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Study of Plant Diseases and Their Management in Agricultural Crops

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ABSTRACT

One of the main issues in crop production, quality and farmers' income is plant diseases. Fungal, bacterial, viral, nutritional and physiological diseases are common diseases affecting agricultural crops. These diseases affect various parts of plants including roots, stems, leaves, flowers, fruits, seeds and grains. Consequently, plants become weak, their photosynthesis rate is lowered and plant growth is affected, reducing yield. All plant diseases require susceptible plant host, a disease-causing pathogen and favourable environmental conditions. Other conditions that promote disease include infected seed, poor soil health, excess moisture, high humidity, and the lack of rotation and good field sanitation. Wheat rust, rice blast, bacterial leaf blight, maize downy mildew, potato late blight, tomato leaf curl, wilt disease and root-knot disease are major crop diseases which lead to significant losses in agricultural production. Thus, disease management is an important factor in sustainable agriculture. Reduction of disease spread by cultural, biological, chemical, resistant variety, seed treatment, crop rotation, and proper irrigation and field sanitation. The most effective approach is Integrated Disease Management (IDM) which incorporates various control modalities in a well-balanced and environmentally sustainable way. Therefore, plant disease and plant disease management studies are crucial to the increase of the productivity of crops, the security of food and sustainable agriculture development.

Keywords: Plant diseases, agricultural crops, fungal diseases, bacterial diseases, viral diseases, nematode diseases, disease management, crop protection, integrated disease management, sustainable agriculture.

1. INTRODUCTION

Plant diseases are one of the most important problems affecting agricultural crop production. Agriculture is a major food, fodder, resource, job and income source to a significant population particularly in the agricultural rich countries. Crops need to be healthy from seed to harvest to ensure good crop production. During the growth period, however, a large number of diseases affect crop plants. These diseases cause a decrease in plant growth, a disruption of physiological activities, damage leaves, stems, roots, flowers, fruits and seeds, and ultimately lower yield and quality of crops. Hence, the importance of the study of plant diseases and its management in modern agriculture cannot be over emphasized. Disease in plants is a disorder of the plant caused by some abnormal condition that causes the plant to not grow and function normally. Plant activities like photosynthesizing, breathing, absorbing water and nutrients, flowering, fruiting and seed making occur properly in a healthy plant. If disease causing organisms or conditions disrupt these activities, the plant becomes diseased. The symptoms of plant diseases may appear as leaf spots, yellowing of leaves, wilting, rotting, blight, rust, smut, powdery mildew, mosaic pattern, stunted growth, cankers and poor

fruit development. The symptoms assist in diagnosis of the disease and choice of appropriate management strategies for the farmer and the plant pathologist. The major causes for plant diseases are biotic and abiotic factors. Biotic factors are the living organisms like fungi, bacteria, viruses, nematodes, phytoplasma and parasitic plants. Of these, fungal diseases are common and important in crops and affect cereals, pulses, oilseeds, fruits and vegetables.

Diseases such as rust of wheat, blast of rice, late blight of potato, powdery mildew and downy mildew are examples of fungal diseases. Bacterial diseases also cause significant losses due to their symptoms of wilting, leaf spots, soft rot and blight. Viral diseases are extremely hard to control because they are spread by insect vectors, infected seeds and plant sap. Abiotic diseases are diseases that occur when there is a lack of nutrients, water stress, extreme temperature, soil salinity, pollution and chemical injury. There are three key components to the development of plant disease: susceptible host plant, disease causing pathogen, and favorable environment. This is referred to as the disease triangle. In the absence of any of these 3 factors, disease development may be inhibited. For instance, if a pathogen is available, the disease cannot spread if the crop variety is resistant or environmental conditions are not conducive to the pathogen's growth. The temperature, humidity, rainfall, soil moisture, wind and cropping pattern are important factors in the development and spread of diseases. Climate change is leading to more severe plant diseases as the changing temperature and/or humidity are suitable conditions for pathogens. Agricultural productivity and farmers' income is affected directly by plant diseases. Diseased crops yield less and yield poor quality grains, fruits and vegetables. If disease control measures are not applied at the correct time, the entire crop can be lost in some instances. Crop diseases also raise the expense of production as the farmers must allocate needed capital to pesticides, fungicides, resistant seeds, labor and disease control methods. In addition to economic loss, plant diseases also have an impact on food security by decreasing food crop availability. Crop diseases can cause significant social and economic issues in developing countries where the livelihoods of many farmers rely on agriculture. Sustainable agriculture requires management of plant diseases. Disease management is not just about chemicals, it's about multiple methods including cultural, biological, mechanical, chemical and genetic control. Cultural practices are crop rotation, disease-free seed selection and proper field sanitation, timely sowing, balanced fertilization, and proper irrigation management. Biological control is the practice of using beneficial microorganisms to control harmful microorganisms. Chemical control involves application of fungicides, bactericides and other pesticides, but must be used judiciously to minimize environmental pollution and pesticide resistance.

Integrated Disease Management is looked upon as most effective and sustainable disease management. It integrates various disease control strategies in a scientifically and balanced way. The primary goal of integrated disease management is to lower the frequency of disease occurrence, preserve crop production, decrease the use of chemicals and keep the environment safe. This includes the use of resistant crop varieties, seed treatment, crop rotation, biological control and appropriate field monitoring and judicious chemical application. This approach is particularly beneficial for farmers, as it offers sustainable disease management and less reliance on chemical pesticides. New technologies are also contributing in a prominent way to detection and management of plant diseases in modern agriculture. Crop diseases are early identified through remote sensing, mobile applications, artificial intelligence, molecular diagnosis and biotechnology and disease forecasting systems. If the disease is caught in the early stages, the farmer can take action before the

disease gets far out of hand. Biotechnology has aided in the creation of disease-resistant crops and digital technologies have assisted in managing crop health. The modern techniques are providing more precise, quick and farmer-friendly plant disease management. Therefore, research on plant diseases and their control in crops is very important for enhancing the production of crops, safeguarding the incomes of the farmers and ensuring food security. Correct knowledge of the causes, symptoms, ways of spread and control will help minimise crop losses. To ensure protection of crops, sustainable disease management practices are required, as well as protection of the surrounding environment. Hence, plant disease management is a part of agricultural development and crop production and should be taken as a must.

2. MAJOR TYPES OF PLANT DISEASES

- **Fungal Diseases**

Fungal diseases are one of the most prevalent and prevalent diseases in agricultural crops. These diseases are fungal diseases, or diseases caused by microscopic organisms that grow on or in plant tissue. Fungi can infect virtually any portion of plants—roots, stems, leaves, flowers, fruits and seeds. They can generally be dispersed by spores (small reproductive structures). They may be spread by insect, soil, seeds, tools and plant debris, or the wind. Fungal diseases can move around very quickly in crop fields when the environment is conducive to their growth, including high humidity, warm temperatures, poor air circulation and excess moisture. Fungal pathogens cause damage to the plants by absorbing nutrients from plant tissues and disrupting normal plant functions. Can cause leaf spots, blight, rust, smut, mildew, wilting, root rot, fruit rot and stem canker. Fungal diseases of wheat, rice, potato, vegetables and grape are important such as rust disease in wheat, blast disease in rice, late blight in potato, powdery mildew in vegetables and downy mildew in grapes. In fungal infection leaves may become yellow or brown, spots may occur on the surfaces of leaves, stems may be weak and fruits may rot before maturity. In severe cases, the whole plant can dry out and die totally. Fungal diseases affect photosynthesis, as infected leaves are unable to make food. As a result, crop growth becomes poor and yield decreases. It is important to maintain proper field sanitation, crop rotation, disease-free seeds, seed treatment, resistant varieties, balanced irrigation and timely fungicide application in the management of fungal diseases. The removal of infected plant material from the field should be undertaken by farmers, as this may harbor fungi. Spacing between plants is also considered to be important as it will allow air circulation and lower humidity around the crop. Biological control measures like Trichoderma also help in the control of soil borne fungal pathogens. Thus, the early identification and timely management of fungal diseases are essential to avoid the losses in yield and quality of crops.

- **Bacterial Diseases**

Bacteria are single cells that cause bacterial diseases. These bacteria invade plants through hydathodes, lenticels, natural openings (stomata) and wounds made by insects, pruning, mechanical damage or hail or agricultural practices. Bacterial diseases are very common in a variety of crops particularly vegetables, fruits, cereals and pulses. These are spread by infected seeds, irrigation water, rain splash, insects, contaminated tools and infected plant debris. Bacterial growth and spread typically occurs under warm and moist conditions. Plants can be impacted by bacterial diseases in various ways. They may cause leaf spots, blight, soft rot, wilting, cankers and galls. Water-soaked spots on the leaves, followed by brown or black discoloration, are usually caused by bacterial infections. The soft rot bacteria degrade plant tissue and cause it to become watery, soft and foul tasting. Bacterial wilt interferes with the

flow of water in the plants, so that the plant suddenly wilts despite the presence of moisture in the soil. Rice bacterial blight, citrus canker, bacterial wilt of tomato, soft rot of potato and black rot of cabbage are some examples of bacterial diseases. After the bacterial disease has been established, it is hard to control because bacteria multiply rapidly under favorable conditions. Chemical control is not as effective as fungal diseases. Thus, prevention is the most effective way to control bacterial diseases. Control measures include using healthy and certified seeds, crop rotation, removing infected plants, ensuring good drainage and using clean irrigation water and disinfecting farm equipment. Use of resistant varieties, if available. When the leaves are wet, bacteria can easily spread from plant to plant so farmers should not work in wet fields. Bactericides, which are copper-based products, can be used in some cases, but must be used with caution and following the recommendations.

- **Viral Diseases**

Viral diseases are caused by viruses that are very small particles that cause infection. Viruses cannot survive outside living cells. They invade the plant cell and multiply within the plant cell system. Viral diseases are extremely serious because, after they are in the body, they cannot be readily treated with chemicals. Infection with a virus typically leads to lifelong infection. The majority of viral diseases are transmitted by insects like aphids, whiteflies, leafhoppers and thrips. They also can be transmitted on infected seeds, grafting, vegetative propagation, farm tools, plant sap. The normal growth and development of plants is usually disturbed by viral diseases. Symptoms are mosaic patterns on the leaves, yellowing, leaf curling, stunted growth, vein clearing, ring spots, decreased flowering, and misshapen fruit and poor fruit set. Mosaic symptoms are light and dark green patches on leaves. Leaf curl disease causes leaves to become curled, thick and deformed. Infected plants tend to be stunted, weak and have a low yield. Examples are tobacco mosaic disease, yellow vein mosaic of okra, leaf curl of tomato and chilli, papaya ring spot disease, and banana bunchy top disease. The management of viral diseases is mainly based on prevention and control of insect vectors. Virus-free seeds and planting materials need to be used by farmers. Early removal and destruction of infected plants to reduce the spread of infection. It is very important to control the vector insects as they are vectors of viruses from diseased plants to healthy plants. Use of resistant varieties, clean cultivation, removal of weeds, use of yellow sticky traps and proper insect management can reduce viral disease incidence. Only good planting material should be used in crops grown from cuttings, tubers or suckers. Once infected, there is no cure for viruses, so diagnosis and prevention are the best ways to fight them.

3. NEMATODE DISEASES

Plant-parasitic nematodes are the cause of nematode diseases. Nematodes are tiny, worm-shaped creatures that are found primarily in soil. There are many nematodes that are not harmful, but some are harmful to plant roots and cause significant damage to crops. Plant parastic nematodes feed on the roots, make penetration through plant cells with a needle-like stylet. They absorb the nutrients from the roots and interfere with the normal uptake of water and minerals. Farmers typically only discover nematode damage when the above-ground symptoms are observed, as the damage is typically below ground. The nematode infected plants grow poorly and experience yellowing of leaves, wilting, stunting, reduced tillering and yield. Roots will be damaged and plants will not be able to absorb sufficient amounts of water and nutrients even in “good” soil conditions. Root-knot is one of the most common nematode diseases, caused by Meloidogyne species. This disease is characterized by small swellings or knots on the roots. Such knots prevent plant roots from working properly and

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weaken plants. Other examples are cyst nematodes in wheat and soybean, lesion nematodes and burrowing nematodes in banana. Nematode infection also makes other pathogens more likely to infect as damaged roots act as an entry point into the plant. An integrated approach is necessary to manage nematode diseases. One of the most effective ways of decreasing nematode numbers in soil is to rotate with non-host crops. Use of resistant varieties is recommended when available. Deep summer ploughing can aid in exposing the nematodes and their eggs to sunlight and decrease their survival. Neem cake, compost and farmyard manure are used as organic amendments which help in promoting helpful microorganisms in soil that suppress nematodes and improve soil health. Biological controls such as Paecilomyces or Pochonia may also be used to control nematodes. Solarization of soil can be employed in vegetable nurseries and in small fields. In severe cases chemical nematicides can be used, but must be applied with care as they can also harm soil organisms and the environment.

4. NUTRITIONAL AND PHYSIOLOGICAL DISORDERS

Living pathogens like fungi, bacteria, viruses and nematodes do not cause nutritional or physiological disorders. Poor environmental conditions, nutrients imbalances, water stress, temperature stress, soil problems, chemical injury or improper crop management is responsible for these disorders. They are abiotic disorders, as the cause of their is non-living. These disorders can appear similar to infectious diseases, but are not spread between plants. It is crucial to accurately diagnose them as their management is different from pathogen diseases. Nutritional disorders are caused by a deficiency in providing plants with necessary nutrients. Nitrogen, phosphorous, potassium, calcium, magnesium, sulfur, iron, zinc, boron, manganese, copper and molybdenum are essential nutrients for plant growth. Abnormal symptoms can be caused by deficiencies or excesses of any nutrient. Yellowing of older leaves and poor growth due to N deficiency. Symptoms of phosphorus deficiency include dark green or PURPLE leaves and stunted root growth. Leaf Margin Burning, weak stems symptom is caused by potassium deficiency. Yellow young leaves, green veins is a symptom of iron deficiency. Small leaves and stunted growth are symptoms of zinc deficiency. Blossom-end rot of tomato and chilli can result from a calcium deficiency. These diseases decrease the quality of the product, plant structure and yield.

Table 1: *Major Types of Plant Diseases and Their Impact Value*

S. No.	Major Type of Plant Disease	Main Cause	Common Symptoms	Impact Value (%)
1	Fungal Diseases	Fungi	Leaf spots, rust, blight, mildew, root rot	90
2	Bacterial Diseases	Bacteria	Wilting, leaf blight, soft rot, canker	82
3	Viral Diseases	Viruses	Mosaic pattern, leaf curling, yellowing, stunted growth	78

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4	Nematode Diseases	Plant-parasitic nematodes	Root knots, poor growth, yellowing, wilting	72
5	Nutritional Disorders	Deficiency or excess of nutrients	Yellowing, leaf burning, weak growth	68
6	Physiological Disorders	Environmental stress	Fruit cracking, blossom-end rot, sunscald	65

Physiological disorders are due to the environmental and plant factors. Excessive fertilizer use, pesticide injury, poor soil aeration, salinity, drought and high and low temperature may upset the normal plant metabolism. The fruit cracking in tomato and pomegranate may be caused by irregular water supply. In leafy vegetables, tip burn can occur due to calcium deficiency and water imbalance. Sunscald is a result of strong sunlight exposure to fruits. Water logging lowers oxygen availability in soil, and leads to root damage and plants turning yellow. Salinity influences the absorption of water and burns the leaves as well as stunts growth. Correcting the underlying cause is essential for the management of nutritional and/or physiological disorders. Soil testing is very important to determine the nutrient status of the field. Balanced fertilization practice should be adopted based on the requirement of the crop. Organic manure enhances soil structure, nutrient availability and water holding capacity. Irrigation management is important to minimize drought stress and waterlogging. Excessive use of fertilizers and pesticides should be avoided as it could cause plant injury and toxicity. Appropriate crop varieties, optimal sowing dates, mulching, establishment of drainage systems and weather protection are also beneficial. In contrast to infectious diseases they can usually be corrected if the problem is detected early and appropriate management procedures are adopted. When you look at overall plant diseases, they are of various kinds and every disease has a varied impact on crops. Diseases caused by living organisms are known as fungal, bacterial, viral and nematode diseases and those caused by non-living factors are known as nutritional and physiological disorders. First and foremost in disease management is proper identification of disease type. If farmers are aware of the cause, symptoms, spread and control of each disease type, then they can better protect their crops and limit losses in their farms.

Figure 1: *Major Types of Plant Diseases and Their Impact Value*

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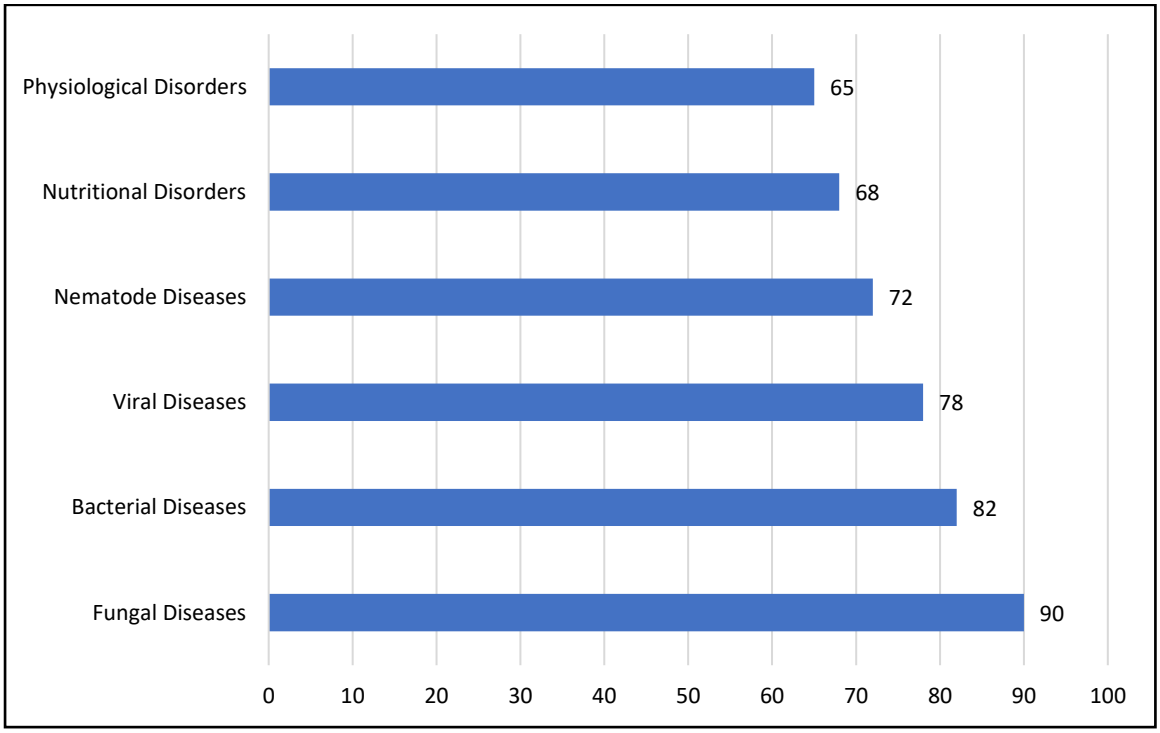

5. COMMON DISEASES IN AGRICULTURAL CROPS

Numerous common diseases infect agricultural crops while they are growing. Diseases can be found in cereals, pulses, oilseeds, vegetables, fruits and cash crops. Fungi, bacteria, viruses and unfavorable environmental conditions are the cause of most crop diseases. The damage occurs on roots, stems, leaves, flowers, fruits, seeds and grains. These diseases cause the plants to become weak and yellow, spots on leaves, rot of roots, decay of fruits and reduction in crop production. Rust, smut, blight, wilt, leaf spot, powdery mildew, downy mildew, root rot, bacterial blight, viral mosaic, leaf curl and other nematode diseases are common diseases of agricultural crops. Wheat has a habit of getting infected with different diseases such as rust, loose smut and karnal bunt. Blast, bacterial leaf blight, sheath blight, brown spot and tungro disease are some of the diseases that affect rice. Maize suffers from downy mildew, leaf blight, rust, stalk rot and ear rot. Such diseases cause losses in crop yield and have an impact on the quality and value of agricultural products. Crop diseases only occur if infected seeds, diseased crop residues, poor soil health, excess moisture, high humidity, poor temperature and poor field sanitation and poor crop rotation are present. Diseases can severely impact farmers' economic loss if not controlled when they should be. Hence, adequate disease control is essential for satisfactory crop production. Disease-free seeds, resistant varieties, seed treatment and rotation, correct irrigation, field sanitation, biological control and chemical control when necessary help to reduce crop diseases and boost productivity.

- **Diseases of Wheat**

Wheat is one of the most important cereal crops in the world and is widely grown for food security and economic support. But wheat suffers from a number of infections at various growth stages. These diseases affect the roots, stems, leaves, spikes and grains, causing poor plant growth, decreased grain formation, shriveled grains, and lower yields. Fungi, bacteria, viruses, nematodes and unfavorable environmental conditions are the most common causes of wheat diseases. Of these, fungal diseases are most prevalent and harmful. Climatic

conditions, wheat variety, soil health, sowing date, irrigation and field hygiene are factors determining the severity of wheat diseases. Rust diseases are one of the most important diseases of wheat. These are the forms of rust known as yellow rust, brown rust and black rust. Rust diseases typically occur as yellow, brown, or black powdery pustules on leaves, stems and spikes. The fungal spores in these pustules are spread by wind from plant to plant. Rust infection causes a decrease in the photosynthetic surface of leaves, decreases the vigor of the plant, and harms grain filling. Yellow rust is more prevalent in cool, wet weather, and brown rust tends to occur under warmer weather conditions. The black rust is highly destructive as it is present on stems and can lead to lodging and substantial losses in yield.

Cultivating resistant varieties, optimum seeding dates, and the removal of volunteer wheat plants and routine management of the field is important in rust control. Loose smut is another important disease of wheat. A fungus disease that is seed borne and infects the wheat plant causing the host plant to appear normal in the initial stages of infection, but at the flowering stage the wheat ear is replaced by a black powdery mass of spores. The spores are spread to healthy flower buds and infect the developing seed. The disease is latent in the seed, and may not be apparent to the farmer until sowing is undertaken. The reduction in grain production due to loose smut is due to infected spikes not producing healthy grains. Use of certified disease-free seed and a suitable seed treatment before sowing is the best management approach. Karnal bunt is also a significant wheat disease particularly due to its impact on grain quality and market value. Some grains in the wheat spike are partially infected in this disease and the result is the formation of a black powdery mass with a fishy smell. The disease can cause very high yield loss when present, but can also be a problem due to grain quality in storage, for trade and consumption. Transmitted by seed, soil and crop residues. Good field cleanliness, judicious seed selection, rotation and limiting irrigation during flowering may minimize Karnal bunt problem.

Powdery mildew is a fungal disease which manifests itself as white/grey powder on leaves, stems and sometimes spikes. It is prevalent under cool, moist and compact crop conditions. As the disease progresses, leaves become yellow and dry. This slows down photosynthesis, and impacts plant growth. The disease is favoured by high levels of nitrogenous fertiliser, high sowing rates and inadequate air movement. Management consists of balanced fertiliser application, effective plant spacing, resistant varieties and according to the agriculture recommendations the application of fungicides. Root and Foot Rot Diseases of Wheat are those that occur in the lower portion of wheat plants. These diseases occur more frequently in poorly drained soils or on fields that have been cropped many years with wheat. Infected plants have yellowing, poor growth, weak roots and drying. Occasionally plants do not reach maturity because of poor root structure. Good crop rotation, adequate drainage and seed treatment and organic matter management are effective in controlling root and foot rot diseases. Wheat diseases cause a decrease in yield and quality in general. Good disease management must start before sowing, selecting healthy seed, using disease resistant varieties, seed treatment and field preparation. Farmers should regularly monitor their fields and look for signs of disease early in the crop's growth. Integrated disease management is the most effective method to control wheat, as it combines cultural, biological, genetic and chemical control in a balanced manner.

- **Diseases of Rice**

Rice is grown in waterlogged and humid condition and it is a staple food crop. Rice fields tend to be moist and many diseases that arise and spread easily. Rice diseases can infect leaf, stem, root, panicle and grain. These diseases result in less tillering, less grain filling, empty

grains, and lower yield and quality. Fungi, bacteria, viruses, and nutritional/environmental stress are the large factors responsible for rice disease. The risk of disease is higher when continuous rice cultivation is used, infected seed is planted, drainage is inadequate, nitrogen levels are too high, planting density and high humidity is used. Rice blast is one of the most harmful diseases of rice. A fungus is the cause and can infect leaves, nodes, neck and panicles. Leaves show spots that are grey in the center and brown around the edge, in a spindle shape. The disease attacking the neck of panicle is known as neck blast. Neck blast is very injurious as it causes inadequate filling of the grain and empty or partially filled grains. Blast disease is spread quickly in cloudy weather, or in fields with high N fertiliser application and high humidity. Management includes resistant varieties, use of balanced fertilizer, spacing, clean seed and timely disease monitoring.

There is another serious disease of rice, called Bacterial leaf blight. Symptoms include yellowish water-soaked spots along the margins of the leaves that dry and become brown. In severe infection, the entire leaf surface can take on a 'burnt' appearance due to entire leaf dryness. The disease is transmitted by irrigation water, rain splash, infected seedlings and wounds made during transplanting or by insects. It is worse in flooded areas, strong winds and when there's a lot of rain. Too much nitrogen also contributes to the disease. Management involves use of resistant varieties, appropriate drainage, timing and levels of fertiliser application, infested crop debris removed, and no plant damage during field operations. Sheath blight is a fungal disease of rice which occurs in the leaf sheath close to the water level. They are oval or irregular greenish-grey spots which develop into brown spots. In favorable conditions, the disease ascends from the lower parts of the plant to the leaves and panicles. Sheath blight is higher with dense planting, high nitrogen fertilizer and high humidity. This disease slows down photosynthesis, decreases the plant's strength and can lead to lodging. Spacing, balanced fertilization and field sanitation and judicious fungicide use are helpful in management. Brown spot is one of the major diseases of rice on leaves, grains and seedlings. It can be seen as tiny brown oval-shaped spots on leaves. Many spots can fuse in severe cases and cause leaves to dry out. Brown spot is frequently found on water-stressed, weak plants with poor soil fertility and/or a nutrient deficiency. It also results in poor grain quality, discoloration and poor seed development. Management comprises healthy seeds, seed treatment, balanced nutrition, watering and soil fertility improvement.

Rice tungro disease is a viral disease, in most cases, spread by green leafhopper insects. Infected plants are stunted, leaves are yellow or orange and tillering is reduced. If infected in the early stages, the disease may cause significant losses in yield. The treatment of viral diseases is impossible and prevention is extremely significant after infection. Management involves managing insect vectors, removing infected plants, using resistant varieties, clean cultivation and avoiding continuous rice cropping under high disease pressure. Rice grain disease caused by fungus, false smut. This disease causes spore balls (yellow or greenish) to form on individual grains. Diminishes grain quality and market value. Conditions conducive to false smut are high humidity, rainfall during flowering and excessive nitrogen. Management: Balanced fertilizer management, healthy seed, cleanup of crop residues and field monitoring during flowering. Hence, moisture, humidity, seed quality and crop density and fertilizer management are closely linked to rice diseases. Rice is a crop that grows in wet condition and therefore, disease control should be based on good seedling, resistant varieties, balanced nutrients, good water management and field sanitation and timely observation. Integrated disease management is the key to ensure the productivity of the rice crop and minimise crop losses.

- **Diseases of Maize**

Maize is an important cereal crop used for food, fodder, animal feed and industrial purposes. It is grown in various climatic zones and is subject to various diseases at the seedling, vegetative, flowering and grain formation stages. The leaves, stalks, roots, ears and grains of maize may be attacked by diseases. These diseases cause a decrease in plant height, leaf area, cob formation, grain size and yield. Fungi, bacteria, viruses and nematodes are the main disease causing agents of maize. Diseases are incited by poor field sanitation, infected seed, repeated maize cultivations, high humidity, water-logging, drought stress and insect damage. Downy mildew of maize is one of the serious diseases of maize particularly in warm and humid regions. Caused by organisms of fungal like nature and typically occurring on young plants. Leaves are pale yellow or whitish with infected plants. A downy growth can be seen on the underside of the leaves in humid conditions. Plants suffering from heavy infestation are stunted and may never set a normal cob. Sometimes the tassel is abnormal and leaves. Disease is spread by infected seed, spores carried by the wind and soil. Management includes use of resistant varieties, disease-free seed, seed treatment, crop rotation, removal of infected plants and avoiding sowing in disease-prone fields. Northern corn leaf blight (also called turcicum leaf blight) is a significant disease of maize caused by a fungus. It appears as long, greyish-green or brown spindle-shaped lesions on leaves. Leaves with these lesions lose green area and interfere with photosynthesis. Usually the infection results in significant drop in yield due to insufficient food production to support grain fill. This disease is favored by cool, humid and cloudy weather. Management includes resistant hybrids, crop rotation, destruction of infected residues, proper spacing and timely fungicide use when disease is severe.

Another significant maize disease caused by fungi is called maydis leaf blight (southern corn leaf blight). Produces brown lesions on the leaves of varying size. Under severe circumstances, leaves prematurely wilt and the crop presents as burnt. This disease acts to decrease photosynthesis, to weaken the crop and to cause a reduction in cob development. More prevalent in warm and humid environments. Frequent cultivation of maize and the use of infected crop residues add to disease pressure. Management involves the use of resistant varieties, clean culture and crop rotation and crop residue management. Maize common rust is caused by a fungus and is a small reddish-brown pustule on the leaf surfaces. The spores are wind borne in these pustules. Rust infection can decrease leaf surface area for photosynthesis and can cause plant weakness. The disease is more rapid under cool and moist conditions. While some rusting may not result in significant losses, heavy rusting may lead to loss of yield. Resistant varieties and field monitoring and control as needed are helpful for management. Maize stalk rot is a complex disease of maize which is caused by several fungi and bacteria. It occurs in the lower part of the stem and causes the plant to become weaker. Plants can have symptoms of premature drying, hollow stems, weak stalks and lodging. Harvesting is problematic in lodging, and yield is reduced. Stalk rot is usually severe under situations of drought, flooding or when plants are stressed due to nutrient deficiency or insect damage. Stalk rot control practices include good crop nutrition, irrigation, stem borer control, crop rotation and selection of resistant hybrids.

Image 1: *Common Diseases in Agricultural Crops*

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Crop	Disease	Symptoms	Affected Part
Wheat	Rust Disease	Yellow, brown or black powdery spots on leaves and stem	
Wheat	Loose Smut	Ear head changes into black powdery mass	
Rice	Blast Disease	Spindle-shaped spots on leaves and neck infection	
Rice	Bacterial Leaf Blight	Yellowing and drying of leaf margins	
Maize	Downy Mildew	Pale stripes, stunted growth and poor cob formation	
Maize	Leaf Blight	Long brown lesions and drying of leaves	
Potato	Late Blight	Dark patches on leaves and rotting of tubers	
Tomato	Leaf Curl Disease	Curling of leaves, stunted growth and poor fruiting	
Pulses	Wilt Disease	Sudden wilting and drying of plants	
Vegetables	Root-Knot Disease	Swelling on roots, yellowing and weak growth	

Maize cobs and grains may be damaged by ear rot and grain mould diseases. They occur when the cob is infected with fungi, particularly in wet weather or where insects have damaged the cob. Infected grains can turn discolored, shrivel, mold and be unsuitable for food or feed. Some fungi can also be harmful, producing toxins which render grain unfit for consumption. Management encompasses timely harvest, proper grain drying, safe storage, insect control and application of good seed and preventing grain stress during grain formation. Affected maize crop growth can also be caused by maize viral diseases. Spreads are typically by insect vectors like aphids and leafhoppers. Mosaic patterns, yellowing, stunting, leaf curling and cob quality may be observed in infected plants. There is no cure for viral diseases, once infected the plant will die so preventing is important. The use of resistant

varieties, control of insect vectors, removal of infected plants and weed management reduce the spread of viral diseases. To sum up, all parts of the plant are susceptible to maize diseases and these diseases can result in decreased yield and grain quality. The resistant varieties, healthy seeds, seed treatment, crop rotation, balanced use of fertilizers, adequate irrigation, control of insect pests and field sanitation are some of the most important parts of the disease management program in maize. Suggestions for farmers: Maize fields should be regularly inspected from seedling to harvest to detect symptoms of disease and take action to prevent its rapid spread.

Table 2: *Common Diseases in Agricultural Crops and Their Disease Impact Value*

S. No.	Agricultural Crop	Common Disease	Disease Type	Major Symptoms	Disease Impact Value (%)
1	Wheat	Rust Disease	Fungal	Yellow, brown or black powdery spots on leaves and stem	88
2	Wheat	Loose Smut	Fungal	Ear head changes into black powdery mass	76
3	Rice	Blast Disease	Fungal	Spindle-shaped spots on leaves and neck infection	90
4	Rice	Bacterial Leaf Blight	Bacterial	Yellowing and drying of leaf margins	84
5	Maize	Downy Mildew	Fungal	Pale stripes, stunted growth and poor cob formation	80
6	Maize	Leaf Blight	Fungal	Long brown lesions and drying of leaves	78
7	Potato	Late Blight	Fungal	Dark patches on leaves and rotting of tubers	86
8	Tomato	Leaf Curl Disease	Viral	Curling of leaves, stunted growth and poor fruiting	82
9	Pulses	Wilt Disease	Fungal	Sudden wilting and drying of plants	79
10	Vegetables	Root-Knot Disease	Nematode	Swelling on roots, yellowing and weak growth	72

Figure 2: *Common Diseases in Agricultural Crops and Their Disease Impact Value*

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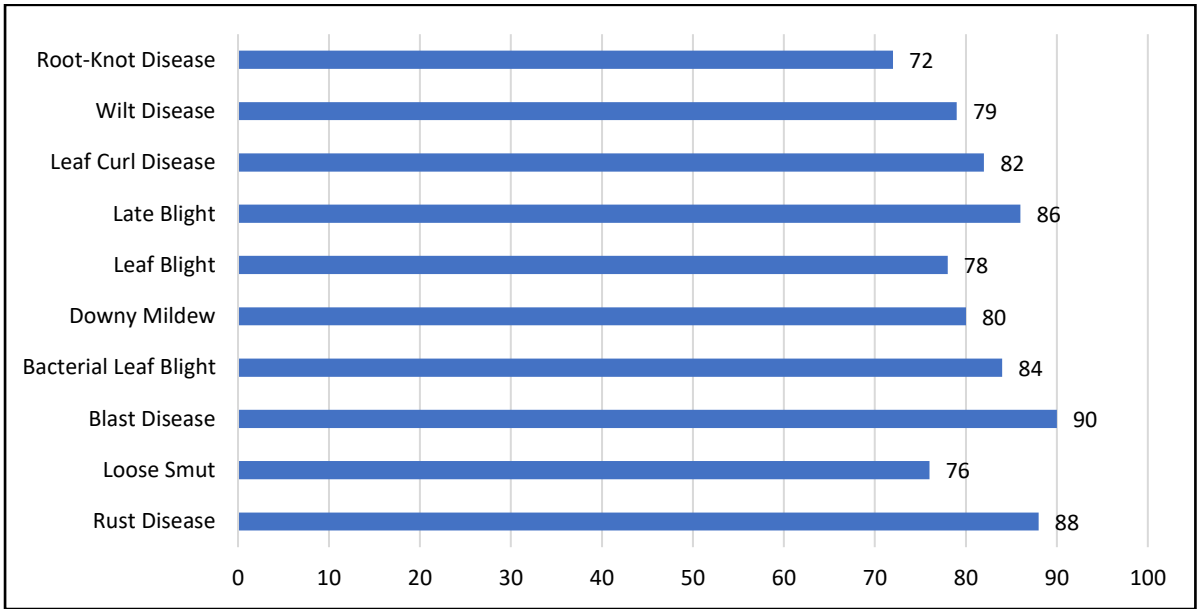

Table 2 explains the common diseases found in major agricultural crops and their disease impact value. It shows that different crops are affected by different types of diseases such as fungal, bacterial, viral and nematode diseases. These diseases damage various parts of the plant, including leaves, stems, roots, ear heads, fruits and tubers. As a result, crop growth becomes weak, yield decreases and the quality of agricultural produce is also reduced. The table shows that rice blast has the highest disease impact value of 90%. It is a fungal disease that produces spindle-shaped spots on rice leaves and may also affect the neck of the panicle. This disease can cause serious yield loss if it appears during the flowering or grain-filling stage. Wheat rust disease also has a high impact value of 88%. It appears as yellow, brown, or black powdery spots on leaves and stems. Rust reduces the photosynthetic ability of the plant and affects grain formation.

The impact value of potato late blight is 86%, indicating the severity of the disease to potato production. It produces black spots on plants and tubers rot. The impact value of the rice bacterial leaf blight is 84% and it causes yellowing and drying of the margins of the leaf tissue. Tomato leaf curl disease (82%) is a virus-induced disease that results in leaf curling and reduced growth and fruit production. The diseases have a direct impact on the productivity and market value of the crop. The impact of maize downy mildew and maize leaf blight are 80% and 78% respectively. Downy mildew produces white stripes, stunted growth and weak cob structure, and leaf blight produces long brown lesions and withering leaves. Wilt disease is a common problem affecting pulses, and has an impact value of 79%. The disease is a fungal ailment resulting in an acute wilting and drying of plants. Nematode root-knot disease is also a problem with vegetables, at 72% impact value. Causes root swelling, -yellowing of leaves and poor plant growth.In overall, the table clearly shows that fungal diseases are the most common and mostly damaging disease in agricultural crops. Some of the most damaging diseases of crops include rice blast, wheat rust, potato late blight and bacterial leaf blight. Hence, it is essential to be timely in the diagnosis, use of disease-free seeds, resistant varieties, crop rotation, proper irrigation, sanitation of fields and chemical control of disease if and when needed, to minimize the impact of the disease and increase agricultural productivity.

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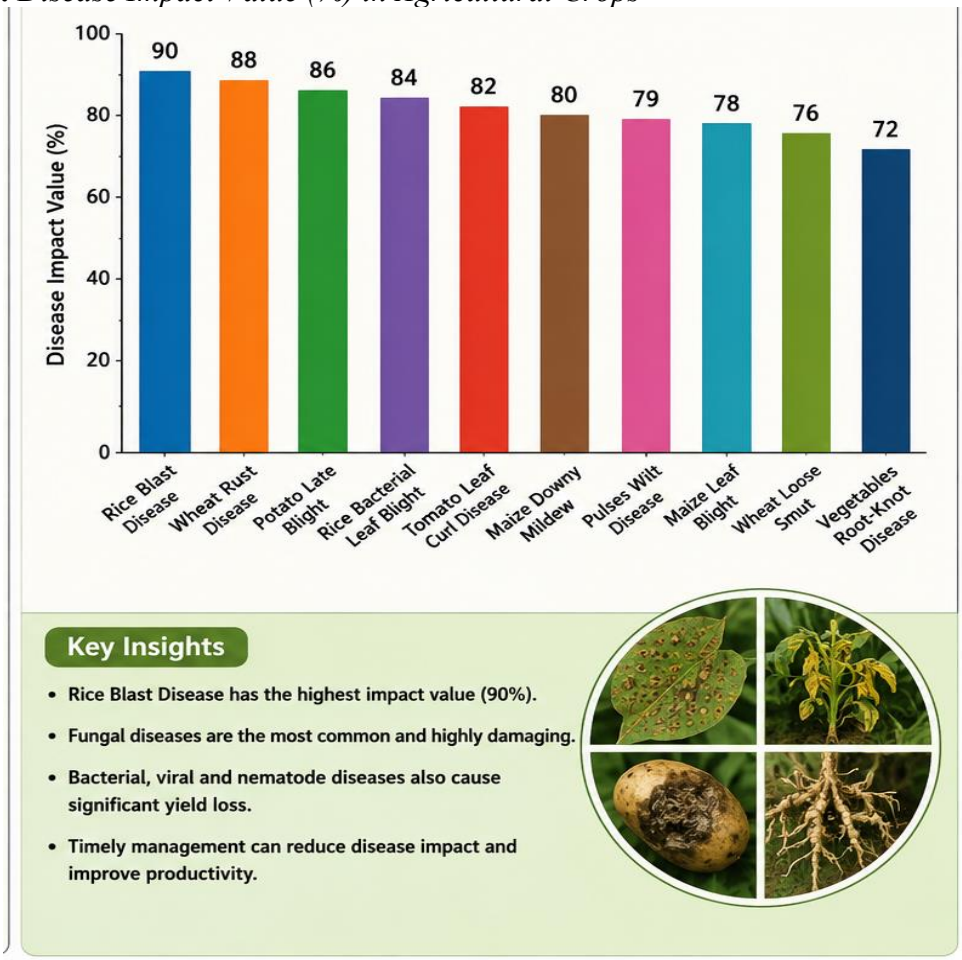
Image 2: *Disease Impact Value (%) in Agricultural Crops*



6. FACTORS THAT AFFECT THE DEVELOPMENT OF PLANT DISEASE

The development of plant disease is a complex process which requires several internal and external factors. Presence of a pathogen in the field is not a prerequisite for a disease to manifest. Three things are required for disease development: susceptible host plants, disease-causing pathogen and favourable environment. The three factors combine to make the "disease triangle." The presence of none or insufficient of these factors can limit the development of disease, or make them non-existent. Thus knowledge of the causes of plant disease development is of great importance in the effective management of plant diseases in agricultural crops.

1. Susceptible Host Plant

One of the most crucial factors contributing to disease is a susceptible host plant. When a crop variety is susceptible to a specific pathogen, it is able to be infected easily. Resistance of individual crops and varieties varies. The one is very resistant and the other is very susceptible. For instance, some varieties of wheat are susceptible to rust disease, whereas resistant varieties are able to withstand or not get sick from that disease. Disease development also is related to the age and stage of plant growth. Diseases like damping-off, root rot and seedling blight occur more often in young seedlings due to the softness and weakness of their tissues. Likewise, many crops have a susceptible stage when they are flowering and fruiting which is prone to diseases that have direct impact on yield and quality. Pathogens are more

apt to attack weak plants, nutrient deficient, or stressed plants. So, variety selection and keeping plants healthy is important to prevent disease. The presence of pathogens that can cause disease. Any pathogen that could cause disease.

The presence of a pathogen is necessary for infectious plant diseases. Pathogens include fungi, bacteria, viruses, nematodes, phytoplasma and parasitic plants that cause disease. These organisms inflict damage on plant tissues and disrupt plant growth and functions. Fungi can lead to rust, smut, blight, mildew and rot. Bacteria can cause wilt and canker, and soft rot and leaf blight. Mosiaicing, leaf curling, yellowing and stunting can be disease symptoms caused by viruses. The nematodes are primarily on the roots and they cause plants to absorb less water and nutrients. Disease severity also depends on the quantity of the pathogens present in the field. With low population of pathogens, disease may be limited. However, infection of seeds, disease in plant residues, contaminated soil and infected irrigation water will allow the pathogen to build up in number and disease to spread quickly. A number of disease causing organisms are able to survive in soil, crop residues, weeds, seeds and alternate host plants. These pathogens are reactivated when the next crop is planted and infect healthy plants again. Thus, the removal of infected residues, disease-free seed and crop rotation are important for minimizing pathogen survival.

2. Favorable Environmental Conditions

The environment is important in the development of plant disease. Disease may not occur even if both the host and pathogen are present if they are not under favorable conditions. Pathogen growth and infection is affected by temperature, humidity, precipitation, wind and soil moisture and light. A large number of diseases caused by fungi are capable of developing quickly when the environment is warm and humid. When humidity is high and leaves stay wet for an extended period, diseases like rust and blast, blight and mildew become serious. Root rot, damping-off, bacterial wilt and soft rot are diseases caused by excess moisture and poor drainage. Drought stress, on the other hand, can cause plants to be more vulnerable to diseases. Disease development is also influenced by temperature. Some diseases are more prevalent in cool weather, others in warm weather. For instance, powdery mildew tends to occur under cool, humid conditions, while bacterial diseases are more likely to occur in warm and humid conditions. So disease spread is dependent on environmental conditions and their rate of occurrence in crop fields.

3. Infected seed and planting material

Infected seeds and planting material are major sources of plant diseases. A high percentage of pathogens may live within or on seeds. If such seeds are spread, the disease begins to develop at a very young age of the crop. Seed-borne diseases are extremely risky as they are latent in the seed and can spread over wide areas. Loose smut of wheat, seedling blight, bacterial blight and many viral diseases. Pathogens can be carried from one crop season to another on infected tubers, cuttings or suckers/ rhizomes in vegetatively propagated crops like potato, sugarcane, banana and ginger. Diseases spread rapidly in the field if farmers plant with infected plantings. Thus, certified seed free from disease and treatment of planting material to ensure their health is of great importance. Fungicides or bio-control agents can be used in seed treatment to control seed-borne and soil-borne diseases.

4. Soil Conditions

Plant disease development is highly dependent on soil health and soil conditions. Stress is the condition of plants caused by poor soil structure, low organic matter, nutrient imbalance, salinity, acidity, alkalinity and poor drainage. Under stressed plants are weakened and more vulnerable to pathogen attack. Fusarium, Rhizoctonia, Pythium, Phytophthora and nematodes

are soil-borne pathogens that can remain in the soil for long periods of time and infect plant roots. When soil is too wet, root rot and wilt diseases are favored due to lack of oxygen in the soil and a weak root system. Dry soil can also cause plants to be more stressed and thus less resistant. The pH of the soil influences availability of nutrients and activity of pathogens. Some diseases are more severe under acidic conditions and the others are more under the alkaline condition. Specific pathogens increase in the soil with repeated cultivation of the same crop in the same field. Soil-related diseases can therefore be reduced by crop rotation, use of organic manure, composting, soil solarization, drainage and balanced fertilization.

7. MANAGEMENT OF PLANT DISEASES

The application of various methods for the prevention, reduction or control of disease in crops is known as plant disease management. The primary objective of disease management is to control the disease while at the same time keeping crop growth and yield up, crop quality good, economic losses minimized and sustainable agriculture promoted. Plant diseases are caused by fungi, bacteria, viruses, nematodes and unfavorable environmental conditions. So it is not possible to use a single technique to eradicate all diseases. Proper identification, understanding of the cause of the disease, knowledge of the disease cycle and timely use of appropriate control methods is essential for good management. The important approaches to plant disease management are cultural management, biological management and chemical management.

- **Cultural Management**

Cultural management is one of the oldest, safest and most important methods of plant disease control. It includes those farming practices that reduce the chances of disease development and spread in crop fields. Unlike chemical techniques, cultural techniques do not rely on chemicals, rather they establish conditions that are not conducive to the survival of pathogens while benefiting the survival of healthy crop growth. Such practices are highly beneficial as they are economical, environment friendly and are fit for long-term disease management. The use of disease free seeds and planting material is one of the important cultural management practices. Infected seeds, tubers, cuttings, rhizomes and seedlings are sources of many diseases. Once disease occurs, with infected planting material, it is evident early in crop growth and spreads quickly in the field. Hence, certified seeds and healthy planting material should be used by the farmers. Using seed selection before sowing will help reduce seed-borne diseases like loose smut of wheat, seedling blight, bacterial diseases and many viral diseases.

Crop rotation is also one of the significant cultural practices. A pathogen specific to a crop will build up in the soil when the same crop is grown in the same field year after year. For instance, problems with soil-borne fungi, nematodes and bacterial wilt can be exacerbated with continuous cultivation of tomato, potato, wheat or rice. Crop rotation prevents the spread of pathogens by eliminating their host for one or more seasons. Lawns that do not support pathogens help reduce their numbers in the soil and improve soil health. Disease management is also greatly influenced by field sanitation. Sources of infection are diseased plant residues, dead leaves, infected fruits, weeds and volunteer plants. Crop residues are infested with many fungi, bacteria and viruses that will attack the next crop. Therefore, it is advisable to properly remove and destroy infected parts of plants. Weeds also need to be eliminated as they could serve as alternate hosts to disease and insect vectors. Washing tools and equipment, irrigation channels and nursery beds helps to prevent the movement of disease from one field to another. Cultural practices such as sowing time and appropriate distance between the plants are also important. Poor seeding date can lead to weather conditions that can favor disease

development. Fungal and bacterial diseases can be exacerbated due to high humidity, excessive rainfall and/or inappropriate temperatures. Correct spacing optimises air circulation and minimises the humidity levels in the crop canopy. Powdery mildew, downy mildew, rust, blight and leaf spot are diseases that are favored by dense planting. Balanced fertilization is also necessary for disease management. Excessive nitrogen causes plants to be soft, weak and prone to disease. Conversely, nutrient deficiencies weaken the plant and lessen its natural resistance. K, Ca, P and micronutrients are critical for the strengthening of plant tissues and better disease tolerance. Fertilizers should be applied based on soil test and crop needs. Organic manures (compost, farmyard manure) enhance soil structure, plant health and microbial activity.

Another aspect of cultural disease control is water management. Overwatering and waterlogging accelerate root rot, damping-off, bacterial wilt and other soil related diseases. Overhead irrigation allows leaves to be wet longer and thus facilitates leaf spot, blight and mildew diseases. Good drainage, proper irrigation and the elimination of standing water will limit disease occurrence. With crops such as rice, control of water level is essential to avoid disease dissemination. Resistant varieties are also included in the list of cultural and genetic methods used. Resistant varieties are able to withstand or to not be infected by specific pathogens. For instance, varieties of wheat that are resistant to rust, varieties of rice that are resistant to blast disease and varieties of vegetable crops that are resistant to wilt disease minimize losses from disease. Resistant varieties are very useful in sustainable agriculture and reduce chemical usage. So, cultural control is an action that helps to avoid having significant disease problems. It is best when taken up by farmers at the start of cultivation of crop plants. It decreases the survival time of pathogens, helps to stop spreading the disease, enhances the health of the crop and decreases the need for chemical pesticides.

- **Biological Management**

Biological management involves management of plant diseases through the use of beneficial living organisms. These organisms inhibit and eliminate pathogenic bacteria naturally. Biological control is an environment-friendly strategy and plays increasingly important role in the sustainable agriculture as it lessens the overuse of chemical pesticides. It is particularly effective against soil-borne pathogens and fungal diseases, nematodes and some bacteria diseases. Biological disease management uses beneficial microorganisms like fungi, bacteria and actinomycetes. They fight harmful pathogens for food and space, generate antibiotics, break down the structure of pathogens and stimulate plant immunity and growth. Some important biological control agents include Trichoderma, Pseudomonas fluorescens, Bacillus subtilis, Paecilomyces, Pochonia and Gliocladium. Trichoderma is one of the most commonly used bio-control agents. Useful fungus to manage a number of soil-borne fungal diseases including Fusarium, Rhizoctonia, Pythium and Sclerotium. Diseases such as root rot, collar rot, damping-off and wilt are caused by these pathogens. Trichoderma colonizes around the plant root, inhibiting damaging fungi. It also generates enzymes and antibiotics which are destructive to the cell walls of pathogens of fungi. It is applied to seed, soil and nursery seed. Pseudomonas fluorescens is a beneficial bacterium effective for control of various fungal and bacterial diseases. It is found in the vicinity of plants and helps to defend them against pathogens. It secretes substances which fight disease and also increases plant growth. It is beneficial in the control of diseases like wilt, root rot, sheath blight and some leaf diseases. Bacillus subtilis is another significant bacterium with the ability to produce antibiotics and regulate fungal and bacterial pathogens.

Organic amendments like compost, farmyard manure, neem cake, green manure and vermicompost are also used in biological management. These materials will enhance soil health and the beneficial microbial activity. A healthy soil contains numerous beneficial soil organisms which naturally inhibit the growth of undesirable soil organisms. Neem cake is particularly effective on nematode and some soil borne pests. Organic matter also enhances soil structure, moisture and nutrient holding capacity, resulting in a stronger, more disease resistant plant. Mycorrhizal fungi is another form of biological control. These mushrooms are in a mutually beneficial association with plant roots, which can aid the plants in obtaining water and nutrients, particularly phosphorus. They also increase the resistance of plants to stress and the reduction of the impact of some root diseases. Healthy roots are more resistant to the attack of pathogens. Biological management is an environmentally friendly, beneficial, animal and human safe method. Does not leave toxic residues on crops and does not pollute. Biological control agents are, however, more time consuming than chemicals, and need specific conditions. They are effective when the soil has adequate moisture, temperatures and organic matter, as well as correct method of application. Thus biological control should be employed as a precautionary approach and in fact in conjunction with cultural control. Biological Management is one of the components of Integrated Disease Management in modern agriculture. It decreases the usage of chemicals, regulates soil fertility, preserves useful organisms and promotes sustainable crop production.

- **Chemical Management**

Chemical management – the use of chemical pesticides for plant disease control. These chemicals consist of fungicides, bactericides, nematicides and other chemicals used for disease control. Chemical control is very common as this will provide rapid results and it is effective when disease pressure is high. It is particularly critical under conditions where diseases are highly contagious and need to be controlled immediately to prevent loss of crop production. Chemical management is to be used however, carefully, scientifically and only when necessary. Chemicals used for the control of plant diseases are most commonly fungicides. Are effective against various fungal diseases, including rust, smut, blight, mildew, leaf spot, sheath blight, root rot and fruit rot. Fungicides can be protective or systemic. Protective fungicides are applied onto the surface of the plant and are effective in preventing the germination of fungal spores. Their application should be made prior to infection or at the early stages of disease. Systemic fungicides penetrate plant tissues and consequently kill pathogens within the plant. These are of benefit if infection has already occurred, and used at recommended dose and time. Chemical management practice is crucial: Seed treatment. Seeds are often contaminated with many pathogens. Seed borne and soil-borne diseases can be minimized by treating the seed with fungicides or bactericides prior to sowing. Seed treatment prevents damping-off, seed rot and root rot, as well as loose smut and other early diseases of the young seedlings. This is a low cost, effective method as a small amount of chemical protects the crop in the early growth stage.

Chemical sprays are applied when disease symptoms are observed in the field and/or weather conditions are conducive to disease development. Fungicidal sprays can be used, for instance to control rust in wheat, blast in rice, blight in potato, powdery mildew in vegetables or downy mildew in crops. Application at the proper chemical, dose, time and application method is most important. Disease control may not be achieved in the case of improper usage of chemicals, and may cause injury to the crop. Chemical control of bacterial diseases is less likely to be successful than chemical control of fungal diseases. Prevention is a greater priority than the use of copper based chemicals and some bactericides to control bacterial leaf

spots, blights and cankers. If bacterial infection reaches severe levels, chemicals will not work as well. Thus, chemical control of bacterial diseases should be used in conjunction with good sanitation, resistant varieties, clean seed and proper water management. Nematicides are used to control plant-parasitic nematodes. These chemicals are used to decrease nematode numbers in soil and to guard the roots. Many nematicides, however, are expensive, and if not applied correctly, can be detrimental to the environment. Hence, their use should be recommended only in the event of a severe infestation. Said methods for the control of nematodes include biological control, crop rotation, neem cake and organic amendments, which are safer alternatives. There are a number of benefits to chemical management. It provides rapid disease control, slows down the disease spread, protects yield and is beneficial in disease epidemics. But the overuse and misuse of chemicals can pose numerous issues. Repeated use of fungicides can lead to the development of resistance in the pathogens. Food may have chemical residues that can have an impact on the health of people. Use of chemicals can also adversely affect beneficial insects, soil microorganisms, water bodies and the environment. So, chemicals should not be applied without knowledge.

The safe use of chemicals is extremely important. Pesticides should not be used unless disease is properly identified. Recommended dose, spray interval and safety instructions should be followed. When spraying, use protective clothing, gloves and masks. Chemicals should not be sprayed with wind. Chemicals should not be sprayed close to water sources. Harvest is recommended to wait after to avoid the presence of pesticides in food. Chemical management is most effective when used as a part of Integrated Disease Management. It should be used in conjunction with cultural, biological and resistant-variety methods. The use of chemicals according to needs is beneficial for control of diseases and minimizing environmental impacts and production cost. Plant diseases have to be managed to ensure crop health, yield and quality. Disease prevention through cultural management involves better farming practices and will reduce pathogen survival. Biological management is the suppression of harmful pathogens in an environment friendly way with the help of beneficial organisms. Chemical management offers a fast solution in high disease pressure areas and should be used with caution and in a scientific manner. In all the methods, Integrated Disease Management (IDM) is the most effective as it is a combination of all the above-mentioned methods. This is an equilibrium that benefits crops, minimizes loss of economic value, preserves soil health and sustainable agriculture.

8. CONCLUSION

Since plant diseases directly impact on plant growth, yield, quality and economic return, they can be a serious problem in agricultural crops. Crop diseases like fungi, bacteria, viruses, nematodes, nutritional and physiological disorders have different impacts on crops. Fungal diseases are the most prevalent and most detrimental as they grow quickly under favorable conditions like high humidity and moisture. Wilting, blight, canker and soft rot are caused by bacterial diseases while mosaic, leaf curl, yellowing and stunted growth are caused by viral diseases. The primary root damage from nematode diseases is on roots, and they decrease the plant's ability to uptake water and nutrients. Non-living factors include nutrient deficiency, temperature stress, water stress, salinity and poor soil conditions which may cause nutritional and physiological disorders.

Plant diseases are developed when the host plant, pathogen and environment are interacting. Diseased crop residues, poor field sanitation, imbalanced fertilizer applications, continuous cropping and insect vectors contribute to the spread of disease as well as infected seeds and poor irrigation practices. So early detection of symptoms and prompt management is of great

importance to minimize losses in crops. A combination of cultural, biological and chemical methods are necessary for effective plant disease management. Natural measures like crop rotation, disease-free seeds, and spacing, balanced fertilization, and prevention of field sanitation and resistant varieties help to minimize disease development. Biological management is the control of harmful pathogens by beneficial or non-harmful microorganisms such as Trichoderma, Pseudomonas and Bacillus in an eco-friendly manner. Chemical management can be used rapidly in cases of severe disease outbreaks, although care needs to be taken to ensure that it is not used to pollute the environment and to prevent the development of pesticide resistance and health risks. Integrated Disease Management is the most suitable and sustainable approach for modern agriculture. It involves a combination of preventive, biological, cultural, chemical and resistant-variety strategies for disease control. This provides a more chemical-free method that helps maintain soil health, yields better crop production and helps to ensure environmental safety. Therefore, plant disease and management research plays an important role in sustainable crop production, food security and farmers' economic wellbeing.

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