Open Access

***Phytopathogenomics and Disease Control*., 2024, 3(1):77-86**
ISSN (Online):2957-5842; ISSN (Print):2957-5834
DOI: https://doi.org/10.22194/Pdc/3.1009
https://societyfia.org/journal/PDC

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Distribution and Etiology of Gummosis Syndrome Associated with Apricot Fruit Trees of Gilgit-Baltistan, Pakistan

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Gummosis syndrome is a serious disease of apricot trees in Gilgit Baltistan (GB), Pakistan. The symptoms of gummosis syndrome on branches, twigs, and the trunk of apricot trees include oozing of a gummy or resinous material, lesions or cankers, bark discoloration, and the disintegration of bark integrity. The disease can weaken branches and twigs, making them more susceptible to breakage. In severe cases, affected branches can die back. In this study, we investigated the fungal species associated with gummosis syndrome in apricots across four districts in GB: Nagar, Hunza, Gilgit, and Ghizer. We recovered a total of 40 isolates from different locations of above four districts, and the most frequently isolated fungal species was *Botryodiplodia theobromae*. *Fusarium solani* was also isolated from several locations, and *Neoscytalidium* spp. were isolated from a few locations in Nagar and Hunza. The spatial distribution of gummosis syndrome in apricots in GB is not uniform. The disease is more prevalent in the northern and western parts of GB, and in areas with higher elevations and cooler temperatures. The Nagar district is the most affected by gummosis syndrome, followed by Ghizer District. Our findings suggest that *Botryodiplodia theobromae* is the major fungal pathogen associated with gummosis syndrome in apricots in GB. *Fusarium solani* and *Neoscytalidium* spp. may also play a role in the disease. The spatial distribution of gummosis syndrome in GB suggests that environmental factors, such as elevation and temperature, may contribute to the disease. Further research is needed to develop effective control measures for gummosis syndrome in apricots in GB. This research should focus on identifying resistant apricot varieties, developing new and more effective fungicides, and developing integrated pest management (IPM) programs.

Keywords: Gummosis syndrome, Apricot trees, Fungal pathogens, Disease severity, Spatial distribution.

INTRODUCTION

The economy of Gilgit-Baltistan (GB), Pakistan, primarily relies on producing dry fruits, emphasizing almonds, plums, apricots, cherries, and peaches (Shahzad *et al.*, 2021). Among these fruits, apricots stand out as a symbol of ecological abundance and cultural significance. The unique characteristics of GB's apricots, in terms of flavor, nutritional content, and organic nature, set them apart from other fruits cultivated in the region and beyond. GB is the main apricot-growing region in Pakistan's Himalayan range. The share of GB in apricot production is almost 67% of the total production of Pakistan (Hussain *et al.*, 2012). However, apricot trees face a critical challenge in the form of fungal gummosis syndrome, leading to a significant decline in yield and quality. Trees exhibiting disease symptoms display excessive gum exudation on the trunk, limbs, branches, twigs, and sunken lesions on the bark. The affected tissue undergoes necrosis, resulting in black-to-brown staining in the xylem. As the disease progresses, the wilting and eventual death of

Ahmad, R., A. Ali, A. Abbas, I. Hussain, Z. Hussain, A. Razaq, S.U. Din, W. Hussain, S.A. Hussain and Z. Ali. 2024. Distribution and etiology of Gummosis Syndrome associated with Apricot Fruit Trees of Gilgit-Baltistan, Pakistan. Phytopathogenomics and Disease Control 3:77-86.
[Received 17 Nov 2024; Accepted 10 Mar 2024; Published 4Apr 2024]

twigs, branches, shoots, and limbs become apparent. In some instances, infected shoots or dead wood may produce black stroma. Fungal gummosis syndrome is attributed to multiple fungal pathogens, including species belonging to the genera *Botryosphaeria*, *Alternaria*, *Neoscytalidium novaehollandiae, Fusarium solani* and *Cytospora* and wood decay fungi. For example, *Neoscytalidium* sp. (syn. *Hendersonula* sp.) has been identified as the causal agent of gummosis syndrome affecting almonds, plums, and apricots in Egypt (Ogawa, 1995). *Botryosphaeria dothidea* and *Diplodia seriata* have been isolated from symptomatic trees in the United States and Japan. *Lasiodiplodia theobromae* (Syn. = *Botryodiplodia theobromae),* and *Cytospora* spp. has been reported as the causal agent of gummosis syndrome in Japanese apricots, cherries, and peaches in China and South Africa (Li *et al.*, 2014; Pan *et al.*, 2020). Additionally, wood decay fungi associated with the syndrome have been observed in peaches in the USA and Canada (Chen *et al.*, 2015). In recent years, gummosis syndrome has been increasingly observed in different fruit trees in Gilgit-Baltistan (GB), including plum, peach, apricot, cherry, and almond. The severity of gummosis is also dependent on the fungal species and the season of infection (Li *et al.*, 2014). Besides, various epidemiological factors such as soil moisture, relative humidity, air temperature, and rainfall can predispose fruit trees to pathogenic attacks. Heavy and continuous rain during fruit growth and ripening increase the likelihood of gummosis. Mechanical injuries caused by pruning, insects, or winds also create entry points for pathogens to initiate gummosis. However, the exact cause of gummosis syndrome, the source of initial inoculum, the relative susceptibility of different cultivars, epidemiology, and the timing of gummosis invasion in fruit trees in GB remain unknown. Although the symptoms closely resemble those described earlier. Traditionally, chemical treatment has been the go-to approach for managing foot rot/gummosis. However, this method has drawbacks such as disrupting the microbial community balance, harming beneficial microorganisms, causing environmental pollution, introducing toxicity to food products, and promoting pathogen resistance. Gummosis syndrome of apricots has recently become increasingly prevalent across different GB districts. The causative agent remains unidentified in most instances, but the symptoms closely resemble those outlined above. Concerning the gummosis syndrome, the lifecycle of deciduous plantations can be categorized into four distinct phases. The initial phase spans from planting to 2 to 3 years post-planting, during which symptomatic (young) trees are dispersed irregularly throughout the orchard. These trees exhibit abundant gum secretion on the lower sections of their trunks, and a considerable number of symptomatic trees eventually succumb to wilting and death. The second phase encompasses the period from 2-3 years to 5-7 years post-planting. During this period, trees establish themselves, experience growth, bear fruits, and flourish. In most instances, the trees remain symptom-free and are deemed healthy. The third phase extends from 5-7 to 10-14 years post-planting, characterized by a resurgence of gum secretion observed on branches, limbs, and trunks of sporadic trees in the orchard. Concurrently, sporadic wilting and death of side shoots and branches are noted. Additionally, the regular growth and development of affected trees are hindered, and the canopy of symptomatic trees appears less dense compared to adjacent asymptomatic trees. In many cases, restricted growth and shoot dieback manifest in trees exhibiting gum secretion. The fourth phase of gummosis syndrome development in the timespan of deciduous plantations lasts from 10-14 years to 15-20 years after planting. During that phase, gum secretion from the main limbs and trunks is intensified and drying and wilting of main limbs and entire trees become widespread in the orchard. Yield is significantly reduced and the profitability of production is evidently diminished. Eventually, the growers decide to uproot the in- fected orchard to minimize their losses. The current report focuses on the fourth phase of the gummosis syndrome of apricot trees. It is not known which pathogens are associated with the syndrome in Gilgit, the source of initial inoculum, or when they invaded the trees. In that regard, our research hypothesis is that the syndrome results from a complex of multiple fungi that attack the trees mutually. Hence the objective of the present study was to identify the fungi (etiology) associated in the gummosis syndrome of apricot trees in GB Pakistan.

MATERIALS AND METHODS

***Orchard's selection*:** Apricot trees in the advanced stage of gummosis syndrome, specifically in the period ranging from 10-14 years to 15-20 years post-planting. In this stage, there is an escalation in gum secretion from the twigs, primary branches and trunks, accompanied by prevalent drying and wilting of both primary branches and entire trees throughout the orchard. In July, 2023 samples from main trunk, branches and twigs of symptomatic and asymptomatic apricot trees showing gummosis were collected from 20 orchards, 5 orchards from five collection sites (Valleys) of four districts (District Gilgit, Ghizer, Nagar and Hunza) of GB, Pakistan as shown in Figure 1.

***Severity Assessment*:** Severity is a crucial measure of the impact of gummosis on apricot fruit trees. It reflects the extent of damage or the degree of symptom expression in infected trees. To assess the severity, systematic field surveys are conducted. During these surveys, gummosis symptoms are visually examined on individual trees or parts of trees, such as branches. A visual rating scale is employed, typically ranging from 0% (indicating no symptoms) to 100% (representing complete damage). By observing and documenting these symptoms, the average severity for each tree or sample is calculated.

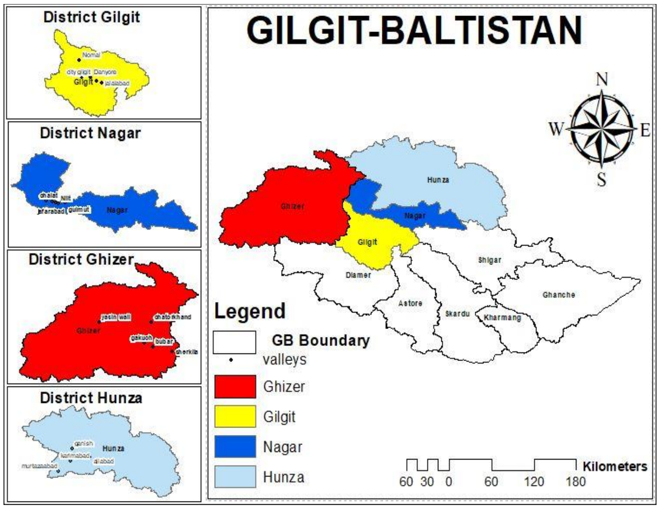

Figure 1. Map of study area

Incidence Evaluation**:** Incidence quantifies the proportion of trees affected by gummosis within the surveyed area. To determine incidence, the number of infected trees is counted and divided by the total number of trees included in the survey. This percentage is then multiplied by 100 to express it as a ratio. For instance, if a survey covers 100 trees and gummosis symptoms are found on 20 of them, the incidence is calculated as (20/100) * 100% = 20%.

Prevalence**:** Prevalence refers to the proportion of trees or samples infected with the pathogens within the surveyed area. The prevalence of the pathogen is assessed by counting the number of trees or samples that test positive for pathogens and dividing this by the total number of trees or samples surveyed. This value is then multiplied by 100 to express it as a percentage. It's important to note that prevalence provides insights into the presence of the pathogen within the surveyed area and may not always align with observable disease symptoms.

Spatial Distribution Analysis**:** The spatial distribution of gummosis in apricot orchards was systematically analyzed by establishing a geospatial database with X and Y coordinates for the study area. This procedure involved the utilization of Geographic Information System (GIS) software, specifically ArcGIS 10.7. Within the GIS project, three distinct fields, namely X, Y, and Z, played a crucial role in data management and spatial analysis. The X-field was dedicated to X-coordinates, the Y-field to Y-coordinates, and the Z-field was employed for storing disease-related data, such as disease severity or incidence. The ArcView Spatial Analyst tool was instrumental in conducting the analysis, where the "Interpolate grid option" was selected. To ensure accurate alignment with the geographical extent of District Nagar, the grid extension in the output was configured accordingly. For this spatial interpolation, the inverse distance weight (IDW) method was chosen to create interpolated surfaces based on the known data points. The spatial distribution of the disease variable was further characterized through the semivariogram function, employing equations suggested by previous researchers to provide valuable insights into the spatial patterns and trends of gummosis incidence within the study area. This geospatial analysis contributes to a deeper understanding of the disease's distribution, facilitating targeted interventions for disease management and control.

Isolation and identification: A meticulous collection effort yielded a comprehensive set of 100 samples manifesting symptoms of gummosis. Subsequent to the collection, laboratory analyses were conducted, resulting in the successful recovery of 40 fungal isolates, as elaborated in Table 1. These preserved fungal isolates are presently stored at the Integrated Pest and Disease Management Laboratories, Department of Agriculture, Gilgit-Baltistan.

To ensure isolation of fungi bark of main trunk, branches and twigs were cut into 3 cm thick slices that were dipped in 75% ethyl alcohol for 5 minutes, the samples' surfaces were disinfected: the branches followed by two 5 min rinses in distilled water. The small pieces were then placed on potato dextrose agar media, five pieces per Petri dish (90 mm), and incubated at 25°C in the dark for about 7 days during which fungal growth was monitored. Whenever fungal growth was detected, a plug of agar with mycelia was transferred to a new PDA plate and let to grow for 5 to 7 days before it was evaluated for morphological and microscopic identification. As part of the identification process for fungal colonies, a hybrid approach incorporating various identification keys was adopted. These keys, authored by experts documented both microscopic and macroscopic symptoms (Moller and Carter, 1970; Dy *et al.*, 2022). By harnessing the insights provided by these references, a comprehensive and multifaceted strategy was implemented to accurately identify the fungal colonies under examination.

Preservation of pathogens associated with gummosis**:** To preserve pathogens associated with apricot gummosis syndrome, a series of steps was undertaken to ensure the integrity and viability of the pathogen material. Initially, sterile agar slants were prepared within sterile test tubes. These agar slants served as a suitable substrate for the fungal mycelium or spores. Carefully selected pathogen material was then transferred onto the surface of these agar slants, ensuring an even distribution. To maintain the pathogen's viability while preventing uncontrolled growth or deterioration, the sealed test tubes with agar slants were preserved at 4°C.

Statistical analysis: Statistical analysis was employed to assess the significance of differences in severity, incidence, and prevalence among different orchards or regions within Gilgit-Baltistan. Appropriate statistical tests were utilized to provide a robust evaluation of the data, facilitating the identification of patterns and trends in disease prevalence and severity.

Table 1. Isolate Distribution by District and Collection Site.

S.No.	Isolate name	District	Collection site
1	G-1	Nagar	Jafarabad
2	G-3	Nagar	Chalat
3	G-5	Nagar	Ghulmat
4	G-7	Hunza	Ghanish
5	G-9	Hunza	MurtazaAbad
6	G-10	Hunza	NasirAbad
7	G-11	Gilgit	JalalAbad
8	G-12	Gilgit	Nomal
9	G-13	Gilgit	Danyore
10	G-15	Gilgit	Oshikhandas
11	G-16	Ghizer	SherQila
12	G-17	Ghizer	Ghakouch
13	G-19	Ghizer	Bober
14	G-20	Ghizer	Singul
15	G-22	Nagar	Skinderabad
16	G-23	Nagar	Chalat
17	G-24	Nagar	Nilt
18	G-26	Hunza	KarimAbad
19	G-27	Hunza	Ghanish
20	G-28	Hunza	AliAbad
21	G-29	Hunza	MurtazaAbad
22	G-32	Gilgit	Nomal
23	G-34	Gilgit	Gilgitcity
24	G-35	Gilgit	Oshikhandas
25	G-36	Ghizer	SherQila
26	G-39	Ghizer	Bober
27	G-2	Nagar	Skinderabad
28	G-6	Hunza	KarimAbad
29	G-14	Gilgit	Gilgitcity
30	G-18	Ghizer	Chatorkhand
31	G-21	Nagar	Jafarabad
32	G-25	Nagar	Ghulmat
33	G-30	Hunza	NasirAbad
34	G-31	Gilgit	JalalAbad
35	G-33	Gilgit	Danyore
36	G-37	Ghizer	Ghakouch
37	G-38	Ghizer	Chatorkhand
38	G-40	Ghizer	Singul
39	G-4	Nagar	Nilt
40	G-8	Hunza	AliAbad

RESULTS

***Symptoms*:** In this study, we investigated the symptoms of gummosis on branches, twigs, and the trunk of apricot trees as shown in Figure 2. There was oozing of a gummy or resinous material from affected areas, including branches, twigs, and the trunk of the apricot trees. This gum was observed to be sticky and, upon drying, formed a hard, amber-colored deposit. Lesions or cankers were commonly associated with gummosis. These lesions appeared as sunken or discolored areas on the affected plant parts, indicative of bark damage. Bark discoloration was a noticeable feature, with affected areas displaying changes in color. The bark often became darker, and in severe cases, it appeared black or brown. Further in trees with severe gummosis, cracking and peeling of bark around the affected areas, exposing the inner wood of the tree. Gummosis was found to weaken branches and twigs, making them more susceptible to breakage. In severe cases, affected branches had undergone dieback (Figure 2).

Figure 2. External and internal apricot symptoms associated with gummosis diseases of apricot in GB. a-b: typical gummosis symptoms; c: side necrosis on apricot; d: severe brownish internal necrosis, e; Infected pieces were cut for fungal isolation from gummosis symptoms

***Fungal Pathogens Associated with Gummosis Syndrome in Apricots*:** In this study, a total of 40 isolates were recovered from different locations across four districts: Nagar, Hunza, Gilgit, and Ghizer. These isolates were analyzed for their fungal species composition, and the findings are summarized in Table 2. In the Nagar district, various collection sites were sampled. The most frequently isolated fungal species was *Botryodiplodia theobromae*, with isolates such as G-1 from Jafarabad, G-3 from Chalat, G-5 from Ghulmat, and others, collectively contributing to the majority of the isolates in this district. Moreover, in Nagar, isolates G-2 from Skinderabad were identified as *Fusarium solani*. Finally, in the Nagar district, isolates G-4 from Nilt and G-8 from Ali Abad were determined to be *Neoscytalidium* spp. In the Hunza district, isolates from locations like Ghanish, Murtaza Abad, and Nasir Abad were also dominated by *Botryodiplodia theobromae*, as seen in isolates G-7, G-9, and G-10. Similarly, *Fusarium solani* was identified in G-6 from Karim Abad. In the Gilgit district, various collection sites, including Nomal, Danyore, and Oshikhandas, yielded isolates primarily consisting of *Botryodiplodia theobromae*, with examples like G-12, G-13, and G-15. Also, isolates from Gilgit City were found to be *Fusarium solani*, as shown in isolate G-14. The Ghizer district exhibited a similar pattern with isolates like G-16, G-17, and G-19 from Sher Qila, Ghakouch, and Bober, respectively, being *Botryodiplodia theobromae*. Furthermore, isolates from Chatorkhand and Singul were identified as *Fusarium solani* (G-30 and G-37). These findings provide valuable insights into the distribution of fungal species in different districts and collection sites, highlighting the prevalence of *Botryodiplodia theobromae*, *Fusarium solani*, and *Neoscytalidium* spp. among the isolated specimens. These results indicate that *Botryodiplodia theobromae* is the most prevalent fungal pathogen associated with gummosis syndrome in apricots across all districts, followed by *Fusarium solani*. The presence of *Neoscytalidium* spp. was observed in a few isolates collected from District Nagar and Hunza (Table 2).

Morphological characterization of pathogens: *Botryodiplodia theobromae* colonies cultivated on PDA-tet initially displayed a hyaline appearance, which progressively turned into brownish mycelium as they matured (Figure 3). The mycelium development eventually led to the formation of black pycnidia containing conidia. These conidia were singularly celled and had an elliptical shape with a rounded upper end and a flat lower end. Over time, the conidia darkened to a brown color (Figure 3). Each conidium exhibited a single septum along its length, and its surface displayed longitudinal striations a shown in Figure 3. For *Fusarium solani*, the colony exhibited distinct features both on the front and back surfaces. Additionally, conidiophores were observed, which are the structures responsible for the production of conidia. We also documented the presence of macro- and micro-conidia, which are integral to the reproductive cycle of this fungus. Moving on to *Neoscytalidium novaehollandiae*, the colony displayed characteristics on both its front and back surfaces. Premature arthroconidia were evident, along with arthroconidia arranged in chains. The conidia observed were light brown and exhibited 1 and 2 septate characteristics, providing valuable information about this fungal isolate. In the case of *N. dimidiatum*, the colony morphology was examined on both the front and back surfaces. Notably, we observed branched and septate brown hyphae, which are a distinctive feature of this fungus. The presence of contiguous arthroconidia was also noted, and the conidia displayed a variety of shapes, further aiding in the identification and characterization of this fungal isolate. These morphological characteristics serve as valuable markers for distinguishing between the different fungal species, contributing to a deeper understanding of their biology and taxonomy (Figure 3).

Table 2. Fungal pathogens associated with gummosis syndrome in apricots.

Sr.	Isolate	District	Collection site	Fungal species
1	G-1	Nagar	Jafarabad	*Botryodiplodia theobromae*
2	G-3	Nagar	Chalat	*Botryodiplodia theobromae*
3	G-5	Nagar	Ghulmat	*Botryodiplodia theobromae*
4	G-7	Hunza	Ghanish	*Botryodiplodia theobromae*
5	G-9	Hunza	Murtaza Abad	*Botryodiplodia theobromae*
6	G-10	Hunza	Nasir Abad	*Botryodiplodia theobromae*
7	G-11	Gilgit	Jalal Abad	*Botryodiplodia theobromae*
8	G-12	Gilgit	Nomal	*Botryodiplodia theobromae*
9	G-13	Gilgit	Danyore	*Botryodiplodia theobromae*
10	G-15	Gilgit	Oshikhandas	*Botryodiplodia theobromae*
11	G-16	Ghizer	Sher Qila	*Botryodiplodia theobromae*
12	G-17	Ghizer	Ghakouch	*Botryodiplodia theobromae*
13	G-19	Ghizer	Bober	*Botryodiplodia theobromae*
14	G-20	Ghizer	Singul	*Botryodiplodia theobromae*
15	G-22	Nagar	Skinderabad	*Botryodiplodia theobromae*
16	G-23	Nagar	Chalat	*Botryodiplodia theobromae*
17	G-24	Nagar	Nilt	*Botryodiplodia theobromae*
18	G-26	Hunza	Karim Abad	*Botryodiplodia theobromae*
19	G-27	Hunza	Ghanish	*Botryodiplodia theobromae*
20	G-28	Hunza	Ali Abad	*Botryodiplodia theobromae*
21	G-29	Hunza	Murtaza Abad	*Botryodiplodia theobromae*
22	G-32	Gilgit	Nomal	*Botryodiplodia theobromae*
23	G-34	Gilgit	Gilgit city	*Botryodiplodia theobromae*
24	G-35	Gilgit	Oshikhandas	*Botryodiplodia theobromae*
25	G-36	Ghizer	Sher Qila	*Botryodiplodia theobromae*
26	G-39	Ghizer	Bober	*Botryodiplodia theobromae*
27	G-2	Nagar	Skinderabad	*Fusarium solani*
28	G-6	Hunza	Karim Abad	*Fusarium solani*
29	G-14	Gilgit	Gilgit city	*Fusarium solani*
30	G-18	Ghizer	Chatorkhand	*Fusarium solani*
31	G-21	Nagar	Jafarabad	*Fusarium solani*
32	G-25	Nagar	Ghulmat	*Fusarium solani*
33	G-30	Hunza	Nasir Abad	*Fusarium solani*
34	G-31	Gilgit	Jalal Abad	*Fusarium solani*
35	G-33	Gilgit	Danyore	*Fusarium solani*
36	G-37	Ghizer	Ghakouch	*Fusarium solani*
37	G-38	Ghizer	Chatorkhand	*Fusarium solani*
38	G-40	Ghizer	Singul	*Fusarium solani*
39	G-4	Nagar	Nilt	*Neoscytalidium novaeholla*
40	G-8	Hunza	Ali Abad	*Neoscytalidium dimidiatum*

***Prevalence, severity and incidence of gummosis*:** The results of the study reveal significant variations in the parameters associated with gummosis syndrome across different districts and valleys in Gilgit Baltistan (Table 3). Disease severity exhibits considerable differences among the surveyed locations. The highest recorded disease severity is 28% in Jafarabad (Nagar district), indicative of severe infection levels. In contrast, valleys such as Singul (Ghizer district) show lower disease severity with a value of 10 %. Disease incidence, ranges from 35 trees in Karim Abad (Hunza) to

58.33 in Jalal Abad (Gilgit). These figures highlight significant differences in the impact of gummosis across the surveyed locations.

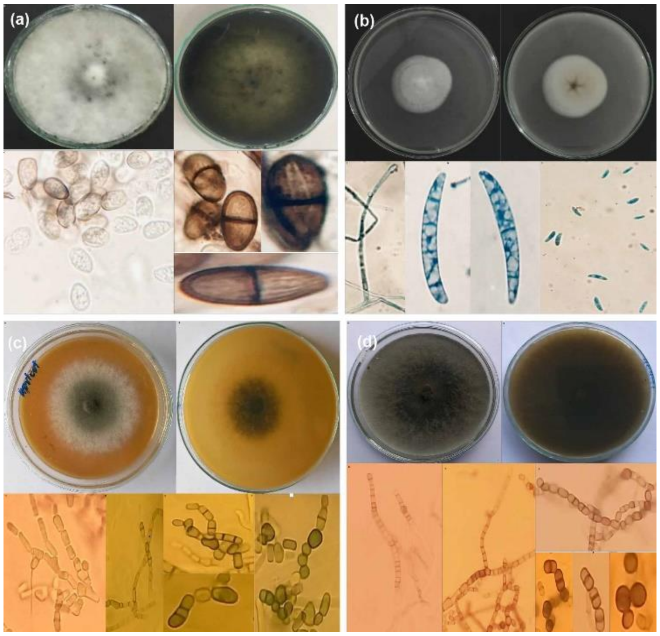

Figure 3. Morphological characteristics of fungal species associated with the Gummosis syndrome of apricots. (a) *Botryodiplodia theobromae*: Colony front and back, Hyaline aseptate conidia, Mature brown septate conidia with striation, (b) *Fusarium solani*, Colony front and back, Conidiophore, Macro-micro conidia, (c) *Neoscytalidium novaehollandiae*: Colony front and back, Premature arthroconidia, Arthriconodia in chain, Light brown 1 and 2 septate conidia, (d) *Neoscytalidium dimidiatum*: Colony front and back, Branched septate brown hyphae, Contiguous arthroconidia, Different shapes of conidia.

Disease prevalence, also shows considerable fluctuations. The prevalence ranges from 69.67% in Oshikhandas (Gilgit) to 85.33% in Jafarabad (Nagar). This indicates that gummosis is widespread in many apricot orchards throughout Gilgit Baltistan. Based on the results provided in the table and the description in the previous response, it appears that the major district affected by gummosis syndrome is Nagar, particularly the Jafarabad valley. The data shows that Jafarabad has the highest disease severity (28 %), relatively high disease incidence (50 %), and a high disease prevalence (85.33%). On the other hand, the district or valley that is least affected by gummosis syndrome appears to be Singul in the Ghizer district. Singul has the lowest recorded disease severity (10 %), which indicates minimal severity (Table 3). However, it's important to note that disease incidence and prevalence values for Singul are not necessarily the lowest, but the low disease severity suggests that the disease is less severe in this area. These observations suggest that Nagar, district, is most affected by gummosis syndrome, while other districts are relatively less affected.

Table 3. Prevalence, Incidence and severity of gummosis syndrome.

District	Valley	Disease severity (%)	Disease incidence (%)	Disease prevalence (%)
Nagar	Jafarabad	28	50.00	85.33
Nagar	Skinderabad	27	40.00	83.67
Nagar	Chalat	26	55.00	80.67
Nagar	Nilt	25	45.00	84.67
Nagar	Ghulmat	24	48.33	80.00
Hunza	Karim Abad	23	35.00	71.33
Hunza	Ghanish	22	50.00	71.00
Hunza	AliAbad	21	53.33	70.67
Hunza	Murtaza Abad	20	41.67	73.67
Hunza	Nasir Abad	19	45.00	75.00
Gilgit	Nomal	18	55.00	70.30
Gilgit	Danyore	17	40.00	70.67
Gilgit	Gilgitcity	16	50.00	76.67
Gilgit	Jalal Abad	19	58.33	72.67
Gilgit	Oshikhandas	15	41.67	69.67
Ghizer	Sher Qila	14	35.00	71.33
Ghizer	Ghakouch	13	53.33	70.67
Ghizer	Chatorkhand	12	45.00	73.33
Ghizer	Bober	11	41.67	75.67
Ghizer	Singul	10	50.00	72.67

***Spatial distribution of gummosis syndrome*:** The figures provided below shows the spatial distribution of gummosis syndrome in apricots across the four districts of GB (Figure 4, 5 and 6). The figure shows that the incidence of gummosis syndrome is highest in Ghizer and Hunza followed Nagar and Gilgit. This suggests that the disease is more prevalent in the northern and western parts of GB. Additionally, the figure shows that the spatial distribution of gummosis syndrome is not uniform within each district. For example, in Ghizer, the incidence of the disease is highest in the northwestern part of the district and lowest in the southeastern part of the district. This suggests that there may be other factors, such as soil type or topography, that also contribute to the distribution of the disease. The prevalence of gummosis syndrome in apricots in district Ghizer and Nagar is high, as compared to district Hunza and Gilgit. Similar trend was also noted for disease severity. Furthermore, the spatial distribution of gummosis syndrome in apricots these districts is not uniform. The disease is more prevalent in the northern and western parts of each district, where the elevation is higher and the climate is cooler. The disease is also more prevalent in some areas within each district than in others (Figure 4, 5 and 6).

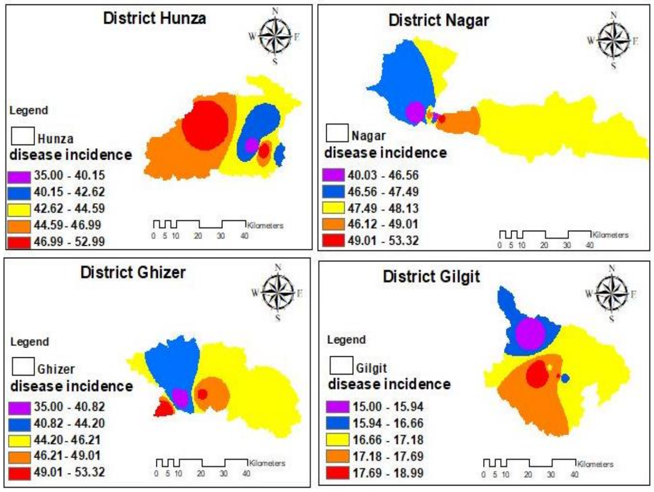

Figure 4. Incidence of gummosis associated with apricots

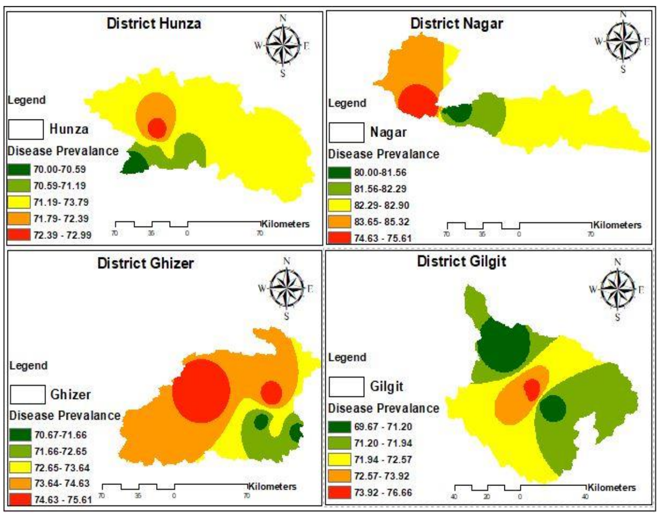

Figure 5. Prevalence of gummosis associated with apricots

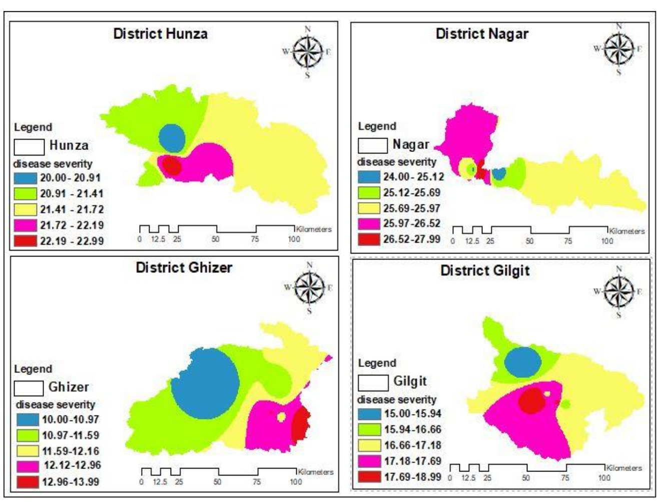

Figure 6. Severity of gummosis associated with apricots

DISCUSSION

The results of this study provide valuable insights into the symptoms and manifestations of gummosis syndrome in apricot trees. Gummosis, a well-recognized and detrimental disease, has been investigated to understand its impact on apricot orchards in the GB region (Ezra *et al.*, 2017; Abbas, 2018). The observed symptoms reflect the complex interactions between the pathogen and the host plant and offer a foundation for disease diagnosis, management, and future research endeavors (Jain *et al.*, 2021). One of the most characteristic symptoms of gummosis is the oozing of gummy or resinous material from affected areas on branches, twigs, and the trunk of apricot trees. This exudate is a hallmark of the disease, distinguishing it from other afflictions. The gummy substance was observed to be sticky, suggesting its adhesive nature. Upon drying, it formed a hard, amber-colored deposit. This observation aligns with the existing literature on gummosis and reinforces the notion that this sticky residue is a key diagnostic feature (Li *et al.*, 2014; Ezra *et al.*, 2017; Jain *et al.*, 2021). Lesions or cankers were consistently associated with gummosis-affected areas. These lesions manifested as sunken or discolored regions on the plant parts, particularly bark. Bark damage is a common outcome of gummosis, as indicated by the presence of these characteristic lesions. Bark discoloration, another noticeable feature, was observed in affected areas. Changes in bark color were evident, with affected regions becoming darker. In severe cases, the bark appeared black or brown, further highlighting the severity of the disease in certain instances. The progression of gummosis in apricot trees was also marked by the disintegration of bark integrity. In severe cases, cracking and peeling of bark around the affected areas exposed the inner wood of the tree. This observation indicates a direct impact on the structural integrity of the tree, potentially affecting its overall health and longevity. Moreover, the weakening of branches and twigs was evident, rendering them more susceptible to breakage. This finding has implications for the structural stability of apricot trees in gummosis-affected orchards. Furthermore, the results of this study indicate that *Botryodiplodia theobromae* is the most prevalent fungal pathogen associated with gummosis syndrome in apricots across all districts, followed by *Fusarium solani* (Zhang *et al.*, 2022). These findings are consistent with previous studies that have reported *Botryodiplodia theobromae* and *Fusarium solani* as the most common fungal pathogens associated with gummosis syndrome in apricots in other parts of the world (Singh *et al.*, 2018). The presence of *Neoscytalidium* spp. in a few isolates collected from District Nagar and Hunza is also noteworthy. *Neoscytalidium* spp. are a group of emerging fungal pathogens that have been reported to cause a variety of diseases in plants, including gummosis syndrome in apricots. Further research is needed to investigate the role of

Neoscytalidium spp. in the etiology of gummosis syndrome in apricots in Pakistan. Moreover, the morphological characteristics of the fungal isolates obtained in this study are consistent with those reported in the literature for *Botryodiplodia theobromae*, *Fusarium solani*, *Neoscytalidium novaehollandiae*, and *Neoscytalidium dimidiatum* (Singh *et al.*, 2018; Zhang *et al.*, 2022). Furthermore, this study showed significant variation in the parameters associated with gummosis syndrome across different districts and valleys in Gilgit Baltistan. The highest disease severity, incidence, and prevalence were recorded Nagar district, while the lowest disease severity was recorded in Gilgit district. These findings suggest that Nagar district is the most affected by gummosis syndrome, while other districts are relatively less affected. There are a number of possible explanations for this variation. One possibility is that the environmental conditions in Nagar district are more favorable for the growth and development of the fungal pathogens that cause gummosis syndrome. For example, Nagar district has a higher elevation and cooler temperatures than other districts. This may create an environment that is more conducive to the growth of fungal pathogens (Cysne *et al.*, 2010). Another possibility is that the apricot trees in Nagar district are more susceptible to gummosis syndrome due to other factors, such as stress or poor nutrition (Cardoso *et al.*, 2004). For example, the apricot trees in Nagar district may be more susceptible to cold stress due to higher elevation than the apricot trees in other districts. This increased stress may make the trees more susceptible to infection by fungal pathogens. Climate change is causing a number of changes in the environment, including rising temperatures, increased precipitation variability, and more extreme weather events (Mancero-Castillo *et al.*, 2018; Wood and Breeyen, 2021; Jo *et al.*, 2022). These changes can create conditions that are more favorable for the growth and development of fungal pathogens, such as those that cause gummosis syndrome. For example, rising temperatures can increase the rate of fungal growth and reproduction. Additionally, increased precipitation variability can lead to periods of drought and flooding, which can stress apricot trees and make them more susceptible to infection. Finally, more extreme weather events, such as hailstorms and windstorms, can damage apricot trees and create wounds that can serve as entry points for fungal pathogens. In addition to the environmental factors discussed above, other factors that may contribute to the high incidence and prevalence of gummosis syndrome in Nagar district include susceptible apricot varieties, inadequate management practices by farmers and the spread of fungal pathogens through irrigation water. Additionally, the spatial distribution of gummosis syndrome in apricots in GB shows that the disease is more prevalent in the northern and western parts of the region. This is likely due to the fact that these areas have higher elevations and cooler temperatures, which are more favorable for the growth and development of the fungal pathogens that cause gummosis syndrome (Alves *et al.*, 2020). The non-uniform distribution of gummosis syndrome within each district suggests that there may be other factors, such as soil type or topography, that also contribute to the distribution of the disease (Guoliang *et al.*, 2014; Ma *et al.*, 2021). For example, areas with poor drainage or heavy clay soils may be more prone to gummosis syndrome. The high prevalence of gummosis syndrome in the Ghizer and Nagar districts is a particular concern for apricot growers in these regions. The disease can cause significant damage to apricot trees and reduce crop yields. In severe cases, the disease can kill trees.

***Conclusion and future perspectives*:** The findings of this study suggest that gummosis syndrome is a major problem in apricot orchards in Gilgit Baltistan. Gummosis syndrome is a complex disease of apricot trees caused by various fungal pathogens, the most prevalent of which are *Botryodiplodia theobromae* and *Fusarium solani*. The disease is characterized by several symptoms, including the oozing of gummy exudate, the formation of lesions and cankers, bark discoloration, and the disintegration of bark integrity. The progression of the disease can weaken branches and twigs, rendering them more susceptible to breakage. The severity of gummosis syndrome varies across different districts and valleys in Gilgit Baltistan (GB), with Nagar district being the most affected followed by Ghizer, Hunza and Gilgit district. This variation is likely due to a combination of factors, including environmental conditions, host susceptibility, and management practices. Climate change is also a potential factor contributing to the high incidence and prevalence of gummosis syndrome in GB. Furthermore, the disease is most prevalent in the northern and western parts of the region, where the elevation is higher and the climate is cooler. The disease is also more prevalent in some areas within each district than in others. The high prevalence of gummosis syndrome in GB is a concern for apricot growers, as the disease can cause significant damage to trees and reduce crop yields. There are a number of things that apricot growers can do to prevent and manage gummosis syndrome, including planting trees in well-drained areas, providing adequate water and fertilizer, inspecting trees regularly for signs of the disease, pruning infected branches, and applying fungicides. Further research is needed to better understand the factors that contribute to the spatial distribution of gummosis syndrome in GB and to develop more targeted and effective control strategies for the disease. Exploring the genetic and molecular landscapes of *Botryodiplodia theobromae* and *Fusarium solani* strains offers a promising avenue for enhancing our understanding of their pathogenicity and evolutionary dynamics, potentially paving the way for finely tuned control measures. Investigating host-pathogen interactions is equally crucial, aiming to unravel the factors that render apricot trees in Nagar district more susceptible to gummosis syndrome.

This involves a meticulous exploration of genetic and environmental influences, potentially leading to the development of more resilient apricot varieties and improved orchard management. Considering the broader context, the analysis of environmental factors, such as temperature, precipitation patterns, and the impact of climate change, becomes imperative to comprehend their intricate roles in shaping the prevalence and severity of gummosis syndrome. Lastly, in the realm of disease management and control, dedicated research tailored to the unique conditions of Gilgit Baltistan is needed, encompassing evaluations of irrigation practices, the introduction of disease-resistant apricot varieties, and the promotion of enhanced orchard hygiene, all vital in the prevention and mitigation of this destructive ailment.

***Author contributions statement*:** R. Ahmad, A. Ali, S.UD. Din, W. Hussain, Z. Ali: Data collection, software; formal analysis; validation, investigation and resources, A. Ali: GIS mapping; A. Abbas: Conceptualization, Supervision, original draft writing and editing, S. A. Hussain, I. Hussain, Z. Hussain and A. Razaq: Technical assistance. All authors read and approved the submitted version.

***Acknowledgments*:** This research is preliminary and is based on an accepted concept note within the ALP-PARC project proposed by the corresponding author, Aqleem Abbas. It is essential to emphasize that the corresponding author cannot definitively assert the acceptance of the entire research proposal, as it is subject to evaluation by ALP-PARC reviewers. Nevertheless, should the research proposal be accepted, this study will be deemed an integral component of the overarching research project.

***Conflict of interest*:** The authors declare no conflict of interest.

***Ethical statement*:** This article contains no studies regarding humans or Animals.

***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere.

REFERENCES

Abbas, A. 2018. First report of Gummosis disease of major fruits in Gilgit-Baltistan (GB) Pakistan. International Journal of Life Sciences and Scientific Research. eISSN 2455:1716. https://doi.org/10.21276/ijlssr.2018.4.3.11

Alves, E.S., W.L. Fonseca, L.G.C.d. Silva, J.S. Lima and J.E. Cardoso. 2020. Effect of climate and geographical conditions on the occurrence of cashew gummosis in the northeast of Brazil. Revista Ciência Agronômica 51. https://doi.org/10.5935/1806-6690.20200051

Cardoso, J.E., A.A. Santos, A.G. Rossetti and J.C. Vidal. 2004. Relationship between incidence and severity of cashew gummosis in semiarid north-eastern Brazil. Plant Pathology 53:363-367. https://doi.org/10.1111/j.0032-0862.2004.01007.x

Chen, C., C.H. Bock, H.H. Hotchkiss, M.M. Garbelotto and T.E. Cottrell. 2015. Observation and identification of wood decay fungi from the heartwood of peach tree limbs in central Georgia, USA. European Journal of Plant Pathology 143:11-23. https://doi.org/10.1007/s10658-015-0661-4

Cysne, A.Q., J.E., Cardoso, A.d.H.N. Maia and F.C. Farias. 2010. Spatial-temporal Analysis of Gummosis in Three Cashew Clones at Northeastern Brazil. Journal of Phytopathology 158:676-682. https://doi.org/10.1111/j.1439-0434.2010.01674.x

Dy, K.S., P. Wonglom, C. Pornsuriya and A. Sunpapao. 2022. Morphological, molecular identification, and pathogenicity of Neoscytalidium dimidiatum causing stem canker of Hylocereus polyrhizus in southern Thailand. Plants 11:504. https://doi.org/10.3390/plants11040504

Ezra, D., M. Hershcovich and D. Shtienberg. 2017. Insights Into the Etiology of Gummosis Syndrome of Deciduous Fruit Trees in Israel and its Impact on Tree Productivity. Plant Disease 101:1354-1361. https://doi.org/10.1094/pdis-12-16-1836-re

Guoliang, L.I., Y.A.O., Li-xian, H.E., Zhao-huan, Chang-min Z., Bao-mei Y., and T.U. Shi-hua, 2014. Primary relationship between nutritional accumulation, distribution, and gummosis on Yingzui peach. Journal of Plant Nutrition and Fertilizers 20:421-428. https://doi.org/10.1094/pd-66-158

Hussain, A., M.S Awan,., S. Ali and H. Azhar. 2012. Pre-harvest Fruit Losses and Physico-Chemical Analysis of Different Varieties of Pomegranate in Gilgit-Baltistan Pakistan. Journal of Agricultural Science and Technology B2(9B):997. https://doi.org/10.17140/aftnsoj-5-156

Jain, S., G. Singh, V. Jindal and A. Singh. 2021. Resolving the etiological conundrum of the gummy stem, sudden death and leaf blight syndromes of bottle gourd in Indo-Gangetic plains of India. Journal of Plant Pathology 103:433-441. https://doi.org/10.1007/s42161-021-00818-0

Jo, Y., D.R. Jung, T.H. Park, D. Lee, M.K. Park, K. Lim et al. 2022. Changes in Microbial Community Structure in Response to Gummosis in Peach Tree Bark. Plants 11:2834. https://doi.org/10.3390/plants11212834

Li, Z., Y.T. Wang, L. Gao. F. Wang, J.L. Ye and G.H. Li. 2014. Biochemical changes and defense responses during the development of peach gummosis caused by Lasiodiplodia theobromae. European Journal of Plant Pathology 138:195-207. https://doi.org/10.1007/s10658-013-0322-4

Ma, X., X. Liu, P. Xiang, S. Qiu, X. Yuan and M. Yang. 2021. Effects of the Contents of Mineral Elements on Gummosis in Prunus salicina Lindl. HortScience 56:568-571. https://doi.org/10.21273/hortsci15649-21

ManceroCastillo, D., A. SarkhoshS. Sherman, M. Olmstead, P. Harmon and T. Beckman. 2018 Fungal Gummosis in Peach: HS1265, rev. 7/2018. EDIS 2018: https://doi.org/10.32473/edis-hs1265-2018

Moller, W.J., and M.V. Carter. 1970. Field evaluation of benomyl for control of limb dieback (gummosis) in apricots. Australian Journal of Experimental Agriculture 10:488-489. https://doi.org/10.1071/ea9700488

Ogawa, J.M. 1995. Compendium of stone fruit diseases. APS Press, the American Phytopathological Society. Google Scholar

Pan, M., H. Zhu, G. Bonthond, C. Tian and X. Fan. 2020. High Diversity of Cytospora Associated With Canker and Dieback of Rosaceae in China, With 10 New Species Described. Frontiers in Plant Science 11. https://doi.org/10.3389/fpls.2020.00690

Shahzad, M.A., S. Abubakr and C. Fischer. 2021. Factors affecting farm succession and occupational choices of nominated farm successors in Gilgit-Baltistan, Pakistan. Agriculture 11:1203. https://doi.org/10.3390/agriculture11121203

Singh, G., S. Jain, A. Singh and M. Pathak. 2018. Standardization of screening protocol and evaluation of bottle gourd genotypes against gummy stem disease caused by Fusarium verticillioides. Plant Disease Research 33:37-40. Google Scholar

Wood, A.R., and A.D. Breeyen. 2021. Incidence of gummosis disease in silky hakea under natural conditions in South Africa. South African Journal of Plant and Soil 38:126-133. https://doi.org/10.1080/02571862.2021.1879286

Zhang, D., X. Shen, H. Zhang, X. Huang, H. He, J. Ye, et al. 2022. Integrated transcriptomic and metabolic analyses reveal that ethylene enhances peach susceptibility to Lasiodiplodia theobromae-induced gummosis. Horticulture Research 9: uhab019. https://doi.org/10.1093/hr/uhab019