IDM STRATEGIES FOR MANAGING POTATO CROP DISEASES IN KEY REGIONS OF UTTAR PRADESH

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DOI: https://doi.org/10.31995/Book.AB334.A25.Chapter3

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ABSTRACT

Solanum tuberosum L., or potato, is one of the world's most important staple crops, and India ranks at the second position in the list after China. At the state level, Uttar Pradesh is on the first position with 15,812.62 thousand metric tons during 2018-19. Potato crop from the region is, however, severely affected by soil-and-tuber-borne diseases and pests. IDM is one of the major approaches taken for the protection of potato crops in Uttar Pradesh that would balance disease control with sustainability and reduced chemical dependency. IDM integrates cultural, biological, physical, and chemical strategies, encompassing crop rotation, intercropping, and the use of disease-free seed strains. It includes beneficial microorganisms like *Trichoderma* spp., *Pseudomonas* spp. and the group of bacteria are the most potent in controlling pathogens such as *Rhizoctonia solani*, which maintains healthy soils and reduces the reliance on chemical pesticides. A critical review is done by including IDM practices such as the early warning system along with judicious use of fungicides to avoid yield loss. Initiatives of the Government, programs for training of farmers and implementation of advanced technologies, including drone monitoring, with regard to their role in improving the effectiveness of IDM. IDM enhances not only productivity and quality of potatoes but also enhances sustainability of livelihood and environment. Taken together, it offers one avenue through which safe and healthy potatoes can be produced in the agricultural sector of the state of Uttar Pradesh as a way to promote food security.

Keyword: IDM, *Trichoderma* spp., *Pseudomonas* spp., Sustainability

Introduction

Potato (*Solanum tuberosum*, Family Solanaceae) is an important non-grain food crop in the world, with a total production of over 376 million tons per year. In India, the major potato growing states are Uttar Pradesh (14430.28 MT), West Bengal (11591 MT), Bihar (6640.60 MT), Gujarat (2499 MT), and Madhya Pradesh (2299 MT). Potato is grown over 20.45 lakh hectares with an annual production of 480.86 lakh tons and having productivity of 23.07 tons per hectare (National Horticultural Research and Development Foundation Nasik, 2016). The production and productivity of potato is impressive in India However, in the background of increasing population there is a need for more production from same piece of land. Management of *Rhizoctonia solani* (teleomorph Thanatephorus cucumeris (Frank, Donk)), the cause of potato black scurf, is complex due to its soil-borne nature and high level of survival. Potato is infected by a number of soil and tuber borne diseases such as common scab (*Streptomyces scabies*), powdery scab 1338 (*Spongospora–subterranean*), brown rot (*Ralstonia solanacearum*), black leg (*Erwinia carotovora sp*.), sclerotium wilt (*Sclerotium rolfsii Sacc*.), VerticiIlium wilt (*VerticiIliumalbo-atrum*, Reinke and Berth), black scurf (*Rhizoctonia solani Kuhn*.), sclerotinia stem rot (*Sclerotinia sclerotiorum L.).* Among these, black scarf caused by *Rhizoctonia solani* appears in severe proportions in the Uttar Pradesh, causing considerable yield losses. Emergence of canker on stem results in poor downward flow of carbohydrates, resulting the development of aerial tubers as well as top rosette due to accumulation of carbohydrates in the aerial parts. The most common phase of the disease is formation of sclerotial masses on the tuber resulting in black scurf which considerably reduces market value of edible tuber .In addition to utilizing disease-resistant varieties, IDM practices in U.P. involve the application of biological control agents, including beneficial microorganisms like *Trichoderma spp.* and *Pseudomonas fluorescens*, to suppress soil-borne diseases effectively. The integration of these biocontrols has been supported by research institutions such as the Central Potato Research Institute, which emphasizes their role in reducing pathogen survival and promoting soil health. Moreover, chemical controls are used judiciously within IDM frameworks, prioritizing minimal and rotational application to slow the development of resistance in pathogen populations. The successful implementation of IDM in U.P. depends on the collaboration between farmers, agricultural extension services, and research institutions to foster knowledge dissemination and technical support. Government initiatives and training programs play an important role in promoting IDM practices, providing farmers with access to disease management tools and techniques suited to regional needs. By reducing crop losses, enhancing quality, and minimizing environmental impact, IDM strategies support U.P.'s potato growers in achieving sustainable production, thus strengthening the state's agricultural economy and food security (Yadav & Kumar, 2021**).**

Overview of major potato diseases in Uttar Pradesh

The major potato diseases observed in Uttar Pradesh are black scarp and stem canker, early blight, late blight, bacterial potato disease and common scab. These are all potato diseases that were widely observed in the area of Uttar Pradesh between 2023 and 2024. For that reason, farmers face several losses. 35% of potato crops are affected by the Black scarf and steam canker disease which affects the black regular lumpy encrustations (Tiwari, *et al.*, 2021). Currently, the biggest killer of the potatoes is the late blight which reduces the yields of potatoes as well as tomatoes. As of December 2023, the news comes from Uttar Pradesh specially in the Saharanpur region that blight disease, a potato outbreak is the crops. It is a fungal infection caused by phytophthora infestans which is the major threat for the potato. The most suitable conditions for the disease are cool and moist weather conditions.

Importance of Integrated Disease Management (IDM)

Integrated Disease Management (IDM) is essential for sustainable and effective crop protection. By using a combination of preventive, biological, and targeted chemical controls, IDM reduces crop losses due to diseases, minimizes environmental impact, and supports long-term agricultural productivity. Here are the major reasons IDM is important, especially for regions with intensive farming practices, like Uttar Pradesh's potato-growing areas**.**

1. Reduced Dependence on Chemical Pesticides

IDM emphasizes the use of multiple control methods, limiting the need for chemical pesticides. Reducing chemical usage helps in lowering production costs, improving farmer profitability, and minimizing harmful residues in food products. Excessive pesticide use also leads to environmental contamination and affects beneficial organisms, but IDM allows for more balanced use of chemicals by integrating cultural, biological, and physical measures with selective chemical treatments.

2. Decreased Pathogen Resistance

Pathogen resistance to fungicides and pesticides is a significant concern. By combining various control strategies and rotating chemicals, IDM reduces the chance of pathogens developing resistance to any one method. This extends the efficacy of available treatments and preserves their usefulness in the long term. For example, the IDM approach for managing late blight in potatoes includes crop rotation, resistant varieties, and controlled fungicide use, which together help delay resistance development in Phytophthora infestans (Fry & Goodwin, 1997).

3. Environmental Protection

By focusing on environmentally friendly practices such as crop rotation, biological controls, and soil health management, IDM contributes to ecological sustainability. Biological agents like Trichoderma species in potato fields enhance plant immunity and reduce soil pathogens naturally, offering a safer alternative to chemical interventions (Yadav & Kumar, 2021). This balanced approach ensures soil, water, and air quality is preserved, benefiting not only crop health but also the surrounding ecosystem.

4. Enhanced Crop Yield and Quality

IDM practices promote healthy crop growth and better disease control, leading to increased yields and higher-quality produce. Healthier crops are more resilient to disease outbreaks, and reduced pathogen pressure allows for better tuber development in potatoes, directly benefiting marketable yield. Resistant varieties, early field monitoring, and strategic irrigation are IDM practices that minimize stress and optimize plant health, improving crop productivity (Rotem, 1994**).**

5. Economic Sustainability for Farmers

IDM's reliance on preventive measures and biological controls can reduce costs compared to conventional pesticide-heavy practices. It encourages long-term strategies, such as investing in disease-resistant varieties and organic soil amendments, which reduce the need for recurring chemical purchases. With IDM, farmers save on input costs and experience fewer losses due to disease, leading to more stable and predictable returns.

6. Support for Climate-Resilient Farming

With changing climate patterns and increased extreme weather events, IDM offers strategies that enhance resilience against climate-induced disease pressures. For example, crop rotation and soil health management practices improve soil structure, enabling better water retention and resistance to drought or flooding. Monitoring and forecasting within IDM frameworks help farmers anticipate and respond to disease risks based on weather conditions, essential in climates like U.P.'s, which experiences seasonal monsoon variability (Singh et al., 2019).

Literature Review: Major Diseases Affecting Potato Crops

Potatoes are one of the most important staple crops globally, and their cultivation is often threatened by various diseases that can lead to significant yield losses. Understanding these diseases, their causative agents, and their symptoms is crucial for improving potato production. This literature review highlights the major diseases affecting potato crops, focusing on their symptoms and causal agents.

Late Blight *(Phytophthora infestans)*

Potato late blight, caused by the Oomycete pathogen Phytophthora infestans, is the most notorious plant disease known, largely due to the epidemic that swept across Europe in 1845– 46, leading to famine and mass emigration in Ireland. Late blight has subsequently spread worldwide and occurs in almost all regions where potatoes are grown, causing losses for large and small-scale growers alike.

The monetary costs of such losses combined with measures to control the disease have been estimated at more than $3 billion/year worldwide. The pathogen produces water soaked lesions with chlorotic borders that are small at first but expand rapidly under humid conditions, blighting the entire plant in only a few days with subsequent rotting of the developing tubers resulting in heavy yield losses under favourable conditions each year with reduction in global production by approximately 15 per cent. Losses of up to 10 to 75 per cent by the disease have been reported in India. The losses mainly depend on the crop growth stage at which the disease first appears and the severity being maximum in humid and high rainfall areas. The disease occurs annually in the cooler Himalayan regions extending from Assam to Kashmir at an altitude of 6,000 ft. or more as the crop is grown in the rainy season (Peerzada et al., 2020).Late blight affects the foliage and tubers of potato. The characteristics foliar symptoms on any susceptible plant are irregular to circular lesions. Initially , in wet weather , the lesions may appear water-soaked ; in dry weather, the centers tend to dry out. The dark centre is often surrounded by yellow, chlorotic tissue or brown, collapsed tissue. Under favourable weather conditions (low temperature, high humidity due to intermittent winter rains) the disease spreads rapidly and whole of the crop may be killed within 10-14 days giving blighted appearance. The lesions also appear on the stem near the growing point when the inoculum of the fungus comes from the infected plants. The infection can also start at nodes and extend both up and down the stem and the plant topples down under congenial weather conditions. The infected portions of the stem bear white fungal growth especially visible in early morning hours but are not as prominent as on leaves. Infected tubers show irregular, shallow or sunken reddish brown patches. Inside infected tissue is spongy and rusty brown to varying depths. In sub-mountainous areas, the lesions on tubers are locally called "Pathar Dag". Later on, these lesions are often invaded by secondary pathogens especially in wet soils or in storage resulting into soft rot. Smaller immature tubers are more prone to infection as compared to the larger ones and rotting is more in heavy wet soils. Late blight does not spread from tuber to tuber in cold stores. Varieties with short stolon's bearing tubers near to stem are more liable to tuber infection as in case of variety Kufri Chandramukhi. The fungus over-summers as mycelium in the infected seed potato kept in cold stores. These tubers when planted in the next crop season (main crop and subsequent ones) serve as the source of primary inoculum. When the plants emerge from such tubers, the fungus invades a few of the growing sprouts and sporulates (produce sporangia) under humid conditions. Further spread of the disease takes place by these sporangia through air or rain splashes. Initiation of the disease generally takes about 3-7 days before clearly visible symptoms develop. The fungus produces white sporulation on the underside of the leaves which is clearly visible in the early morning hours. These sporangia further infect new leaves and stems of the nearby plants and this cycle continues after every 4-10 days depending upon the prevailing temperature and humidity levels. If the temperature is lower than 10^0 C, disease development slows down and takes more time up to 12 days while at temperature of $16\text{-}18^0$ C, it takes only 4-5 days to complete one cycle. Sporangia washed by rain or carried by irrigation water cause infection on tubers in the soil. Partially exposed tubers can easily become infected. These infected tubers serve as the primary source of inoculum for the next year's crop.

Early Blight *(Alternaria solani)*

Early blight was first described in 1882. It is a serious problem in many areas of the world where it not only affects potato, but also tomato and other solanaceous plants. Early blight has received less study than late blight, but in recent years it has been observed as an important disease in many of the warmer potato growing areas. Early blight typically manifests on potato leaves as small, dark brown to black spots with concentric rings, often referred to as "target spots." These lesions can expand, leading to large areas of necrotic tissue on the leaves. As the disease progresses, the leaves may yellow and die, leading to premature defoliation of the plants. This loss of foliage impacts photosynthesis and ultimately reduces tuber size and yield. Tuber infections are characterized by irregular, sunken lesions with elevated borders. They are randomly distributed on the tuber surface. Their color varies from gray, to brown or purple to black. The tissue below the lesions is dark brown, solid and dry, and extends into the tuber from a few millimeters up to 2-3 cm. It is often surrounded by a narrow water soaked zone. A. solani inoculum survives from season to season, but not over several years, as mycelium or spores on plant debris or at the soil surface from where spores spread by wind. Inoculum may also survive on tubers. Initial, primary, spread from this soil borne inoculum may, remain restricted, but it is the basis for often heavy secondary disease propagation. Young leaves appear to be resistant to the primary development of the fungus. They may be infected but do not show symptoms for several weeks. When leaves begin to senesce, typical lesions develop, predominantly on the lower leaves. Middle and top leaves continue to appear healthy even though they may be as heavily infected as bottom leaves. The relatively few lesions developing on the lower leaves are the source of secondary sporulation which leads to heavy infection later in the season. Since primary lesions are often inconspicuous, the beginning of secondary sporulation is hard to notice. It can be monitored by spore traps which reveal secondary sporulation long before spread of the disease (see section 6 below). Relationship between disease development and plant maturity may be confirmed by several observations. Varieties maturing early often show heavier secondary infection. They may serve as a source of inoculum for later maturing varieties. Heaviest infection generally develops towards the end of the growing season. The effect of early blight is difficult to assess when other adverse conditions, such as drought and verticillium wilt, contribute to early senescence of a crop. Foliar infection is favored by warm (around 25 OC) and wet conditions. Rainfed promotes the disease but is not required if heavy dew is frequent. Other factors that increase loss include overhead sprinkler irrigation, mechanical harvesting and storage at elevated temperatures (above 10 °C). Inoculum present on infected foliage or on the soil surface infects the tubers at harvest time. Tubers become less susceptible to mechanical damage and consequently to early blight infection when proper measures are taken to reduce tuber injuries.

Black Scurf or Dry Rot (*Rhizoctonia solani*)

Rhizoctonia solani (teleomorph: Thanatephorus spp.) is a phyto-pathogenic fungus in soil born nature with a wide host range as well as worldwide distribution. (Singh et al.)was claimed that there is hardly any species of plants, which cannot be infected by R. solani. In Japan, Kozaka dentified 188 species of plants from 32 families that can be infected by Rhizoctonia solani. According to (ogoshi), the fungus has a worldwide distribution and isolates of R. solani are highly variable in aggressiveness. Black scurf disease is one of the most widely spread disease and found in all potato growing areas of the world. It is widely dispersed in various proportions and is a significant concern in field where potatoes are cultivated year after year in the same field (Frank & Leach). The Black scurf and stem canker of potato incited by Rhizoctonia solani Kuhn [also known by the name of its sexual stage Thanetophorus cucumeris (Frank) Donk] is a serious disease of potato worldwide and distributed in India in different regions in low to severe form. Black scurf disease of potato has been found to cause marketable yield losses 10-25% in India (Sharma), up to 30% in Canada and up to 50% in other regions, thereby affecting potato production severely . Black scurf fungal disease distributed in India with varied levels of severity in different regions and is a major field disease problem where potato crop is cultivated season after season in the same field. Black or dark brown sclerotia develop on surfaces of mature tubers. Sclerotia may be flat and superficial or large, irregular lumps resembling soil that will not wash off. The tuber periderm under such sclerotia is usually unaffected. Other tuber symptoms include cracking, malformation, pitting, and stem end necrosis. Plants are most severely damaged in the spring short, after planting; killing of underground sprouts delays emergence, especially in cold, wet soils. This results in poor, uneven stands of weak plants and subsequent yield reduction. Emerging potato sprouts may also be infected with cankers on the developing stem, often causing girdling and stem collapse. Potato sprouts that have shown promise may be infected, resulting in girdling and stem crumple. Blackish to dark brown tint sclerotia found on the exterior of mature tubers. The symptoms of potato black scurf disease can be observed on the plant's above-ground and below-ground parts. There are two types of symptoms, i.e., (i) black coloured sclerotia on tubers (black scurf), which is the most visible sign of Rhizoctonia and (ii) brown, necrotic lesions on stems and stolons below the soil surface, which is frequently referred to as stem canker. The pathogen overwinters as sclerotia on tubers, in soil, or as mycelium on plant debris in the soil. In the spring, when conditions are generally favorable, sclerotia germinate and invade potato stems or emerging sprouts, especially through wounds. Roots arid stolons are invaded as they develop throughout the growing season. Sclerotial formation on new tubers is initiated at any time, depending on environmental conditions. however, maximum development occurs as tubers remain in the soil after death of vines. Rhizoctonia populations may increase in soils where little or no rotation is practiced. Planting seed tubers that are heavily infested with sclerotia also favors inoculum build up in soils. Environmental conditions favoring the pathogen are low soil temperatures and high moisture levels. The optimum soil temperature for disease development is 180° may and disease development decreases with increasing temperatures. High moisture levels in soils, especially those poorly drained, also tend to increase severity of sclerotial formation on new tuber. Tuber borne sclerotia range in pathogenicity to stems and stolons from a virulence through moderate to high virulence. The influence of tuber borne sclerotia on the health of the following crop is not consistent and varies from essentially no deleterious effect to a measurable increase in sprout-pruning, stem cankers, and yield reduction.

Integrated Disease Management (IDM) for Potato Crops

Integrated Disease Management (IDM) is a comprehensive approach that combines multiple strategies to manage diseases effectively and sustainably in potato crops. This strategy emphasizes the importance of understanding the biology of the pathogens, the environmental conditions that favor disease development, and the interactions between crops and pests. The goal of IDM is to reduce disease incidence and severity while minimizing the reliance on chemical control methods. Integrated management is a holistic ecosystem approach for crop production and protection with focus on environment sustainability and economic feasibility. Integrated disease management (IDM) to combat potato pathogens requires the implementation of multiple approaches. A unified management strategy involves the sound seed certification system, appropriate phytosanitary measures, use of resistant cultivars, need based pesticide application and managing the tubers during harvest and storage. Increasing intercontinental trade in potato poses a threat for emergence and spread of pathogens worldwide. With advancement in the molecular science and computational technology supplemented with increasing awareness of information technology several advancements have been observed in the management of diseases in potato. The most devastating late blight which is a polycyclic disease capable of causing epidemics under favorable conditions must be managed through an integrated approach. These include, phytosanitary measures to reduce the primary inoculum load, prophylactic sprays of fungicides, judicious curative sprays, use of resistant cultivars and early maturing cultivars to reduce duration of infection etc. The early blight disease is mainly controlled by the use of cultural practices (minimize soil born inoculum), growing tolerant and less susceptible cultivars and the use of fungicides . Most potato viruses are managed by using principal methods: cultural practices, clean seed systems, and host plant resistance.

Cultural Practices

Cultural practices serve an important role in plant disease prevention and management. The benefits of cultural control begin with the establishment of a growing environment that favors the crop over the pathogen. Reducing plant stress through environmental modification promotes good plant health and aids in reducing damage from some plant diseases. Deep ploughing of the field results in exposure of propagules to elevated temperatures and physical killing of the pathogen. This can be regarded as dry soil solarization. Summer ploughing was effective at reducing populations of cyst nematodes and increasing wheat yield. Flooding of the field somewhat resembles soil disinfestation. Long-term summer soil flooding, with or without paddy culture is found to be decreased populations of soil borne pathogens. Sanitation practices aimed at excluding, reducing, or eliminating pathogen populations are critical for management of infectious plant diseases. It is important to use only pathogen-free transplants. In order to reduce dispersal of soil borne pathogens between fields, stakes and farm equipment should be decontaminated before moving from one field to the next. Reduction of pathogen survival from one season to another may be achieved by crop rotation and destroying volunteer plants. Avoid soil movement from one site to another to reduce the risk of moving pathogens. For example, sclerotia of *Sclerotinia sclerotiorum* and *Sclerotium rolfsii* are transported primarily in contaminated soil. Minimizing wounds during harvest and packing reduces postharvest disease problems. Depending on crops and other factors, soil sanitation can be achieved to some degree by solarization. Crop rotation is a very important practice, especially for soil borne disease control. For many soil borne diseases, at least a 3-year rotation using a non-host crop greatly reduces pathogen populations. Weed control is important for the management of viral diseases. Weeds may be alternate / collateral hosts for many important vegetable viruses. Eliminating weeds might reduce primary inoculum. Non-host cover crops help to reduce weed populations and primary inoculum of soil borne pathogens.

Host Plant Resistance

In any disease management program, the development of resistant varieties and utilizing the inherent resistance capacity of the plants is the best possible way of managing a disease. The wild Mexican potato cultivar *Solanum demissum* was an excellent source of disease resistance specifically late blight disease from which 11 resistance genes were incorporated in present day major potato cultivars (Black et al. 1953; Malcolmson and Black, 1966). The gene R8 is still sowing high resistance against the disease (Vossen et al. 2016). More than 50 R genes are reported now against late blight pathogen but only few successful crosses are there because of linkage drag and crossing barriers. The modern genomics approaches must be used in future to reduce the lengthy breeding procedure and due to develop transgenic or non-transgenic resistant varieties. The cultivars showing less susceptibility against early blight are very limited and no resistant cultivar is available. In general, early maturing cultivars are more susceptible than late maturing varieties (Abuley et al. 2017). Initially, the conventional breeding programs proven helpful in manging wart disease in potato using resistant cultivars (Obidiegwu et al. 2014). The pathotype 1(D1) of S. endobioticum was successfully restricted using dominant resistant genes. Unfortunately, other pathotypes developed which were very difficult manage. The available host resistance against bacterial disease in potato is elusive. Conventional breeding has not given suitable resistant varieties. For bacterial disease of solanaceous crops studies have been done in tomato where R gene identified in Arabidopsis and transferred in tomato gave resistance against this disease. Strain specific QTLs showing broad spectrum resistance have been identified in tomato, tobacco and brinjal (Salgon et al. 2017). Similar studies are also required in potato to develop resistant cultivars. The genetic basis of resistance against common scab disease is described as suberization of phellum, thickening of phellum layer, thaxtomin detoxification, expression of defence genes (Thangavel et al. 2016). PVY is now the most widespread viral pathogen in potatoes in most countries. For PVY resistance, breeders have identified and introduced resistant gens in major potato cultivars but these cultivars are show strain specific resistance. A single mutation in helper component gene of PVYO leads to breakdown of resistance. Best option here is to stacking many strain-specific PVY resistance genes in popular cultivars. PVX resistance gene Rx, Nx, Nb are identified in Australian, American and European cultivars. ToLCNDV-[potato] resistance in potato cultivars has been observed in India (Jeevalatha et al. 2016).

Biological management

Biocontrol agents and biopesticides could be a safe option to the use of synthetic fungicides. Antagonism to *P. infestans* by some naturally occurring microorganisms such as *Trichoderma viride, Penicillium virdicatum, P. aurantiogiseum, Chetomium brasilense, Myrothecium varrucaria, Penicillium aurantiogriseum, Epiccocum purpuranscens, Stachybotrys coccodes, Pseudomonas syringae, Fusarium graminearum, Pythium ultimum, Pseudomonas fluorescens, Pseudomonas sp. Aspergillus flavus, A. niger, Penicillium sp., Trichoderma virens* and *T. harzianum* have been observed in laboratory and field studies (Yao et al. 2016; Gupta, 2016). The biopreparation Gluticid (*Pseudomonas aeruginosa)* and alirin-B and gamair (*Bacillus subtilis*) have been reported as effective against early blight. A bioformulation developed at Central Potato Research Institute from *T. viride* strain A-7 was found very effective when used as seed treatment applied before planting potatoes. Efficacy of **Trichoderma viride**, *Bacillus subtilis* and *Bacillus cereus* in consortium further improved for the control of *Rhizoctonia solani*. Combination of biocontrol genera Enterobacter and Pseudomonas and two chitinolytic enzymes from *Trichoderma harzianum* has been reported to have inhibitory effect on spore germination of *F. solani* (Mawar and Lodha, 2008). *Bacillus subtilis* (strain B5) recovered from rhizosphere soil of potato plants from bacterial wilt infested fields of Bhowali, Uttarakhand controlled tuber borne *Ralstonia solanacearum* under different agro-climate conditions and enhanced the crop yield (Reddy, 2010; Arora, 2011). A bio-formulation of *Bacillus subtilis* (strain B5) has been developed at CPRI and is being promoted for the disease control. Bio-control of common scab using antagonists such as *Bacillus subtilis*, non-pathogenic *Streptomyces* spp. and bio-pesticides such as Geranium pretense have shown to be effective against common scab. A number of botanicals are also tested against fungal disease. Some commercially used botanicals against plant diseases are extract of Neem (*Azadirachta indica*, A. Juss), Garlic (*Allium sativum*, Linn., Eucalyptus (*Eucalyptus globulus*, Labill.), Turmeric (*Curcuma longa Linn*.) Tobacco (*Nicotiana tabacum Linn*.) Ginger (*Zingiber officinale Rosc*.) and essential oils of Nettle (*Urtica spp.),* Thyme (*Thymus vulgaris Linn*.), Eucalyptus (*Eucalyptus globules Labill*), Rue (*Ruta graveolens Linn*.), Lemon grass (*Cymbopogon flexuosus* (Steud. Wats.) and Tea tree (*Melaleuca alternifolia*). Foliar sprays with Neem gold @ 20 ml /l or Neemazal @ 3ml/l has been found to be effective in reducing sheath blight and increasing grain yield. Leaf extracts of Eucalyptus globosus (5%) and Azadirchta indica (5%) have been proved to exhibit greater antifungal activity.

Simulation tools to manage major diseases in potato

The better way of integrating management element and implementation is through simulation models and decision support systems (DSS). The disease forecasting and subsequent protection of crops form disease outbreak is very well established in potato against late blight disease. In subtropical plains of India, the late blight prediction model 'JHULSACAST' developed by Singh et al. (2000) is very much effective in preventing the disease epidemics. The model was initially developed for western Uttar Pradesh but now has been modified and used in Punjab and other areas of the country. The developed DSS integrate and organize information related to Phytophthora life cycle, monitoring the inoculum load, weather details, cultivar growth and resistance, fungicide characteristics, etc. DSS can provide very site-specific information to the farmers via telephone, extension officers, e-mail, SMS, and websites (Cooke et al. 2011). Such kind of models and DSS are also needed in managing other diseases.

Advantages of IDM in Potato Production

Reduction in Chemical Dependency: IDM reduces the need for chemical pesticides, which are costly and can harm beneficial organisms and soil health over time. In Uttar Pradesh, farmers often rely heavily on chemical treatments due to their immediate effectiveness. However, IDM encourages a balanced approach, incorporating biological controls and resistant potato varieties to decrease reliance on chemicals. Research shows that biocontrol agents, such as Pseudomonas fluorescens and Trichoderma spp., when used in combination with other practices, effectively manage diseases without environmental drawbacks.

Promotion of Resistant Varieties and Cultural Practices: One of IDM's strengths is its emphasis on developing and using diseaseresistant crop varieties. Potato varieties resistant to late blight, for instance, have proven effective in reducing disease pressure and enhancing yield stability. This is especially significant in Uttar Pradesh, where small-scale farmers benefit from crop varieties that can withstand prevalent diseases without costly chemical interventions.

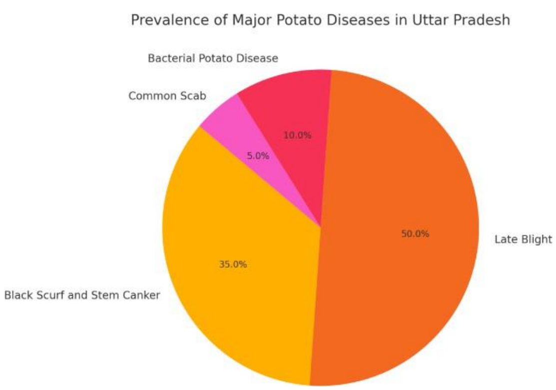
Cost-Effectiveness and Improved Profitability: By reducing pesticide usage and improving yield stability through various disease management practices, IDM proves cost-effective in the long run. Studies have shown that the use of IDM can lower production costs, as farmers spend less on chemical inputs while achieving stable or increased yields. For smallholder farmers in Uttar Pradesh, these savings can significantly improve profitability and resilience against market and environmental fluctuations.

Enhanced Environmental and Soil Health: Traditional heavy pesticide use degrades soil quality and negatively impacts biodiversity. IDM's integrated approach, which includes bio pesticides and organic amendments, not only reduces environmental harm but also promotes long-term soil health. Healthier soil improves nutrient availability and retention, supporting better crop growth and making the farming ecosystem more sustainable. By protecting beneficial soil organisms, IDM supports natural pest and disease control mechanisms, thus reinforcing a balanced agricultural ecosystem.

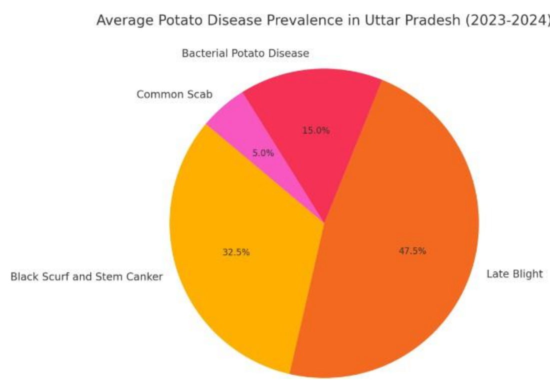
Case study

The regions that are affected in the Uttar Pradesh: In Uttar Pradesh, several regions are affected due to their crop disease especially the potato crop affected by the late blight this is in the year 2023. In the year 2024, late blight black scurf and stem Canker were noticeably high in the potato crops in several regions. The effective areas of Uttar Pradesh are Meerut, Muzaffarnagar, Hapur, Baghpat, Bulandshahr, Bijnor, Amroha, Sambhal, Aligarh, Agra, Etah Firozabad, Hathras and Etawah. Among the areas, Firozabad is the highest affected area regarding the potato disease (Verma, *et al*., 2021). Lucky important aspects related to the potato crop disease are late blight and their affecting parameters in the Western and Central parts of the state. The important factors that are important for the disease spread are weather conditions and temperatures. In 2024 the late blight was around 50%, Black Scurf and Steak Canker

was 35%, common scape was around 5% where the bacterial potato disease was 10% *(refer to Appendix 2)*. In the year 2023, it was around 47.5% for Late blight, 32.5% for the black scarf and steam canker, 5% for common scab and 15% for bacterial potato disease *(refer Appendix 1)*.



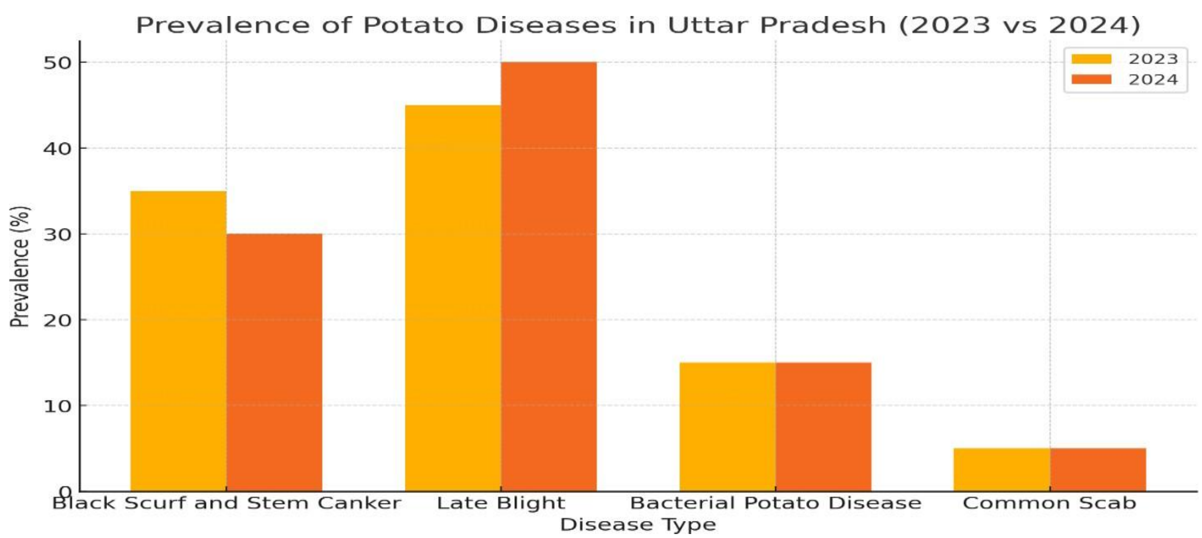
Appendix 1



Appendix 2

Compersion in the year 2023 & 2024

The overall competition between the potato disease in 2023 and 2024 highlights several aspects. The black scarp and steam tanker were noticed in the year 2023 rather than 2024 *(refer to Appendix 3)*. But in the case of Late Blight, it has continuously increased since the year 2023 and now in 2024, it is around 50%. But for the bacterial potato disease and comments curve the card is quite the same



Appendix 3

Conclusion

Integrated Disease Management (IDM) is a crucial approach to sustaining potato production in Uttar Pradesh, where potatoes are a staple crop and a significant source of income for smallholder farmers. Potato crops in this region, however, face substantial threats from diseases, especially late blight, which can devastate yields and lead to major economic losses. IDM offers a sustainable framework to manage these threats by combining various control methods tailored to local environmental and socioeconomic conditions. By integrating biological, cultural, and chemical controls, IDM not only enhances crop resilience but also reduces dependency on chemical pesticides, thus fostering a more environmentally sound and economically viable potato farming system. Overall understanding of the study provides a rough idea regarding the potato disease in Uttar Pradesh. Moreover, the disease increased in the year 2023 and now in 2024, it is widely spread in several areas. The government took action in new initiatives to manage such as an integrated disease management strategy. The IDM strategies for potato disease management are cultural practices, chemical control, biological control, resistance detection and on-the-field monitoring and management purposes.

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