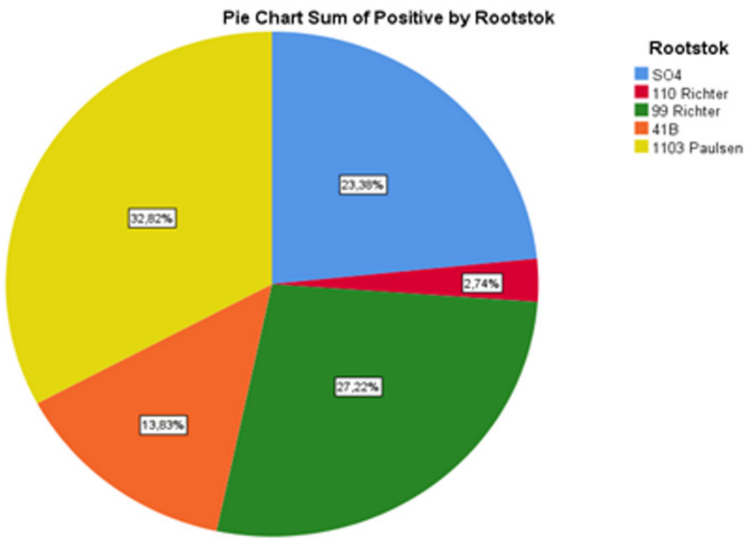

Figure 9 Distribution of the infection rate across rootstocks. The most infected rootstock is 1103 Paulsen while 110Richter rootstock is the least affected by the GFLV virus

The infection rate of 27.22 % was found in 99Richter rootstock. For rootstocks SO4 and 41B, they recorded infection rates of 23.38 % and 13.83 %, respectively. The 110Richter rootstock recorded the lowest rate, with 2.74% of all samples tested.

Discussion

In all the vineyards under study, there is an expression of symptoms potentially indicative of grapevine fanleaf virus (GFLV) infection. Following a statistical analysis conducted through the ACFM test on symptom rating data, three distinct symptom groups emerge as reasonably discriminatory for identifying short-knot disease in the field: growth retardation, formation anomalies, and cluster deformities. This variability illustrates the complex interaction of factors influencing the expression of grapevine diseases, including environmental conditions, management practices, and genetic susceptibility. It highlighted the importance of appropriate monitoring and management strategies to reduce the impact of viral infections and preserve vineyard longevity.

Martelli (1985) studied severe cases of GFLV affecting grape varieties in different regions of the country, in the west (Mascara) and the center (Mitidja, Tipaza, and Médéa). This information was reported in a mission report conducted in collaboration with the National Institute for Plant Protection (INPV) and the Institute of Vine and Wine (IVV), incorporating indexing and ELISA tests performed by the INPV.

The symptomatology results revealed similarities between decline symptoms and those of GFLV, such as branch malformations, leaf wrinkling and chlorosis, rapid vine stunting, berry and cluster impoverishment, and vine fragility under environmental stressors. This resemblance suggests the possibility of an aggressive variant of short-knot rather than an entirely separate disease entity (Yobrègat et al., 2020).

Symptoms varied significantly along with the three distinct groups of grape varieties, showing variable symptom manifestation. These distinct groups present important information on the different severity levels of infection across vineyards and varieties, simplifying targeted management. For example, the Cardinal grape variety in the Naceria vineyard expressed severe symptoms: 50-75% stunting and pronounced coulure. In the Baghlia vineyard, the same Cardinal grape variety exhibited moderate symptoms: 0-25% stunting and minimal drooping. This was despite the two vineyards having similar characteristics, including vine age, 41B rootstock, and soil structure. This discrepancy strongly suggests the presence of distinct strains of GFLV. Furthermore, the anomalies showed correlations with deformation symptoms and abnormal symptoms in proportions of 69.3% and 65.3%, respectively. Additionally, growth retardation symptoms recorded a 57.8% correlation with the flower abortion symptom (color).

Martelli (2010) supports this observation, indicating that the expression of symptoms such as malformation, color change, and growth retardation can vary depending on the viral strain, grape variety, and environmental conditions. Stem malformations in susceptible grape varieties can be induced by typically virulent strains, although less virulent strains don’t cause apparent symptoms, deformities in vulnerable grape varieties can be developed by usually virulent strains. The complexity of GFLV infection dynamics is shown by these results and the importance of considering various factors in disease management strategies is point up.

The infection rate of 46.50 % on 400 samples analyzed from the 27 vineyards indicates that the contamination of GFLV in the majority of the vineyards studied is significant. In the study conducted by Tabouche (2004), of the 870 samples tested from the stations (Chiffa, Blida, Mouzaia, El Affroun, Hamr El Ain, Bourroumi and Hoceinia) and different grape varieties (Muscat, DattierBayrouth, and Gros noir), 395 samples had positive responses to the serological test, which corresponds to an infection rate of 45.40%. For the results reported by Lecheb (2005), the samples tested were obtained from different stations (Tessala El Mardja and Bourkika) and grape varieties (Alphonse la Vallée, Muscat d'Alexandrie, Muscat de Hamburg, King's Ruby, Centenial, Cardinal, Dattier Beyrouth, Merlot, and Pinot noir), with a total number of 150 samples. Only 79 samples responded positively to the DAS-ELISA test, which corresponds to a rate of 52.66%. Khenchelaoui and Guenane (2014) tested 90 samples from three different stations (Boumerdes, Algiers, and Médéa) and different grape varieties (Gros noir, Cardinal, Dattier Beyrouth, Muscat, Dabouki, and Red-Globe), sixty-two samples had positive reactions, which represent an infection rate of 68.88%. In this study, it was noted that the Dattier Beyrouth and Daboukigrape varieties are the most infected, with infection rates of 25.15% and 22.70%, respectively, which represents almost half of all the samples tested. The SO4 rootstock has the highest infection rate, with a 52.15% infection rate, and the Beni Chicao vineyard, occupied by the Dattier Beyrouth, is the most contaminated.

Conclusion

The present study, which covered 27 vineyards spread across 5 wine-growing regions in north-central Algeria, revealed a serious and threatening contamination by the GFLV virus, with the presence of distinctive symptoms associated with the virus, ranging from severe to moderate, and the recording of a significant prevalence of GFLV infection, with an overall infection rate of 46.50%.

The economic repercussions of this infection are significant due to production losses following the symptoms induced by GFLV. Analysis of the symptoms reveals that floral abortion; stunted vine growth and anomalies are the most significant, accentuating the potential impact on yields, economic sustainability and solvency of affected vineyards. Faced with the spread of the disease and its potential vector, it becomes imperative to establish and define a strategy to combat GFLV to reduce the economic impact on producers' incomes and contamination of vineyards.

The results of this study illustrated that grape varieties and rootstocks were vulnerable to the GFLV virus. The Dattier Beyrouth and Dabouki grape varieties recorded the highest infection rate of 47.85%. The 1103 Paulsen rootstock recorded a significant prevalence, with an infection rate of 32.82%, while the 110Richter rootstock recorded the lowest infection rate, oj 2.74%. To support these results, molecular analyses are indispensable to further identify the GFLV virus strains and for the realization of a GFLV management strategy and guarantee the sustainability of the vineyards.

In summary, this study reveals a potential epidemiological scenario in the regions of Boumerdès and Médéa, which are a priori latent foci of GFLV. The variable distribution recorded in the wine-growing regions recommends that local factors mark the spread of the GFLV virus. These include the presence of already infected vines, the use of contaminated plant material during planting and grafting, as well as the credible activity of virus vectors, particularly the nematode Xiphinema index. The grouping of these factors could clarify the important differences in infection rates found among the studied regions.

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