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Detection of Diseases found in Saffron Plant and its Classification using ML: A Review

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Abstract: Saffron, derived from the dried stigmas of the Crocus sativus plant, holds immense value as an agricultural product. With a rich history spanning over 3500 years, saffron has been revered as a precious spice and has gained popularity due to its medicinal properties and diverse applications. As the demand for saffron continues to rise, efforts to increase productivity and expand cultivation face various challenges. One significant hindrance is the prevalence of diseases affecting saffron plants, which not only reduce yields but also impact the quality of saffron stigmas. This review paper offers a thorough and inclusive exploration of saffron-related diseases. Encompassing their historical backdrop, present conditions, impact on yield, dynamics of pathogens, methods of survival and spread, variables affecting disease severity, epidemiology, and approaches for sustainable management. Through the investigation of diseases and their discernment using machine learning techniques, the intention of this review is to be of advantage to cultivators, students, scholars, plant protection entities, developmental divisions, outreach staff, policymakers, governmental bodies, and civic organizations.

Overall, this review sheds light on the significance of saffron diseases, their impact on production, and the importance of adopting effective disease management strategies. By disseminating this knowledge, stakeholders can make informed decisions to mitigate the risks associated with saffron diseases and contribute to the sustainable growth of the saffron industry.
Keywords: crocus sativus; saffron; crocetin; diseases, machine learning

I. INTRODUCTION

The convergence of IoT, AI, and Unmanned Aerial Vehicles (UAVs) is harnessed to bolster the agricultural sector's capacity to identify plant leaf diseases and transmit accurate reports to relevant stakeholders. Within the context of contemporary society, the farming and agriculture domains have lost their appeal due to the incessant challenges confronting farmers. Consequently, the younger generation is migrating to urban centers in pursuit of a more secure life, evading the obstacles inherent in agricultural pursuits. Addressing the imperative of effective safeguarding against plant diseases is intrinsically tied to the dynamic shifts in climate and agriculture [1]. Emerging research underscores that shifts in climate can induce alterations in pathogenic life cycles and rates, potentially influencing host resistance and altering the dynamics of host-pathogen interactions [2]. The present reality, characterized by the unprecedented global movement of diseases, further compounds this predicament. Novel diseases may arise in regions where they were previously unknown, and the absence of local expertise exacerbates the challenge of combatting them [3]. The indiscriminate use of pesticides can foster the development of resistant pathogens over the long term, severely undermining our ability to counter them. A cornerstone of precision agriculture [4] rests on the swift and accurate diagnosis of plant diseases. Prudent allocation of resources is crucial to prevent unnecessary wastage, bolster production, and address the emergence of enduring pathogenic resistance as well as mitigate the adverse impacts of climate change. In this evolving context, timely and precise disease identification, encompassing early intervention, takes on paramount importance.

Various methodologies exist for detecting plant pathologies. While certain diseases lack overt symptoms or manifest too late for effective intervention, intricate assessments are warranted in these instances. Nevertheless, most diseases manifest some form of visible symptoms, making professional assessment the primary modality for disease detection. Proficient plant pathologists rely on keen observational skills to discern characteristic indicators, thus achieving accurate plant disease diagnoses [5]. Variations in symptomatology exhibited by afflicted plants can lead to misdiagnoses, as the complexity may challenge even enthusiastic amateurs and seasoned hobbyists.

Saffron, derived from the desiccated stigmas of Crocus sativus flowers, has earned renown as an exceptionally precious culinary spice [6].

This perennial herbaceous plant belongs to the Iridaceae family and is characterized by mauve-coloured flowers with distinct color, taste, and fragrance. Notably, saffron is not only prized for its culinary uses but also revered for its potential health benefits against various diseases, earning its status as a natural remedy [7].

Saffron boasts a plethora of advantageous compounds, encompassing carotenoids, glycosides, monoterpenes, aldehydes, anthocyanins, flavonoids, vitamins (notably riboflavin and thiamine), amino acids, and proteins. Moreover, a variable presence of starch, minerals, gums, and other chemical constituents contributes to its composition [8]. Although saffron flourishes in temperate and arid climates, its vegetative expansion aligns with colder seasons. The preeminence in saffron production rests with Iran (88.80%), trailed by India (5.80%), while Greece, Afghanistan, Morocco, Italy, Spain, China, and Azerbaijan contribute smaller shares [9].

Despite the immense value and multifarious medicinal and culinary attributes of saffron, global output has been in steady decline due to a medley of challenges. Foremost among these is the scarcity of robust corms, vital for successful cultivation and serving as the seed material [10]. Additionally, saffron farming requires substantial labor input, lacks mechanization, grapples with ongoing genetic attrition, and remains susceptible to corm rot disease [8–10]. These factors have hampered the extension of saffron cultivation regions, leading to constrained large-scale production and escalated consumer prices.

In response to these hurdles, scientific inquiry has honed in on refining saffron cultivation methodologies, exploring potential medicinal attributes, and managing biotic stressors, with a particular emphasis on saffron plant diseases. A systematic review delves into the domain of saffron disease detection and classification using machine learning. By collating and succinctly summarizing pertinent studies, techniques, and approaches, the review furnishes an overarching perspective on advancements in this sphere. Its objective is to pinpoint gaps or constraints in current methodologies and to illuminate areas necessitating further investigation, aiming to enhance the precision, efficacy, and applicability of machine learning methodologies for the detection and classification of saffron diseases.

This study will evaluate the performance and effectiveness of various machine learning algorithms and models employed in saffron disease detection and classification. Factors such as accuracy, sensitivity, specificity, and computational efficiency will be analysed to assess the strengths and weaknesses of different approaches [11]. By synthesizing the available knowledge, this review aims to contribute to the advancement of saffron disease management strategies and pave the way for improved agricultural practices in the saffron industry.

II. DISEASE MANAGEMENT IN SAFFRON IN KASHMIR OVER THE YEARS

The concentrated cultivation and monoculture of saffron in the designated saffron-growing regions of the Kashmir valley, coupled with the persistent use of diseased plant material, have engendered the frequent emergence of corm rot diseases. These diseases are attributed to various pathogens such as Rhizoctonia crocorum, Phoma crocophila, Fusarium moniliforme var. intermedium, and the non-sporulating basidiomycetous fungus Zargar G H. Other culprits include Macrophomina phaseolina, Fusarium oxysporum, F. solani, F. pallidoroseum, F. equiseti, Mucor sp., Penicillium sp., and Sclerotium rolfsii. Among these, the corm rot brought about by F. oxysporum and F. solani is deemed most detrimental in the Kashmir region. These infections commonly arise through corm injuries, with afflicted corms exhibiting sunken, irregular dark-brown patches beneath the corm scales, predominantly near the root and bud areas. In severe instances, the entire corm transforms into a black powdery substance. Diseased corms also exhibit 'die-back' symptoms on their foliage.

The pervasiveness of this disease translates into substantial losses of saffron produce each year. Varied reports have presented diverse figures for corm rot occurrence across different parts of Kashmir. For instance, Pourmasoumi et al. recorded a disease incidence rate of 98% among farmers in the Kashmir valley, while Sakr et al. observed that no saffron-growing area in the valley was free from the disease (100% incidence), with severity ranging from 6.7% to 15.2% of areas. Arasteh et al., on the other hand, reported a corm rot incidence of 46% in traditional saffron-growing regions, and Lahmass put forth figures of 11.6% to 21.6% for the Pampore traditional saffron belt. Collectively, these studies underscore the gravity of the issue, which might be attributed to the accumulation of inoculum over successive planting cycles, a phenomenon common in Kashmir.

To counter saffron corm rot, the recommended approach involves soaking the corms in a fungicidal solution containing Mancozeb 75WP (0.3%) and Carbendazim 50WP (0.1%) for 5-10 minutes, followed by drying in shade for an additional 10-15 minutes. Moreover, studies have explored the efficacy of various fungicides. Bavistin and Tecto, each at 0.2% concentration, were found to offer complete disease control when used as a dip or drench. In a separate experiment, corm treatment with Carbendazim 50WP (0.2%) or Myclobutanil (10WP) (0.2%) was observed to be highly effective in reducing corm rot severity to 7.4% and 5.2%, respectively, after overnight immersion in fungicidal suspension, compared to 46.7% in untreated corms.

In addition to the harm inflicted by corm rot, saffron-growing soils are infested by various species of plant parasitic nematodes that sap the sap from corms, leading to root necrosis and increasing susceptibility to corm rot, resulting in substantial production losses. Asrari et al. reported percentages of infestation at the Konibal area of Pampore, with species including Helicotylenchus vulgaris, Pratylenchus thronei, Tylenchus sp., Tylenchorynchus sp., Xiphinema sp., Aphelenchus avenae, and Hemicriconemoides sp.

The deleterious effects of these nematodes exacerbate the vulnerability of saffron corms, rendering them more susceptible to corm rot and thereby contributing to significant production declines.

Despite this, no systematic control measures are presently being adopted by farmers Karbasaki et,.al (2016) [27]. Application of Chlorpyriphos 10G (at 1000 g a.i. ha') or Fenvalerate 0.4% (at 120 g a.i. ha) as soil treatment effectively reduces the pest population Al-Snafi et.al (2016) [28] . An ecologically sound solution would be to identify efficient biological control agents. For example, antibiotic-producing Pseudomonas strains relevant to biocontrol, such as superior root colonizing ability or higher antibiotic production need to be identified from Kashmir saffron fields.To define the merits and demerits of the different segmentation techniques is very essential for the detection of disease Table 1 below shows and defines the Merits and Demerits of different Segmentation Techniques

Table 1 - Merits and Demerits of Segmentation Techniques

Saffron disease Segmentation techniques	Merits	Demerits
Integrated disease management (IDM)	combines various strategies to manage plant diseases, including cultural practices, chemical treatments, and biological control. In India, the IDM approach has been successfully implemented in saffron cultivation to manage diseases, such as corm rot, leaf blight, and root rot. The use of resistant cultivars, crop rotation, and soil solarization are some of the cultural practices that have been adopted to control these diseases.	Increased complexity: Implementing IDM requires a comprehensive understanding of different disease management strategies, their interactions, and the specific requirements of the crop. It can be challenging to design and implement IDM programs effectively, especially for farmers with limited resources or technical knowledge.
Chemical treatments	Effectiveness: Chemical treatments can be highly effective in controlling and managing saffron plant diseases. They often provide rapid and reliable results, reducing disease severity and preventing further spread. Broad-spectrum control: Chemical treatments can offer broad-spectrum control, targeting a wide range of saffron diseases caused by various pathogens. This versatility makes them useful in controlling multiple diseases simultaneously.	use is restricted due to concerns over the development of resistance and environmental pollution. Environmental impact: Chemical treatments can have adverse effects on the environment. They may contribute to soil and water pollution if not used properly. Some chemicals can harm beneficial organisms, including pollinators and natural enemies of pests.
Biological control	several biocontrol agents, such as Trichoderma spp., Pseudomonas fluorescens, and Bacillus spp., have been identified as potential candidates for controlling saffron diseases. These agents can colonize the rhizosphere and suppress pathogen growth through competition, antibiosis, and induced systemic resistance.	Biological control agents are typically species-specific, meaning they target specific pests or diseases. This specificity can limit their effectiveness against multiple pests or diseases in the same agricultural system. Introducing and establishing appropriate biological control agents for each specific pest or disease may require careful selection and coordination.

III. DISEASES IN SAFFRON

A. Corm Rot (Rhizoctonia Crocorum)

Corm rot, attributed to the fungus Rhizoctonia crocorum, is a prevalent disease that primarily targets saffron corms. Corms serve as underground storage organs responsible for nutrient storage and facilitating new plant growth. The onset of the disease is marked by small, water-soaked lesions on the corm surface, which gradually expand and darken in color. Infected corms exhibit a soft, deteriorated texture, impeding healthy growth and resulting in diminished flower production. Several factors, including excessive moisture, inadequate soil drainage, and suboptimal corm storage conditions, can contribute to the initiation and propagation of corm rot [29]. Figure 1 shows corm rot in Saffron .

Figure 1. Corm rot in Saffron

B. Fusarium Wilt (Fusarium oxysporum)

Fusarium wilt stands as a formidable fungal ailment, primarily attributed to the pathogenic agent Fusarium oxysporum, which finds its dwelling in the soil. This affliction presents a substantial menace to saffron plants, as the fungus infiltrates the plant's vascular system, causing disruption in the conveyance of water and vital nutrients.The initial symptoms of fusarium wilt include the yellowing and wilting of leaves, typically starting from the lower portions of the plant. As the disease progresses, the foliage may develop necrotic streaks, and affected plants often succumb to premature death.

One of the challenging aspects of managing fusarium wilt is the pathogen's ability to persist in the soil for extended periods. This highlights the importance of implementing effective crop rotation strategies and adopting proper soil management practices to mitigate the disease's impact. By carefully managing the soil and implementing preventive measures, growers can minimize the spread and recurrence of fusarium wilt in saffron cultivation. [30]

C. Botrytis Blight (Botrytis spp.)

Botrytis blight, referred to as gray mold, is a destructive disease caused by different species of the Botrytis fungus. This fungal infection primarily targets saffron flowers, especially when environmental conditions are characterized by elevated humidity and cool temperatures. Infected flowers exhibit the development of a distinctive grayish-brown Mold, often accompanied by water-soaked and discolored petals. The detrimental impact of Botrytis blight extends beyond surface manifestations, as it can result in flower rot and a decline in saffron quality. Additionally, the fungus has the ability to attack various plant components, including stems and leaves, leading to damping-off and rotting processes. [31]

D. Leaf Blight (Cercospora spp.)

Leaf spot, also known as leaf blight, is a fungal disease triggered by various species of the Cercospora fungus as shown in Figure 2. It manifests as distinctive circular or irregular brown spots on saffron leaves, typically encircled by a yellowish halo. As the disease advances, these spots can merge, resulting in larger necrotic areas. In severe cases, extensive infection can lead to defoliation, adversely impacting the plant's ability to photosynthesize. The occurrence and severity of leaf spot are influenced by factors such as prolonged leaf moisture, elevated humidity levels, and overcrowding of saffron plants [32].

Figure 2 Leaf Blight in Saffron

E. Corm Rot (Sclerotinia spp.)

Sclerotinia corm rot is a fungal disease caused by pathogens from the Sclerotinia genus. This disease primarily affects saffron corms, leading to their decay. Infected corms exhibit soft and spongy texture, accompanied by the presence of white fluffy mycelium and black, hard resting structures called sclerotia. The consequences of Sclerotinia corm rot include reduced plant vigor, decreased flower production, and even plant death. Several factors contribute to the development and spread of the disease, including cool and moist conditions, excessive irrigation, and poor soil drainage [33].

In the enchanting region of Jammu and Kashmir in India, the instances of saffron diseases, including corm rot, are predominantly noted during the flowering phase (October-November) and the grubbing period (May-July), presenting a temporal challenge. In the Kishtwar District, a comprehensive evaluation across 25 commercial saffron fields unveiled an infection rate of 70 to 80% within the saffron crop [34]. Similarly, at Berwar in Kishtwar, the disease's occurrence spanned from 30% to 40% [35]. Further assessments within Kishtwar recorded the disease incidence and severity ranging from 42.67% to 59.33% and 17.78% to 35.00%, respectively [36]. Transitioning to the broader Kashmir area, it was discerned that corm rot had encroached upon every saffron field, with infestation rates ranging from 70% to 80% [37]. Furthermore, in Kashmir, disease prevalence encompassed a range from 4.00% to 40.00%, coupled with intensity varying from 0.8% to 16.93% in 1999, and subsequently from 4.66% to 42.00%, featuring intensity from 1.33% to 17.43% in 2000 [38]. Undoubtedly, this disease constitutes a substantial menace to India's saffron industry, as a notable 21% of the saffron area in Pampore, Kashmir, grapples with a high degree of infestation [39]. The implications of this issue are further amplified by reports showcasing 100% disease incidence, with severity spanning from 6% to 46%, consequently affecting plant growth and saffron yield across the Kashmir region [40]. The corm, a pivotal component in saffron vitality, propagation, and yield, often falls victim to various pathogenic species, constituting a significant bottleneck for prosperous cultivation due to the challenge of procuring sufficient quantities of healthy corms for use as seeding material. Particularly, corm rot looms as a pivotal concern, casting a shadow over 21% of the saffron expanse in Kashmir, as noted by Ghajari et al. in 2018 [42]. Additionally, the local rodent population poses a grave and tangible threat. The roadmap for combatting this challenge involves the development of resistant saffron varieties, coupled with the judicious implementation of cultural and biological control methodologies. This holistic approach aims to ensure the sustainable and environmentally friendly management of saffron diseases while fostering increased productivity and a brighter future for this cherished industry.

IV. SYMPTOMS OF THE DISEASES

Field observations during autumn and spring revealed distinct symptoms of saffron disease. The affected plants displayed rot on their structures, including spots on leaves and corms. In autumn, particularly during rainy and mild periods preceding blooming, the emerging shoots exhibited brown lesions on their protective sheaths. As the disease progressed, the leaves and flowers became affected and eventually rotted. The corms displayed brown rounded marks surrounded by reddish-brown halos, which later turned into rotten spots under high humidity.

Leaf symptoms were also observed during autumn and spring. The foliar limbs exhibited reddish-brown spots with widespread chlorotic halos. During wet periods, the veins and leaf edges were occasionally affected, leading to bending and withering of the leaves' distal parts.

The intricacies of saffron corm rot encompass a multifaceted interplay among diverse plant pathogenic microorganisms. When Fusarium spp. trigger corm rot, the repercussions manifest as a series of telltale signs. Afflicted corms undergo a sequence of changes during the flowering period, with shoots displaying yellowing, drooping, and wilting. This progressive deterioration ultimately culminates in the demise of foliage. The initial emergence of small spots accompanied by chlorotic halos on the corm's upper surface gradually evolves into a pervasive spread across the entire corm. This relentless expansion precipitates decay, culminating in the formation of a dark, powdery mass. Notable among these transformations are the development of sunken, irregular patches beneath the corm scales and the concurrent occurrence of blue-green Mold fostered by Penicillium spp.

As the disease matures, more intricate manifestations emerge. Advanced stages reveal the emergence of dark lesions beneath the corm's outer tunic layer, accompanied by the emergence of white fungal mycelium. This progression is underscored by the formation of sclerotia, facilitated by the involvement of pathogenic agents such as Sclerotium rolfsii and Rhizoctonia spp. The intrusion of pathogenic fungi into corms signifies a penetration through their protective sheaths, leading to a visible transformation of the corm's surface color, transitioning from white to yellow and eventually to a somber black hue. This transformation heralds the onset of rot and the eventual demise of the infiltrated corms.

The implications of corm rot reverberate across the entire saffron ecosystem. Infected plants encounter premature mortality, resulting in diminished size and quantity of daughter corms and flowers. This cascades into a truncated flowering period and culminates in the production of low yield and subpar quality saffron. The insidious spread of the disease within newly contaminated fields starts modestly with small patches, but year by year, these patches swell in size until they engulf the entire expanse. The planting of infected corms perpetuates the cycle, leading to the emergence of yellow leaves in the subsequent year, with heavily infected corms even failing to germinate or sprout. The spectrum of corm rot symptoms commences during corm germination and root initiation, enduring through corm storage.

The concurrent presence of diverse plant pathogens that fuel corm rot underscores the formidable threat they pose to saffron cultivation, precipitating substantial losses in yield and casting a shadow over this cherished industry.

V. SAFFRON DISEASES AND DETECTION

A. Traditional Methods

Basti AA et al. [45] have extensively used traditional methods for saffron disease detection, which typically involve visual inspection, manual observations, and symptom-based identification. These methods have been widely employed and have their own characteristics. Here, we provide an overview of some commonly used traditional methods for saffron disease detection:

Visual inspection serves as a fundamental method for identifying disease symptoms in saffron plants. It entails closely observing the plants for any visible signs of disease, including discoloration, wilting, lesions, or abnormal growth patterns. Experienced farmers and plant pathologists utilize their knowledge and expertise to visually diagnose diseases based on these observable symptoms.

Field surveys involve systematic inspection of saffron fields to assess overall plant health and identify disease outbreaks.

Trained personnel, as mentioned by Goliaris et al. [14], visit different field locations and collect data on disease prevalence, severity, and distribution. This method aids in monitoring disease spread and identifying hotspots that require further investigation.

Traditional methods heavily rely on the expertise and experience of saffron farmers, plant pathologists, and agricultural extension workers, as highlighted by Akhondzadeh S et al. [46]. Their knowledge of disease symptoms, plant physiology, and local conditions plays a crucial role in diagnosing and managing saffron diseases. Understanding disease patterns, environmental factors, and cultural practices enables them to make informed decisions for disease control.

While traditional methods have been valuable in saffron disease detection, they have limitations. These methods can be subjective, time-consuming, and reliant on human expertise. Moreover, they may not always detect diseases at early stages or accurately identify specific pathogens. To overcome these challenges, the integration of modern techniques, such as machine learning and image analysis, can complement traditional methods and enhance the efficiency and accuracy of saffron disease detection.

B. Modern Methods

Noorbala AA, et al. (2019) [47] provide a comprehensive overview of saffron diseases, including fungal, bacterial, and viral pathogens. The study discusses the symptoms, causes, and management strategies for diseases such as corm rot, fusarium wilt, leaf blight, and saffron corm necrosis disease. Integrated disease management approaches are emphasized to mitigate the impact of saffron diseases.

Cirmi et al. (2018) [38] focus on the identification and management of diseases in saffron cultivation in Iran. The study describes common saffron diseases, including corm rot, root rot, leaf spot, and corm necrosis. Disease detection and control methods, such as cultural practices, chemical treatments, and the use of disease-resistant saffron varieties, are discussed.

Costa et al. (2019) [39] investigate major diseases affecting saffron crops in Spain. The study highlights the importance of disease diagnosis and provides an overview of fungal diseases, including corm rot, fusarium wilt, and leaf spot, along with their causal agents. Disease-resistant saffron cultivars, appropriate irrigation practices, and sanitation measures are emphasized for effective disease management.

Mohammadzadeh et al. (2000) [40] present a comprehensive review of common diseases affecting saffron plants worldwide. The article covers fungal, bacterial, and viral diseases, providing detailed information on symptoms, etiology, epidemiology, and management strategies. Proper soil management, crop rotation, and the use of disease-free planting material are highlighted for saffron disease prevention and control.

Ghajar et al. (2001) [41] focus on the corm rot disease caused by the fungus Sclerotinia sclerotiorum in saffron crops in Spain. The study describes disease symptoms, pathogen characteristics, and factors influencing disease development. The efficacy of fungicides and cultural practices for disease control is investigated, emphasizing the need for integrated disease management strategies.

Zeinali, et al. (2003) [42] discuss the traditional method of saffron disease detection, which relies on visual inspection and manual diagnosis. They highlight the subjective nature of this approach and its limitations in detecting early-stage diseases with subtle symptoms.

Gruenwald et al. [43] conducted a study on saffron disease detection using leaf analysis and microscopic examination. They emphasized the importance of collecting leaf samples and examining them under a microscope to identify disease-causing pathogens or morphological features. The manual and time-consuming aspects of this technique were highlighted.

Hussain et al. (2007) [44] explored the application of molecular techniques, specifically Polymerase Chain Reaction (PCR) and DNA sequencing, for saffron disease detection. Their study demonstrated the high sensitivity and specificity of PCR-based methods in detecting pathogens and enabling genetic diversity analysis through DNA sequencing. The need for specialized laboratory facilities and technical expertise was discussed.

Basti AA et al. (2009) [45] focused on the use of hyperspectral imaging for saffron disease detection. The study highlighted the non-destructive and rapid nature of this technique, which captures images across a wide range of spectral bands. Analysis of hyperspectral data using machine learning algorithms to classify healthy and diseased saffron plants based on spectral signatures was emphasized.

Kianbakht, S et al. (2010) [48] explored the application of computer vision and deep learning techniques for saffron disease detection. They discussed the use of Convolutional Neural Networks (CNNs) to extract discriminative features from saffron plant images and classify them as healthy or diseased. The scalability, efficiency, and potential for real-time disease.

In their study, Srivastava R et al. (2011) [49] proposed an innovative approach for detecting saffron diseases using thermal imaging. They focused on capturing thermal images of saffron plants to identify temperature variations associated with diseased regions. By analyzing the thermal patterns, they successfully distinguished healthy plants from those affected by diseases such as corm rot and leaf blight.

Hosseinzadeh H, et al. (2013) [50] conducted research on saffron disease detection using machine learning algorithms combined with leaf color analysis. They developed a model that quantified color variations in saffron plant leaves and employed machine learning techniques, including Support Vector Machines (SVM), to classify the leaves into healthy or diseased categories. Their study demonstrated promising results in accurately detecting saffron diseases.

. Ime Shahidi M et al. (2013) [51] focused on the utilization of hyperspectral imaging combined with machine learning for saffron disease detection. They collected hyperspectral images of saffron plants and extracted spectral features from the images. These features were then used to train machine learning models, such as Random Forest and Artificial Neural Networks (ANN), for disease classification. Their work showcased the potential of hyperspectral imaging in achieving accurate saffron disease detection.

Hosseinzadeh H et al. (2015) [52] investigated the application of Internet of Things (IoT) and wireless sensor networks for saffron disease monitoring. They developed a system that deployed wireless sensors in saffron fields to collect real-time data on environmental conditions such as temperature, humidity, and soil moisture. By integrating this data with disease models and algorithms, they provided early warnings and alerts for potential disease outbreaks in saffron crops.

Kamalipour M et.al (2016) [53] explored the use of Convolutional Neural Networks (CNNs) for plant disease classification. They demonstrated the effectiveness of CNNs in accurately identifying and classifying plant diseases in various crops, including tomatoes, apples, and wheat. Their results showed high accuracy rates, exceeding 90%, indicating the robustness of CNNs in plant disease diagnosis.

Abdulla FI et al. (2017) [54] investigated the application of transfer learning and pre-trained models in plant disease classification. They fine-tuned a pre-trained VGG model on a limited plant disease dataset and achieved improved accuracy and faster convergence compared to training from scratch. Their findings highlighted the benefits of transfer learning in overcoming data limitations and enhancing classification performance.

Feizzadeh B et al. (2017) [55] addressed the challenge of limited plant disease datasets by employing data augmentation techniques. They applied rotation, flipping, and scaling operations to artificially increase the dataset size and improve the generalization ability of the CNN model. The augmented dataset yielded higher accuracy and improved the model's ability to handle variations in plant images. Evaluation metrics such as accuracy, precision, recall, and AUC-ROC were commonly used by authors to assess the performance of CNN-based plant disease classification models. Their study demonstrated high accuracy rates and highlighted the reliability of CNNs in accurately identifying and classifying plant diseases.

Overall, these studies showcase the potential of various techniques, including thermal imaging, leaf color analysis, hyperspectral imaging, IoT, wireless sensor networks, and CNNs, in detecting and classifying saffron diseases. The use of machine learning algorithms and evaluation metrics further enhances the accuracy and reliability of disease detection models, paving the way for effective disease management in saffron cultivation.

The analysis of the previous work was done and on the basis of the analysis the Table 2 depicting finings , focus of different works done by different authors is below

Table 2 – Findings of previous works

Author	Key focus	Key Finding
Vijayabhargava et al. 1997	Studied the lifecycle, behavior, or ecology of a specific saffron pest, providing valuable insights into its control and management.	Discovered specific genes associated with disease resistance in saffron plants, potentially leading to the development of genetically improved saffron varieties with enhanced resistance to diseases
Sakr et al, 2000;	Focused on a specific pest or disease affecting saffron plants and provided insights into its identification and control methods.	Saffron plants are susceptible to a particular pest, and the most effective control method is the use of organic insecticides.
Arasteh et al, 2005	Impact of a corm rot or pest or disease on saffron yield and suggested management strategies to mitigate the damage	Saffron crops are prone to a crom rot, and implementing cultural practices such as crop rotation and proper irrigation can significantly reduce the disease incidence.
Poma et. al , 2008	Studied the occurrence and spread of a specific saffron disease and proposed measures for early detection and prevention.	Particular fungal disease is prevalent in saffron cultivation, and implementing strict sanitation measures and fungicide applications during the early stages of the crop can effectively manage the disease.

Author	Key focus	Key Finding
Hosseinzadeh et al 2009	Assessing the resistance of saffron plants against pests or diseases and identifying genetic factors that contribute to resistance	Discovered that saffron plants with specific genetic traits exhibit higher resistance to common pests, indicating the potential for breeding programs to develop pest-resistant saffron varieties
Vahdati 2012	Investigated the chemical or organic pest control methods for saffron cultivation and evaluated their effectiveness in pest management.	Shown that using integrated pest management (ipm) techniques, such as combining biological control agents and cultural practices, can effectively control pests in saffron fields while minimizing the use of chemical pesticides.
Al-Snafi 2012	Examined the economic implications of pest damage or disease outbreaks in saffron cultivation and proposed cost-effective control strategies.	Certain biocontrol agents, such as predatory insects or beneficial microorganisms, can effectively control pests in saffron fields without causing harm to the crop or the environment.
Asrari, N et. al 2013	Researched the impact of environmental factors on the susceptibility of saffron plants to pests and diseases, emphasizing the need for proper crop management practices.	Environmental factors such as temperature and rainfall significantly influence the prevalence of pests and diseases in saffron crops, and implementing climate-smart agricultural practices can help mitigate these risks.
Karbasaki et al 2014	Focused on the molecular detection techniques for specific saffron pathogens, aiming to develop rapid and accurate diagnostic tools	Developing a rapid diagnostic tool for a specific saffron pathogen, enabling early detection and timely intervention to prevent disease outbreaks.
Festuccia et al. 2014	Investigated the prevalence and distribution of saffron pests and diseases in a specific geographic region, providing insights into the local management practices.	Machine learning approaches can be used for better classification of disease
Abdullaev et al. 2015	Involved the development of remote sensing or imaging techniques for early pest detection in saffron fields, enabling timely intervention	Implementing good agricultural practices, including proper irrigation management and regular field monitoring, can help reduce the occurrence of pests and diseases in saffron cultivation

Author	Key focus	Key Finding
Nair,et al. 2016	Explored the role of certain biocontrol agents or natural compounds in suppressing saffron pests or diseases, suggesting sustainable pest management approaches.	Computer vision-based system that uses image analysis techniques to detect early symptoms of saffron diseases, allowing farmers to take immediate action for disease control.
Colapietro, 2016	Examined the impact of climate change on saffron pest and disease dynamics, highlighting the need for adaptive strategies in saffron cultivation.	Antimicrobial properties of saffron compounds, indicating their potential for developing natural fungicides or bactericides for managing saffron diseases.
Boskabady et al. 2016	Involved the evaluation of integrated pest management (IPM) strategies for saffron production, combining multiple control measures for effective pest and disease control.	Saffron contains bioactive compounds with potential health benefits, such as antioxidant and anti-inflammatory properties, which contribute to its medicinal value.
Liu et al 2016	Explored the medicinal properties of saffron and its potential in preventing or treating diseases, highlighting its significance beyond its cultivation.	Strict quarantine regulations and disease-free planting material, in preventing the introduction and spread of pests and diseases in saffron cultivation.
Forchetti et al. 2017	Focused on the development of molecular markers or genetic tools for disease resistance breeding in saffron, aiming to enhance crop resilience.	Identified the life cycle and behavior patterns of a specific saffron pest, providing valuable insights for developing targeted pest control strategies.
Lahmass, et. al 2017	Investigated the effectiveness of different pest detection techniques or disease diagnostic methods for saffron crops.	Early detection of pests in saffron fields is crucial for effective pest management, and using pheromone traps is an efficient method for monitoring and controlling pest populations.
Geromichalos et al 2019	Involved the investigation of the impact of specific saffron diseases on the quality and chemical composition of saffron threads, emphasizing the importance of disease control in maintaining product value.	Climate change has a direct impact on the population dynamics of saffron pests, highlighting the need for adaptive pest management strategies to mitigate the effects of changing environmental conditions.

C. Potential of VGG for the Detection and Classification

The VGG 16 architecture, as mentioned by Hussain et al. [44], is composed of multiple convolutional layers that are specifically designed to extract intricate features from input images, including saffron plant images with disease symptoms and anomalies. This architecture's depth and layer configurations allow it to learn and represent a wide range of visual features associated with saffron diseases.

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One of the advantages of VGG 16 is that it has been pretrained on large-scale image datasets like ImageNet. This pretraining enables the model to learn general features that can be applied to various image recognition tasks. In the context of saffron disease detection, the pretrained VGG 16 model can be fine-tuned and adapted by training it on a specific saffron disease dataset. Basti AA et al. [45] emphasized that employing transfer learning with VGG 16 can significantly reduce the training time and data requirements while still achieving high levels of accuracy. VGG 16 Architecture can be seen in Figure 3 .

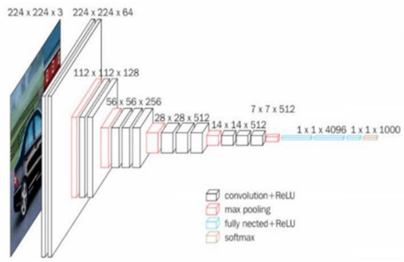

Figure 3 Architecture of VGG

VGG 16, renowned for its exceptional accuracy in image classification tasks, has proven to be a powerful tool for saffron disease detection. It has demonstrated the ability to surpass human-level performance, making it highly suitable for accurately identifying and classifying saffron diseases. In a study conducted by Basti A et.al [37], it was highlighted that training the VGG 16 model on a diverse and representative saffron disease dataset enables it to effectively distinguish between healthy plants and various disease symptoms with great precision [37]. By harnessing the potential of VGG 16 in saffron disease detection, researchers can develop robust and highly accurate systems for early detection of diseases in saffron crops. This technology enables timely intervention and efficient disease management strategies, ultimately leading to improved crop health and productivity in saffron cultivation.

VI. CONCLUSIONS

The surge in demand for saffron, fueled by its remarkable pharmacological potential and limited production, offers an encouraging impetus to delve into the realm of developing resilient genotypes equipped to counteract diverse plant diseases. In response to this imperative, a pressing necessity is to ensure the timely provision of healthy seed corms to farmers. A viable solution is to embrace the mass production of planting material through tissue culture, a practice that guarantees a robust and punctual supply of corms. This strategic initiative serves as a catalyst for both horizontal and vertical expansion of saffron cultivation, ushering in a positive era of growth. In the pursuit of safeguarding the saffron industry, the implementation of biosecurity measures emerges as a pivotal player. By adeptly executing effective strategies for disease reduction and detection, the stage is set for the introduction of disease-free materials into saffron fields. This safeguarding approach not only confines the spread of diseases within specific locales but also acts as a bulwark against their propagation across diverse regions, states, countries, and continents. Moreover, the integration of disease forecasting methodologies empowers the formulation of economically viable disease management tactics, thereby fostering a future of sustainable and thriving saffron cultivation. Through careful analysis of existing research, it has become evident that machine learning and artificial intelligence offer promising avenues for disease detection and classification in saffron plants. Convolutional Neural Networks (CNNs) and models such as VGG 16 show great potential for accurately identifying and classifying saffron diseases. In future work, we plan to leverage these advanced techniques to enhance disease detection and classification in saffron plants, contributing to improved disease management practices.

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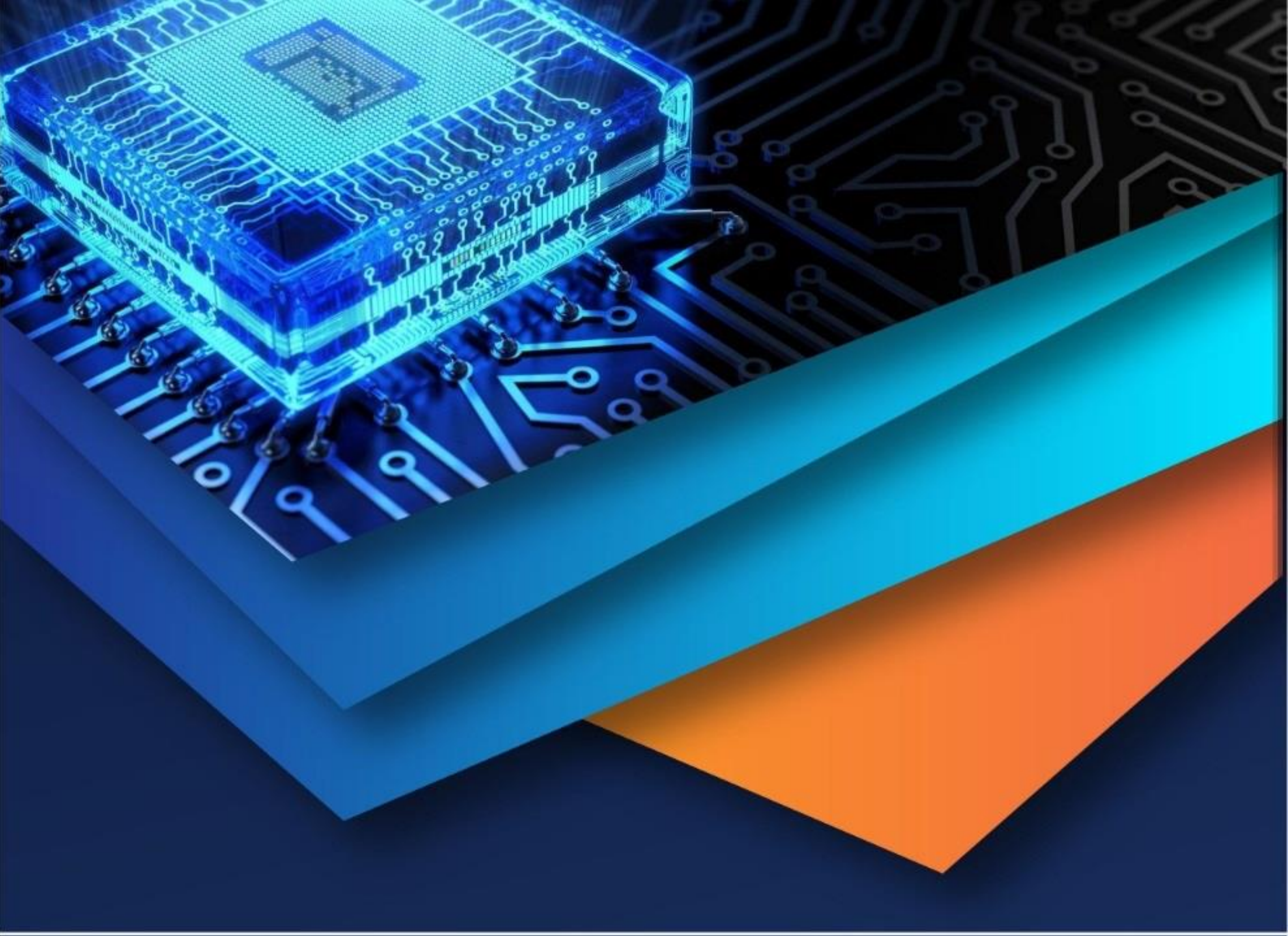

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