



Review Article

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Emerging Plant Diseases of Gilgit-Baltistan (GB) Pakistan: A review



Aqleem Abbas^{1*}, Sartaj Alam Syed² and Anam Moosa³

¹The Provincial Key Lab of Plant Pathology of Hubei Province, College of Plant Science and Technology, Huazhong Agricultural University, China

²Department of Plant Pathology, The University of Agriculture Peshawar, Pakistan

³Department of Plant Pathology, University of Agriculture Faisalabad, Pakistan

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***Corresponding author:** Aqleem Abbas, The Provincial Key Lab of Plant Pathology of Hubei Province, College of Plant Science and Technology, Huazhong Agricultural University, Wuhan, Hubei Province, PR China.

Abstract

Gilgit-Baltistan (GB) region of Pakistan, having unique geographic and climatic conditions was free from plant diseases. Because the disease-resistant traditional varieties of plants were replaced by high-yielding varieties, GB's crops are now threatened by many diseases, such as late blight, early blight, leaf roll virus (affects potato and tomato crops), grey mold (grapes), powdery mildew (cucumbers), Botrytis leaf virus (onions), crown gall disease (cherries), gummosis disease (apricots, almonds, plums, and peaches), and nematodes (potatoes). The effects of these diseases range from mild symptoms to catastrophes in which entire crops are destroyed. These plant diseases are a major yield-limiting factor for many crops and threaten GB's food supplies. Therefore, there is a need to identify the diseases present on farms, identify the causal agents and their virulence, determine the severity of the disease and its effect on yield, and seek proper management. There is also a need to develop resistant varieties against these diseases. Though plant diseases are a major threat to GB's food security, their rapid identification remains difficult due to the lack of the necessary infrastructure. Moreover, research is required to improve food security by reducing the yield losses caused by these diseases. Providing a background that plant diseases are the key constraints to food security in GB, this review paper uses some plant diseases as a case study to illustrate their key influences on the yields of some fruit and vegetable crops

Keywords: Gilgit-Baltistan; Plant diseases; Management; Food security

Abbreviations: KKH: Karakorum Highway; GB: Gilgit-Baltistan; CPM: Cucumber Powdery Mildew; IDM: Integrated Disease Management; BCAs: Biological Control Agents

Introduction

Gilgit-Baltistan (Formerly known as Northern Area) is mountainous region of Pakistan [1]. The total area of Gilgit Baltistan (GB) is 72,971km² (28,174sq.mi). GB having fifty highest peaks and three world's longest glaciers is one of the spectacular regions of the world. It is linked by Karakorum highway (KKH) with Xinjiang region of China to the east and north east, Khyber Pakhtunkhwa to the west, Azad Kashmir to the south and to its north Wakhan Corridor of Afghanistan is located [2]. Gilgit Baltistan (GB) is divided into three divisions i.e. Gilgit, Baltistan and Diamer which, in turn, divided into Districts i.e. Gilgit (Gilgit, Ghizer, Hunza and Nagar), Baltistan (Skardu, Shigar, Kharmang, and Ghanche) and Diamer (Diamer and Astore). In 2000 majority of GB population was involved in the agricultural sector, but recently services have surpassed agriculture as the principal source of income. Cherry, apricot, apple, peach and grapes are the common fruits. Among the vegetables potato is one of the main sources of income of farming community of GB. Wheat and maize are the major cereal crops. Severe winter, cool spring and hot and dry summer of GB make the area suited for the cultivation of

fruits, vegetables and cereals. GB has the most fragile ecosystem and climate change impacts are more drastic and extreme. Recent increase in temperature and heavy rainfall associated with worldwide climate change resulted in the diseases of fruit trees creating food insecurity for the apricot growers of GB. The climate of GB is minimally influenced by the monsoon from the east and mostly winds from the west [3]. The average annual rainfall is 140.73mm per year with the mean maximum of 23.66mm during the months of May and June and mean minimum of 2.26mm and 3.0mm in January and November, respectively. Hot summers, cold winters and great seasonal differences are major climatic conditions. In December and January, the average minimum monthly temperature is $\pm 4^{\circ}\text{C}$ however the average maximum monthly temperature during July and August is $\pm 25.19^{\circ}\text{C}$ [4].

Fruits such as apricots, apples, grapes, pears and pomegranate are widely grown. The region having unique geographic and climatic conditions was free from plant diseases. Since the disease resistant traditional varieties of plants have been replaced by high yielding varieties. The introduction of handful of high

yielding varieties have also reduced the genetic diversity. As a result major threats come in the form of diseases such as Late blight and early blight of potato and tomato crops, Grey mold of Grapes, Powdery mildew of cucumbers, Botrytis leaf virus in onions, Crown gall disease of cherries and nematodes of potatoes. Among the fruit trees apricots, almonds, plums and peaches have severely been infected with Gummosis diseases. Grapes are devastated by botrytis leaf blight. Moreover, potato production is hampered by early blight, late blight and black scurf diseases and cucumbers are severely infected by cucumber powdery mildew (CPM). The immediate management of the above mentioned plant diseases is very important for food production as well as for the sustainability of GB's natural environments. Therefore, there is need to understanding the biology of the emerging plant diseases and to communicate and engage with the stake holders and policy makers to implement an effective plant disease management strategies. The scope of the present review is to compile and discuss plant disease of GB focusing on fungal plant pathogens in agriculture and horticulture. This review will provide a brief overview of important emerging plant diseases and their effects on the production of economically important crops.

Early Blight Disease of Potatoes

Potatoes are highly valuable, nutritious vegetable and major cash crop grown in Gilgit- Baltistan (GB) Pakistan. Recently early blight disease has severely infected the potato fields of Normal valley of GB. Early blight is an important foliar disease under diverse climatic conditions of GB. Over the past few years, early blight became a major threat to potato crops in GB and highest incidences were recorded in Normal Valley of GB. Normal Valley has been divided into six major sectors or Mohallahs. The Mohallahs are as; Mohallah Jigot, Mohallah Batot, Mohallah Majini, Mohallah Das and Mohallah Sigal. During June-July, 2016 a survey were carried out in randomly selected five fields of each Mohallah of Valley Nomal. Within each field five potato plants were randomly selected and observed for typical early blight symptoms. Moreover, at harvesting stage tubers were also observed for early blight symptoms. The disease incidence and disease severity were recorded. The highest percent disease severity (66.4) was recorded in potato fields of Mohallah Jigot followed by potato fields of Mohallah Sigal (63.2%), Mohallah Majini (42%) and Mohallah Batot (36%). Meanwhile the minimum percent disease severity was recorded on the potato fields of Mohallah Das (12%). It can be concluded from the present study that early blight is serious threat to potato production in Nomal Valley of GB [5]. This polycyclic disease can cause more than one disease epidemics within a single cropping season. It produces a lot of secondary inoculum and cannot be controlled easily. Early blight is not only reported from GB but is reported from all potato growing regions of Pakistan and one of the significant foliage diseases in the regions with favorable weather conditions. Two species of genus *Alternaria* (*A. solani* and *A. alternata*) were known to be causal agents of early blight disease. Dry weather and low organic matter containing irrigated potato fields of GB make the conditions favorable for early blight

disease. As aforementioned early blight is causing economic losses of yields on potato crops of GB therefore developing and using effective management strategy is very important [6]. Recently genomes of multiple *Alternaria* species have been sequences and this kind of studies provide valuable data to know about the genes involved in causing diseases. In conclusion the genome assembly is very important step to understand the pathogenicity of *Alternaria* species [7].

Late Blight Disease of Potato

Potato (*Solanum tuberosum* L.) is the most widely grown food crop in the world having high nutritional and economical value. It produces more calories per hectare as compared to cereals such as rice and wheat [8,9]. It is one of the member of Solanaceae family which also included chilli, eggplant, tobacco and tomato [10]. Though it has originated in the Andes region and from there it reached to subcontinent by Portuguese traders. Now it has become an integral part of almost every dish in Pakistan. Pakistan having unique weather is suitable for the production of potato [11]. Recently the production of potato has increased in Gilgit Baltistan (GB) Pakistan due to increased acreage as well as due to the introduction of new cultivars in this area. Potato is a cash crop so it has become major source of income for the farmers. The production of potato crop in 2017 was approximately 20 bags (Each bag was of 70-80Kg) per Kanal area. However, to estimate total annual potato production of GB is difficult to do accurately due to the fact that the region is highly mountainous, and crop mature at different dates depending on the altitudes of potato growing areas. Since the disease resistant traditional varieties of plants have been replaced by high yielding but susceptible varieties. As a result major threats come in the form of various diseases. Among these diseases late blight is the most important one affecting potatoes [12,13]. The causal agent of the late blight is *Phytophthora infestans* (Mont.) de Bary, which is not only limiting the production of potatoes in GB but also worldwide [14]. Currently in GB it is the most destructive disease because of its increasing distribution potential. The potato cultivars were introduced to GB from the Kalam and Malam Jaba valleys of Swat district of Pakistan in 1990s. Ever since late blight has been found from all the potato growing areas of GB notably in the elevated valleys such as Nalter, Nomal and Dayetar Valleys. GB has a cooler climate, so the climate is favorable to pathogen. However, the pathogen has potential to adapt a diverse range of environmental conditions. The disease has devastating effects on potato tubers as well as foliage. The temperate as well as other climatic conditions [15], of GB are favorable for the rapid multiplication of this diseases. The recent erratic and high rainfall have also contributed in the increment of this disease. The pathogen is found to infecting all stages potato crop stems along with the tubers and leaves are also found to be infected. Whitish cottony growth on the lower side of foliage and on the edges of the leaves. Brownish green lesions are found on the upper side of foliage. However, the dark brown or black lesions were observed on the petioles and stems. Potato tubers were found to be rotting. Management Late blight of potato

can be controlled by the integrated disease management (IDM) strategy the ideal way to combat this disease is

through the development of resistant cultivars. However, there is not any such Plant Breeding and Plant Pathology institute in GB for the screening of potato germplasm against late blight of potato. Currently every commercial variety is susceptible to late blight disease. In other provinces of Pakistan new varieties have been developed however need to be test for the presence of resistance genes to late blight disease. Fungicides may play an important role in reducing the incidence of late blight however in GB the farmers have no access to fungicides [16]. Moreover, the application of fungicides may reduce the local diversity of other organisms as well as pollute the environment. The convincing arguments for the continued emergence of late blight diseases were given by Fry et al. [14]. Novel strains of late blight diseases with increase virulence and appearance to the new location with high intensity make the *P. infestans* most notorious plant pathogen of potato crop. The authors further provided the recent knowledge about the current population biology and molecular genetic analysis of late blight diseases.

Grey Mold Disease of Grapes

The economy of the people is largely dependent on these horticultural crops [17]. Among the horticultural crops the grapes are the most popular fruit of GB [17]. There are numerous locally grown grape varieties of specific characteristics in GB. Recently the diseases of grapes have posed problems for the viticulturists in GB Pakistan. The higher amount of rainfall in the recent years which is associated with the climate change favor the development of diseases. Among the diseases the grey mold fungus *Botrytis cinerea* Pers. Fr. [Teleomorph *Botryotinia fuckeliana* (de Bary) Whetzel]. a necrotrophic fungus causes severe losses in the ripening grapes [18,19], in GB However the other areas of Pakistan such as Lahore where approximately 40% of grape fruits were reported to infect with grey mold or *Botrytis* bunch rot disease [20]. The fungus (*Botrytis cinerea*) is asexual form of fungus because the sexual form (Teleomorph; *Botryotinia fuckeliana*) is rarely observed [21]. Gray mold fungus affect grape berries, resulting in yield losses and reduced fruit quality [22]. The grapes infected with the fungus are more often damaged to such an extent that they are useless for consumption. In the recent years frequent spring rains have caused moist conditions which cause shoot blight of grapes prior to fruit ripening. Soft brown tissues develop on the infected plant parts. The leaf axils are also infected which cause the shoots to wilt or collapse. The infected berries become brownish or reddish depending on cultivars. As wind speed is very low and temperature is moderate therefore epidermal cracks appear in which fungal product mycelium and spores are formed. As a result, the whole bunch of grapes exhibited characteristic gray and velvety appearance. The fungus produces hard resistant structures called sclerotia particularly on the diseases berries which are felled on the ground or left hanging on the vines [18]. During rain or irrigation these hard-resistant structures germinate and produce spores which are moved by air

currents or splashing rain. If free water and moderate temperature is available infection by this spore is real. During spring flowers can become infected through the stigma and through a scar on the tip of pedicel. The fungus then begins to dormant and waiting for late in the season when the sugar concentration increases in the infected berry. The fungus then start to infection and rapidly spread throughout the berries. When the infection increases the berries split and become crack, thus pathogen transfer and spread to adjoining berries. If the relative humidity is very high and free moisture is present and temperature is moderate the late infections become more severe. The berries are also infected when insets and birds are causing injuries. When the fruit begin to ripe there is much water and nutrients available consequently fungus can proliferate well and cause severe infection. This disease can be managed by development of resistant cultivars, cultural practices and as well environmentally friendly bio control agents [23]. Though it is difficult to manage this disease because it has diversity in modes of attacks, broad host range and can survive as mycelia, conidia and sclerotia for extended periods of time. The precipitation patterns of the region are unreliable and erratic and therefore the timely management of grape diseases have become difficult. There are no resistant cultivars available to minimize the economic losses faced by farmers due to gray mold disease. The cost of fungicides are so high as well as not ecofriendly. Moreover, the lack of storage and marketing facilities for grapes also inflict heavy post-harvest losses to grapes.

Powdery Mildews on Cucumbers

Cucumber is the most important vine crop and widely grown in Gilgit Baltistan (GB) Pakistan [24]. A study was conducted in open fields of cucumbers of village Nomal of GB. Cucumbers were found to be severely infected by cucumber powdery mildews (CPM) disease. The village Nomal has been divided into five major sectors i.e. Sigal, Das, Batot, Jigot and Majini (In local language called Mohallahs). In each sector five fields were randomly selected. In each field twenty plants were randomly selected and observed for the presence of powdery mildews. The disease severity and percent disease incidence of CPM were recorded. Among the Mohallahs the highest percent disease incidence of CPM was recorded in cucumber fields of Majini Mohallah with a value of 60% followed by Batot (58%), Jigot (49%) and Das (43%) Mohallahs respectively. However, the minimum percent disease incidence of CPM was recorded in Sigal (37%) Mohallah. It can be concluded that open fields of cucumbers in Majini Mohallah were severely infected by CPM diseases [25]. Cucumber powdery mildew caused by *Erysiphe cichoracearum* and *Sphaerotheca fuliginea* has worldwide importance and it is considered to be one of the most devastating diseases as its occurrence and incidence assumes greater significance resulting in reduction of fruit yield. Recently he fungus *Leveillula taurica* was also reported to cause powdery mildew on cucumber in Mexico [26].

Gummosis Disease of Major Fruits

Gilgit-Baltistan (GB) is one of the major fruits producing a region of Pakistan. The fruits are primarily produced as cash crop

and notably the apricot, cherry, almonds, plum and peach. Among these fruits, apricots are widely planted in GB. Furthermore, GB is major apricot producing region in Pakistan. According to one estimate the total fruit production is about 170680 tons fruits per annum [27]. Regular grafting and planting seeds from the superior trees have increased the variations. However, due to varying climatic and soil conditions, the fruit trees are exposed to disorders. Heavy floods due to melting of glaciers in summer season change the soil conditions and interrupt the normal gaseous exchange between fruit trees and their environment. Moreover, causes sedimentation and weaken trees. The roots, root collar, and lower stem of fruit trees are significantly affected by floods. The injuries in these parts make fruit trees susceptible to pests and diseases. Moreover, high winds in late autumn season because severe injuries consequently fruit trees become vulnerable to severe diseases. Severe frost, snow and ice are also causing cracks in the main trunk, branches and twigs of fruits trees. These cracks become the entry point for the diseases. These diseases are continuously reducing the productive capability of fruit trees and adversely affect the fruit quality. Moreover, the introduction of high yielding varieties are continuously replaced the local varieties. Though these varieties are high yielding however in varying climatic conditions these varieties soon become exposed to diseases. The production of apricots, cherry, almonds, plum and peach has dropped largely as a result of diseases such as gummosis, cankers, crown galls, Grey mold and Shot hole disease [28]. Among these diseases, gummosis is one of the devastating diseases on these fruit trees. The causes of gummosis are still obscure. Gummosis is associated with the diseases, pests and also with other abiotic factors such as high winds and snow. Pruning and grafting with unsterilized tools can also cause gummosis. Some researchers consider gummosis as non-specific defensive response of trees against the diseases and other differential stresses [29]. Anyhow the disease has seriously affected thousands of apricots, cherry, almond, peach and plum trees in Gilgit-Baltistan (GB). The disease is characterized by deposition of gums that has oozed through the barks of main trunk, twigs, and branches and even on the fruits. With the age, cankers develop along the main trunks, branches, and twigs of fruit trees [30].

The association of gummosis disease with the fruit trees has a long history. Therefore, gummosis can be considered as a perennial disease of fruit trees in GB. Local people usually consume the gum exudates as an edible food. The gums have Functional, antioxidant, antimicrobial, and medicinal properties [31]. In June 2016 the fruit trees are surveyed and assembled first information regarding gummosis disease Gum deposits were yellowish, transparent and irregular in shape. The diameter of the gum deposits was 4 to 5cm around lenticels of trunk and branches. However, the diameter of the gum deposits on the twigs was 1 to 2cm. Gummosis is continuously spreading to other fruit growing regions of GB. Not a single variety of fruit tree is found to resistant to the gummosis. Therefore, timely management of this disease is very important. Cherry fruit becomes prolific gum producers in particular rainy days followed by peach, apricots, almonds and plum. The diseases

enter through wounds or lenticels on the branches, twigs and main trunks of fruit trees. Lenticels are breathing holes in twigs, branches and main trunk and these are entry points for the plant pathogens. Around the lenticels and injuries, small, depressed and discolored spots appear. Afterward, the area becomes dark and cracked with yellowish or whitish gummy exudation. Yellowing and drooping of leaves are common symptoms in young fruit trees. The disease has a significant economic impact in fruit trees orchards. Moreover, the disease is continuously reducing the fruit tree longevity and causing considerable losses in GB.

Crown Gall disease

Fruit diseases develop under a well-defined, optimal range of climatic variables such as temperature, rain, relative humidity. The occurrence and severity of any disease depends on the deviation of each climatic variables within the optimal range for disease development [32]. Therefore, recent heavy rainfalls and high temperature might be favorable and act together in the initiation and development of various bacterial, fungal and viral diseases of fruits in GB. Among the fruits, grapes are severely infected by Grey mold disease caused by *Botrytis cinerea* [28]. Apricot (*Prunus armeniaca* L.) is an economically important fruit of Gilgit-Baltistan (GB). According to a publish report of local Newspaper GB is the largest apricot producing region of Pakistan. Apricots covers 6170 hectares that gives 60305 tons of production annually in the GB. Nagar, Hunza and Nomal valleys are famous for Apricot production [33]. The varieties of apricot grown in Baltistan Division of GB are Halmand, Wahphochuli, Lonakpochuli, Sherakarpochuli Shakhanda, Margulam, Karpochuli, Ambah, Staachuli, Khochuli and Brochuli. Similarly the varieties of apricot grown in Gilgit Division of GB are Dugli, Neeli, Bedeiri, Chalpachu, Loli, Frugui, Khormagui, Alishah Kakas. Recently crown gall disease caused by *Agrobacterium tumefaciens* poses a serious threat to the apricots production in GB. In November 2008, crown gall disease was observed on apple apricot and cherry trees in Nagar and Nomal valleys of GB. These fruit trees were investigated from November 2008 to February 2008 to determine the incidence prevalence and severity level of the Crown gall in the District Gilgit and Nagar. Disease incidence and severity of the crown gall were about 99% in cherry and 97% in apple trees of Nomal valley. Likewise, disease incidence and severity of crown gall were 97% in cherry and 98% in apples of Nagar valley. Surprising no attack of crown gall disease was recorded on apricots of these valleys [34]. In spring, 2016 the apricot trees in Nagar and Nomal valleys of GB were observed with crown gall symptoms. Abnormal galls and tumors were observed on the roots and crown regions of the apricot plants. Moreover, secondary wood rots were also observed in some of the infected apricot trees. The symptoms observed were similar as described by [35]. Moreover, for further confirmation there is need to characterize the pathogen morphologically (colony color, colony shape etc.), biochemically (Fatty acid analysis, oxidase and catalase activities etc.) and more importantly through molecular methods (16SDNA based identification etc.). Gall tissues and soil are the main source of crown gall bacteria. The bacteria can enter

into apricot trees through injuries. To our knowledge improper apricot cuttings, grafting and picking with unsterile things and unhygienic methods might have caused injuries and that injuries have become entry point for the pathogen. Recently apricot cuttings have been introduced, therefore it is possible that the crown gall bacteria may have been introduced in GB through these cuttings. The apricot growers of GB need to grow certified and non-infected clean apricot trees. Moreover, to prevent the dissemination of crown gall disease to avoid injuries are very important. The disease can also be managed by Biological control agents (BCAs) such as *Agrobacterium radiobacter* strain K84 however BCAs are currently unavailable to apricot growers of GB. Crown gall disease can also be managed by application of antibiotics. In a previous study the most of the *Agrobacterium tumefaciens* strains isolated from the apple and cherry trees of Nagar and Nomal valley were found to resistant against the antibiotics such as Lincomycin, Amoxicillin, Ampicillin and Cloxacillin while Cephadrine, Tetracycline and Doxycycline [34]. Moreover, these antibiotics have medical and veterinary uses and are not cost effective and environment friendly therefore use of these antibiotics against crown gall disease is not a robust idea. Further research regarding the interaction of pathogen with apricot trees is needed.

Black Scurf

Black scurf is one of the most serious threats to potato crops in Gilgit, Baltistan. The causal agent is *Rhizoctonia solani*, which has so far been isolated from all the potato growing valleys of Gilgit-Baltistan. In Pakistan, black scurf is a commonly occurring fungal disease and is a severe problem in all potato production regions [33]. The disease is soil- and seed-borne and its incidence was first reported by Kuhn in 1858 [36]. The pathogen produces resistant structures of sclerotia ranging from 1mm to 10mm on potato tubers. The sclerotia stick to potato tubers and are difficult to remove by washing [37]. The disease reduces the size of potato tubers [38]. The other symptoms of this disease include creaking, deformity and pitting and consequently low quality of potato tubers [39]. This disease is found in all the potato growing regions of the world.

Black scurf is not limited to GB but also reported from other areas of Pakistan especially the northern areas of Khyber Pakhtunkhwa province and a few areas of province Punjab have also been affected by black scurf disease. Detailed information on geographical distribution of a crop disease is important for planning and development of efficient disease management strategies. The assessment of the incidence, prevalence and severity of black scurf disease was conducted in 2012–13 at the harvesting stage of the potato crops. For this purpose, a total of four valleys (Bagrote, Harmoush, Shigar and Hoper) of GB were selected, and four valleys from each valley were selected. In each village, 3 to 7 fields were randomly selected. The potato tubers were sampled based on visible symptoms of black scurf disease. Then, the overall prevalence range (25–75%), incidence (5.55–23.89%) and severity (1.67–6.55%) were noted in all the four valleys. Azhar et al. [40], further illustrates concepts important

for the analysis of black scurf disease, using the GIS technology. The black scurf pathogen is a soil born basidiomycete fungus with a necrotrophic lifestyle having fourteen reproductively incompatible anastomosis groups (AGs). The disease cause quantitative and qualitative yield losses through stem canker and black scurf in potato [41].

Conclusion and Future Prospects

Plant diseases have affected the production of crops since the beginning of the recorded history; therefore, their impact throughout the course of human history cannot be denied. The devastation of late blight of potato, for example, resulted in famine in Ireland, leading to the starvation and death of many of its people and forcing survivors to migrate to America or to other European countries. Quality of life has always been influenced by plant diseases; however, the synthesis of fungicides and the development of pathogen-free and resistant varieties have considerably reduced the number of plant diseases. In recent years, the spread of plant diseases has, however, increased due to the advent of rapid transportation modes and the free movement of people, which have introduced exotic diseases into areas in which they did not previously exist. Moreover, as a result of the increase in global warming, the effects of plant diseases have been exacerbated; consequently, these diseases are emerging as even greater threats to plants and, thus, to food security of GB. Monitoring and detection of above-mentioned plant diseases of GB is very essential for sustainable agriculture. Detailed sampling using molecular methods such as PCRs are very important for identification of diseases. Moreover, cultural practices, vector control through biopesticides and disease specific chemical and biocontrol agent applications can reduce the severity of these diseases and can improve productivity. Moreover, there is need for developing a fast, reliable and cost-effective technologies such as spectroscopic, GIS (imaging based) and volatile profiling based plant diseases detection techniques that can be used to monitor health and diseases of plants under field conditions.

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