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15. Impact of Climate Change on Root Crop Diseases: Their Management and Future Prospects

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Abstract:

Climate change is having an increasing influence on agriculture, with root crops being especially sensitive. Rising temperatures, changed precipitation patterns, and increased frequency of extreme weather events all contribute to the spread of infections, resulting in an increase in root crop diseases. These shifting conditions intensify diseases like potato late blight, cassava brown streak, and yam anthracnose, posing a substantial danger to global food security, particularly in places that rely largely on these products. A multifaceted approach is required to handle root crop diseases in the face of changing environmental circumstances.

Traditional approaches, such as the adoption of resistant types and chemical treatments, are becoming less effective as diseases adapt and spread to new locations. Integrated pest management (IPM) tactics, which include biological control, crop rotation, and enhanced sanitation practices, provide a more sustainable approach. Precision agriculture, remote sensing, and genetic engineering are all examples of technological advancements that have the potential to improve disease management by allowing for early identification and targeted therapies. Looking ahead, it is critical to invest in research to better understand the intricate relationships between climate change, root crops, and diseases.

Developing climate-resilient crop varieties, as well as promoting sustainable farming techniques, will be critical in minimizing the effects of climate change on root crop diseases. Collaboration among scientists, politicians, and farmers is required to execute successful solutions and ensure food security in a warming planet.

Keywords:

Root crop, Climate change, Diseases, Management

15.1 Introduction:

The effects of climate change on soils are expected mainly through alterations in soil moisture conditions and increases in soil temperature and CO2 levels as a consequence. Global climate change is projected to have variable effects on soil processes and properties important for restoring soil fertility and productivity. The major effect of climate change is expected through an elevation in CO2 and increases in temperature and salinity. Global warming and greenhouse gas (GHG) emissions are considered major factors responsible for adversely accelerating the degree of climate change Pandey *et al*., (2022 a). There are numerous effects of climate change on agriculture, many of which are making it harder for agricultural activities to provide global food security. Rising temperatures and changing weather patterns often result in lower crop yields due to water scarcity caused by drought, heat waves and flooding. Many pests and plant diseases are also expected to either become more prevalent or to spread to new regions Misci *et al*., (2022). Climate change is known to increase the frequency and severity of heat waves, and to make precipitation less predictable and more prone to extremes, but since climate change attribution is still a relatively new field, connecting specific weather events and the shortfalls they cause to climate change over natural variability is often difficult.

To tackle these limitations and guaranteed food security there is a need for production of new climate-smart crop cultivars. Cassava (*Manihot esculenta* Crantz), sweet potato (*Ipomoea batatas* (L.) Lam.), greater yam (*Dioscorea alata* L.), elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson), and taro (*Colocasia esculenta* var. *antiquorum* (L.) Schott) are some of the major tropical root and tuber crops cultivated across the world Pandey *et al*., (2022 b). Apart from their use as a staple food, cassava and sweet potato are also widely used in bio-fuel, animal feed, and textile industries. Climate change can significantly affect the prevalence, distribution, and dynamics of pests and diseases that harm crops. Temperature and humidity changes can influence the life cycles, geographic ranges, and population dynamics of various pests and diseases. Plant growth and yield are greatly influenced by abiotic stresses. Integrated disease management practices, including early detection, cultural practices, and biological control methods, may require adjustments to address the changing dynamics of diseases in the context of climate change Pant *et al*., (2023). The effects of elevated temperature and unpredictable and irregular precipitation can disrupt the normal growth and development of plants which ultimately affect crop productivity. Environmental stresses severely affect the soil organic matter decomposition, nutrient recycling, nutrient and water availability to the plant.

These factors include the distribution and abundance of taxa (geographical range, niche preference), their fitness and virulence, abiotic interactions, plant–microorganism evolutionary processes, host and vector biology, and environmental conditions.

For instance, many soils opportunistic pathogens can cause disease outbreaks when environmental conditions become favourable for pathogen replication and vulnerable hosts are available Ravishankar *et al.*, (2023).

Indian agriculture is highly vulnerable to climate change; especially drought, as 2/3rd of the agricultural land in India is rainfed and even the irrigation system is dependent on monsoon rains. Flooding is also a major problem in many parts of the country, especially in the eastern part, where flooding is a frequent occurrence. In addition, frost in the northwest, heat waves in the central and northern parts and cyclones on the east coast also cause havoc.

In recent years, the frequency of these climatic extremes is increasing due to rising atmospheric temperature, resulting in increased risks with heavy losses in agricultural production. Climate change can affect agriculture through its direct and indirect effects on crops, soil, livestock and pests. Increase in atmospheric carbon dioxide has a fertilizing effect on crops with C3 photosynthetic pathway and thus promotes their growth and productivity.

Increase in temperature may reduce crop duration, increase crop respiration rate, alter photosynthesis process, affect the survival and distribution of pest populations and thus develop a new balance between crops and pests, accelerate mineralization of nutrients in soil, decrease fertilizer use efficiency and increase evapotranspiration Ravishankar *et al.*, (2023).

Climate change also has considerable indirect impacts on agricultural land use in India through changes in irrigation water availability, frequency and intensity of inter- and intra-seasonal droughts and floods, soil organic matter changes, soil erosion, changes in pest and disease profile, reduction in cultivable areas due to submergence of coastal lands and energy availability.

15.2 Origin and Distribution of Major Tuber Crops in India:

There are five major areas of distribution of root and tuber crops in India. These are (i) South-western hilly and coastal region, (ii) Southern peninsular region, (iii) Eastern coastal region, (iv) Northeastern region and (v) North-western region. The important tuber crops grown in India and the regions of biodiversity are given in (Table 15.1).

The economically and socially important tropical tuber crops are Cassava (Manihot esculenta), Sweet potato (*Ipomoea batatas*), Yams (*Dioscorea alata, D. esculenta and D. rotundata*), Aroids which include Elephant foot yam, Taro and Tannia (Amorphophallus, Colocasia or Taro, Xanthosoma or Tannia) and other minor tuber crops namely Chinese potato, Arrow root, Yam bean, Canna etc.

Table 15.1: (H – Hindi, S- Sanskrit, M-Malayalam, MR-Marathi, TE-Telugu, T-Tamil, K-Kannada, B-Bengala, NE – North east)

Sr. No.	Common Name	Scientific Name	Family	Vernacular Name	Places/Areas Grown
1.	Cassava	*Manihot esculenta* Crantz 2n = 36	Euphorbiaceae	Maracheeni kizhangu & Kappa (M); Maravalli kizhangu & Ezhalai kizhangu (T); Maraganasu (K); Karrapendalamu (TE)	North eastern & western regions
2.	Sweet Potato	*Ipomoea batatus* (L.) Lam. 2n = 90	Convolvulaceae	Mitha alu & Shakarkand (H); (*Cheeni kizhangu* & *Madhura kizhangu* (M); *Shakkareivalli kizhangu* (T); Genasu (K); Chelagada (TE); Ratalu (MR); Lal alu & Ranga alu	Introduced and found all over but mostly concentrated in Eastern U.P, Bihar, West, Bengal and Orissa
3.	Greater Yam	*Dioscorea alata* (L.) 2n = 40, 60, 80	Dioscoreaceae	Pind Aaluk(H); Kachil & Kavithu (M); *Peruvalli kizhangu* & *Vetrilaivalli kizhangu* (T)	South & North Eastern region
4.	White Yam	*Dioscorea rotundata* (Poir.) 2n =40	Dioscoreaceae	Safed Aaluk (H); African kachil (M); African valli kizhangu (T)	Introduced to India and spread to South and North Eastern region
5.	Lesser Yam	*Dioscorea esculenta* (Lour.) Burk. 2n =30-100	Dioscoreaceae	Kayu(H); *Cheruvalli kizhangu*, Cherukizhangu, *Nana kizhangu*, Mukkizhangu (M); *Siruvalli kizhangu* (T)	South, N.E & Eastern region

Sr. No.	Common Name	Scientific Name	Family	Vernacular Name	Places/Areas Grown
6.	Potato Yam	*D. bulbifera* var sativa 2n = 40, 60	Dioscoreaceae	Mekkachil & Erachikachil (M)	Southern, North East and Eastern region
7.	Taro	*Colocasia esculenta* (L.) Schott 2n =28, 42	Araceae	Chamadumpa & Chemagadda (TE); Alu (MR); Kachu(B) Arvi, Kachalu & Ghuiya (H); Kachu(S); Chempu (M); Seppan-kizhangu (T); Kachchi (K); Shamagadde(K);	Throughout India with greater diversity in North east, Eastern region and South
8.	Tannia	*Xanthosoma sagittifolium* 2n =26	Araceae	Palchempu (M)	South and North eastern region
9.	Elephant Foot Yam	*Amorphophallus paeoniifolius* (Dennst.) Nicolson 2n =28	Araceae	Zamim-kand & Gimmikand (H); Arsaghna & Balukand (S); Chena (M) Karnai-kilangu (T); Suvarna gadde(K); Kanda (TE); Suran MR); Ol (B)	Southern, North East and Eastern region
10.	Chinese Potato	*Solenostemon rotundifolius* (Poir.) J.K. Morton *Plectranthus rotundifoliu*	Labiatae	*Koorka kizhangu* (M); *Sim kizhangu* (T)	Southern parts of India
11.	Yam Bean	*Pachyrrhizus erosus* (L.) Urban 2n=26	Leguminosae	Misri Kand (H); *Pachi kizhangu* (M)	North Eastern region
12.	Winged Bean	*Psophocarpus tetragonolobus* (L.) D.C. 2n =26	Leguminosae	*Chadhura payar* & Goa payar (M)	South & North East
13.	West Indian Arrow Root	*Maranta arundinaceae* L. 2n = 48	Marantaceae	Koova (M)	Adapted to plain areas with high rain fall; shade loving

15.2.1 Impact on Soil Properties:

The variation in temperature and rainfall has direct effects on the growth and maturity time of root crops, due to which the crops are adversely subjected to various biotic and abiotic stresses. According to a recent study, these biotic and abiotic stresses are responsible for losses of 30–50% of agricultural productivity worldwide.

In addition to this loss of productivity, climate change is also a threat in terms of a significant expansion in the range of pests and pathogens that could lead to an increased frequency and severity of root crop plant diseases. Soil management, including supplemental irrigation, optimizes tuber yield and quality, particularly for potatoes (Opena & Porter, 1999).

Cold temperatures below 10°C pose challenges for root and tuber crops. Chilling injury can significantly damage yam plants, resulting in stunted growth and decreased tuber yields (Sanginga *et al*., 2019). Protecting yam and other root and tuber crops from chilling temperatures is essential for optimal growth and productivity John *et al*., (2019 a).

When the temperature is low the pathogens active and infect the plant and root crops. Moderate temperature increases during the tuber bulking stage and varying water availability affect potato yield and quality (Ávila-Valdés *et al*., 2020).

Climate change has significant implications with soil for diseases in root and tuber crops such as potato, yam, carrot, ginger, sweet potato etc. (Bellotti *et al.*, 2012; John *et al.*, (2019 b). Climate change affects pathogen life cycles, population dynamics, and disease spread through temperature and humidity changes (Legrève and Duveiller, 2010; Maurya *et al*., 2023 a). Microscopic soil-dwelling pests causing root galling and yield reduction in potatoes, influenced by changes in temperature and soil conditions.

Climate change affects them by accelerating their life cycle in warmer temperatures, altering soil moisture conditions, weakening plant resistance, and potentially shifting their distribution. Tropical roots and tuber crops, such as cassava, sweet potatoes, yams, elephant foot yam, and taro, are vulnerable to climate change due to their unique characteristics (Yadav *et al*., 2018). Promoting agro ecology, conservation agriculture, and integrated pest management can enhance root and tuber crop resilience Maurya *et al.*, (2023 b).

It is highly possible that climate change will affect food security at the global, regional, and local levels. Climate change can disturb and reduce food availability as well as lower food quality. For example, increases in temperatures, changes in extreme weather events, changes in precipitation patterns, and reductions in water availability could all result in reduced agricultural productivity Maurya *et al*., (2023 c).

Prevalence of extreme weather conditions can also interrupt food delivery and result in increases in food prices due to low supply after extreme events, which are expected to be more frequent in the future. Moreover, increasing temperatures can contribute to spoilage and contamination.

15.3 Crop Modelling:

Crop modelling is essential for developing reliable forecasting systems to predict the effects of climate change on root and tuber crops' productivity. These models provide valuable insights, inform adaptation strategies, and aid decision-making for farmers and agricultural stakeholders.

With the arrival of advanced analytical tools like machine learning, combining climatic, weather, and agricultural data becomes feasible, enabling accurate predictions of annual crop yields at a country level in West African countries (Cedric *et al*., 2022; Maurya *et al*., 2020). Such modelling efforts are crucial for addressing food security challenges and ensuring sustainable agricultural production in the face of climate change.

15.3.1 Diseases of Root and Tuber Crops:

Carrot- Cercospora leaf spot (*Cercospora carotae*), Alternaria blight (*Alternaria carotae*), Sclerotinia rot (*Sclerotinia sclerotorum*), Bacterial blight (*Xanthomonas campestris* pv. *Carotae*) and Bacterial soft rot (*Ervinia carotovora* pv. *Carotovora*).

Radish- Alternaria blight (*Alternaria raphani*) nad White rust (*Albugo candida*).

Beetroot- Leaf spot (*Cercospora beticola*), Downy mildew (*Perenospora sachachtii*), Curly top (Beet curly top virus) and Beet yellows (Beet yellows virus).

Potato- Late blight (*Phytophthora infestans*), Early blight (*Alternaria solani*), Black scurf/stem canker (*Rhizoctonia solani*), Dry rots (*Fusarium* spp.), Wart disease (*Synchytrium endobioticum*), Powdery scab (*Spongospora subterranean*), Soft rot /blag leg (*Ervinia carotovora* subsp. *carotovora*), bacteria wilt/brown rot/bangle blight (*Psedomonas solanacearum*), Common scab / corky scab (*Streptomyces scabies*), Leaf roll (Potato leaf roll virus), Purple top roll (Mycoplasma) and Severe mosaic (Potato virus Y).

Sweet Potato- Black rot (*Ceratocystis fimbriata*), Rhizopus soft rot (*Rhizopus stolonifer*), Bacterial soft rot (*Erwinia chrysanthemi*), Scurf (*Monilocheaets infuscans*) and Charcoal rot (*Macrophomina phaseolina*).

Cassava- Brown leaf spot (*Cercospora henningsii*) and Mosaic (Indian cassava mosaic virus)

Turmeric- Leaf spot (*Collatotricum capsici*), Leaf blotch (*Tafrina maculans*) and Rhizome rot (*Pythium aphanidermatum*).

Ginger- Rhizome rot/soft rot (*Pythium aphanidermatum*, *P. vexans*, *P. Myriotylum*), Yellows disease (*Fusarium oxysporum f. Sp. zingiberi*), Bacterial Wilt (*Ralstonia solanacearum)* and Leaf spot (*Phylllosticta zingiberi*).

Turnip- Alternaria leaf spot (*Alternaria* spp.).

Garlic- Purple bloch (*Alternaria porri*), Stemphylium blight (*Stemphylium vesicarium*), White rot (*Sclerotium cepivorum*), Leek yellow stripe virus (LYSV), Irish Yellow Spot Virus (IYSV) and Onion yellow dwarf virus (OYDV).

Onion- Purple blotch (*Alternaria porri*), Smut (*Urocystis cepulae*), Pythium root rot (*Pythium aphanidermatum, P. Debaryanum, P. ultimum*), Smudge (*Collatotricum circinans*), Basal rot (*Fusarium oxysporum* f. sp. *cepae*), Downy mildew (*Perenospora destructor*), white rot *Sclerotium cepivorum*), Leaf blight (*Botrytis* spp.) and Onion yellow dwarf (*Virus*).

Asparagus- Crown rot/seedling blight (*Fusrium oxysporum f.sp. asparagi, F. Proliferatum, F. verticilloides*), Purple rot (*Stemphylium vesicarium*) and Rust (*Puccinia asparagi*).

15.3.2 Effect of Temperature:

Elevated temperatures driven by climate change affect developmental and physiological plant processes that, ultimately, impact on crop yield and quality. Plant roots are responsible for water and nutrients uptake, but changes in soil temperatures alters this process limiting crop growth. Temperature affects the growth of the crop, host–pathogen interactions and will alter the susceptibility window Misci *et al.*, (2022).

Effect of increase in temperature Changes in temperature and precipitation regimes due to climate change may alter the growth stage, development rate and pathogenicity of infectious agents, and the physiology and resistance of the host plant. In general, increase in temperature would significantly raise the severity and spread of plant diseases but quantity of precipitation could act as regulator in deciding the increase or decrease in disease severity and spread Maurya *et al.*, (2018). Temperature is one of the most important factors affecting the occurrence of bacterial diseases such as *Ralstonia solanacearum*, *Acidovorax avenae* and *Burkholderia glumea*. Thus, bacteria could proliferate in areas where temperature-dependent diseases have not been previously.

Crops face rising temperatures by triggering a heat response, whose timing and effectiveness will determine if the plants overcome the stress. The effect of increased temperatures on aerial parts of the plants and their responses has been well studied, whereas their influence and response on roots has been less explored. If we attempt to enhance adaptation of crops to severer environments triggered by climate change, we need to take into account below ground traits. For that, first, we need to improve our understanding of the processes regulating the root response to increased temperature.

Certain minimum temperature is required by both plants and pathogens to grow. Temperature affects the chain of events in disease cycles such as survival, dispersal, penetration, development and also reproduction rate for many pathogens. With increasing temperature spore germination of rust fungus *Puccinia substriata* increases. Moderate temperature is the best for fungal growth that cause plant disease. *Phytophthora infestans*, late blight of potato and tomato, infects and reproduces most successfully at high moisture when temperatures are between 7.2°C and 26.8°C. Even the incidence of virus and other vector borne diseases also alter.

Mild and warmer winters make aphids easy to survive thus spreading Barley yellow dwarf virus (BYDV) and also increase viruses of potato and sugar beet.

15.3.3 Effect of Moisture on Plant Disease:

With increased temperature various models on climate change predict frequent and extreme rainfall events and higher atmospheric water vapour concentrations. These encourage the crops to produce healthier and larger canopies that retain moisture as leaf wetness and RH for longer periods and results in condition conducive for pathogens and diseases such as late blights and vegetable root diseases including powdery mildews. High moisture favours foliar diseases and some soil borne pathogens such *Phytophthora*, *Pythium, R. solani* and *Sclerotium rolfsii.*

15.3.4 Effect of Climate Change on Vector-Borne Diseases:

Plant viruses interact with their host plants and vectors. The risk of vector-borne disease at local and regional levels is limited by the climatic requirements of the vectors (Malmström *et al.*, 2011). Both host plant and insect vector populations are affected by climate change and spread plant viruses (Jones, 2009). Global warming also affects the primary infection of the host, the spread of infection within the host, and/or the horizontal transmission of the virus by the vector to new hosts.

The phenology and physiology of the host are also affected by climate change, affecting its virus susceptibility and the virus's ability to infect. In turn, effects on host physiology may affect the host's attractiveness to vectors and/or virus transmissibility. Climate change has various effects on vectors such as changes in the phenology of the vectors, overwintering of the vectors, density, migration, and its stability. Higher levels of CO_2 have little effect on natural enemies of insect herbivores. This increased CO_2 has an indirect effect at the third trophic level, altering the size and structure of insect prey populations. Any change in host plant or insect vector populations due to climate change can spread plant viruses (Canto *et al*., 2008).

Plant-infecting viruses operate in intimate association with their hosts and vectors. The risk of vector-borne disease at the local and regional level is limited by the climatic requirements of disease vectors (Malmstrom *et al*., 2011). Climate change may affect both host plant and insect-vector populations, thereby affecting the spread of plant viruses (Jones, 2009). Global warming may influence the primary infection of the host, the spread of the infection within the host and/or the horizontal transmission of the virus to new hosts by the vector. Climate change may also affect the phenology and physiology of the host, which may affect its susceptibility to the virus and the ability of the virus to infect, as well as the geographic range and densities of alternative hosts/reservoirs. In their turn, the effects on host physiology may affect the attractiveness of the host to vectors and/or viral transmissibility. Modification of the geographic range of the potential vectors and/or vector phenology, as well as the vector's over-wintering, density, migration and activity can follow. Virus stability, replication and movement rates, as well as synergism and complementation between viruses can be affected. Although elevated CO_2 levels have been shown to have little direct effect on natural enemies of insect herbivores, they can influence the third trophic level indirectly, by altering the size and composition of populations of prey insects available to predators and/or by disrupting developmental synchrony for parasitoids.

15.3.5 Climate Change and Microbial Interactions:

Increased levels of CO_2 in the atmosphere have a profound effect on carbon cycling and the functioning of various ecosystems. Nitrogen deposition levels, CO_2 concentrations and temperature are important factors affecting soil microbial communities (Garrett *et al*., 2006). Short-term and long-term changes in abiotic conditions not only affect plant growth and productivity but also affect the populations of microorganisms living on plant surfaces. Any change in the phyllosphere microflora affects plant growth and the ability of plants to withstand aggressive attack by pathogens, leading to impacts on production and productivity.

15.3.6 Impact of Soil pH:

Climate is a primary variable that affects all other aspects of the ecosystem, and it will also have an impact on soil characteristics, including pH. Host plants are also affected by soil pH. At high pH, plants are stressed and susceptible to attack by pathogens. Soil pH can affect the nature of root exudates, which attract soil-borne pathogens. It also affects the nutrients available to the plant. In cruciferous, acidic soils have a higher incidence of club root (*Plasmodiophora brassicae*) than alkaline soils. A pH of 5.2 promotes Streptomyces scabiei, which shows reduced growth and incidence at pH 8.5 (Lawrence *et. al*.). At a neutral pH of 7.0, Fusarium wilt of flax is controlled (Agrios G N). Soil nutrient availability, plant growth and vigour are affected by soil response and this also indirectly affects disease development and infection (Colhoun J).

15.3.7 Vulnerabilities of Root and Tuber Crops To Climate Change:

Tropical root and tuber crops, such as cassava, sweet potato, yam, elephant foot yam and taro, are vulnerable to climate change due to their unique characteristics (Yadav *et al*., 2018). Understanding their adaptation processes and vulnerabilities is important for sustainable production and food security (Heider *et al*., 2021). Researchers have studied the impact of climate change on root and tuber crops in different regions, highlighting the need for resilience-enhancing strategies (Parker *et al*., 2019). To address these challenges, the focus is on seed systems, adaptation strategies and plant growth-promoting microorganisms in the rhizosphere (Parker *et al*., 2019). Like other root and tuber crops, potatoes also face consequences of climate change, including temperature rise and increased risk of disease and pests (Yadav *et al*., 2018; van der Waals *et al*., 2013). Potato production has declined by more than 87% when grown in warmer temperatures in the Peruvian Andes due to increased incidence of new pests. In addition, crop quality and value have been adversely affected under simulated migration and warming scenarios (Tito and Feeley, 2018), and local farmers may suffer significant economic losses of up to US$ 2,300 per hectare per year due to these adverse effects. Efforts are underway to develop climate-resilient potato varieties and implement integrated pest management practices (Yadav *et al*., 2018; Hijmans, 2003).

Increasing CO2 concentrations contribute to climate change. Research suggests that yam, taro, sweet potato and yam crops have the potential to tolerate high CO2 levels, which may be beneficial for cultivation of these crops in a changing climate (Ravi *et al*., 2017; Ravi *et al*., 2021; Ravi *et al*., 2022). However, more research is needed to determine the long-term effects of high CO2 on the growth and yield of these crops. It is estimated that the potential impact of climate change, particularly focusing on average temperature and total rainfall changes, on yam (Dioscorea spp.) cultivation will face growing difficulties in many regions across India as a result of the changing climate by 2030 (Remesh *et al*., 2019).

Genetic diversity is important in selecting stress-tolerant varieties for sweet potato and taro (Mukherjee *et al*., 2015). However, root and tuber crops have limited tolerance to biotic stresses and are susceptible to pests and diseases (George *et al*., 2017). Specific diseases such as Cassava brown streak disease and Cassava mosaic disease pose a major threat to cassava due to climatic uncertainties (Yadav *et al*., 2018).

To mitigate the adverse effects of climate change on root, tuber and root crops, focus is on increasing genetic diversity and developing climate-resilient varieties (Mukherjee *et al*., 2015; George *et al*., 2017). These efforts aim to cultivate varieties with improved tolerance to climatic stresses, thereby ensuring sustainability and resilience of root and tuber crop production (Yadav *et al*., 2018).

15.4 Yield Prediction of Tropical Root and Tuber Crops:

Climate change predictions point to a warming of the world in the coming years, with temperatures rising every year, a trend increasingly supported by ‘ground reality’. Climate change threatens to increase crop losses, increase the number of people facing malnutrition, and alter the growth pattern of diseases and pests of root and tuber crops. Agricultural production of rainfed areas, which account for about 68% of the area under cultivation and about 40-45% of total production in India, varies from year to year. Therefore, to maintain and increase the production of rainfed crops of semi-arid tropical regions, it is necessary to use the knowledge of climate variability to formulate practical innovative cropping patterns and pest and disease management for location-specific agro-climatic zones. Given the present, newly developed varieties have to be used to minimize the losses incurred.

15.5 Management Practices:

Climate change has a substantial impact on root crop diseases because it changes the environmental variables that influence pathogen life cycles, disease severity, and dispersion. Warmer temperatures, variable precipitation patterns, and extreme weather events all contribute to the increasing occurrence and severity of root crop diseases including potato blight and black rot in sweet potatoes. Warmer and wetter weather, for example, can increase the spread of soil-borne diseases such as Phytophthora and Fusarium, resulting in higher infection rates and crop losses Garrett, K.A. (2020).

Root crop disease management requires a comprehensive approach in response to changing climate conditions. Integrated Disease Management (IDM) tactics are critical, which include cultural approaches, resistant crop cultivars, and biological control methods.

Crop rotation and diversification limit pathogen accumulation in the soil, while disease-resistant varieties provide frontline protection. Furthermore, advances in biocontrol using antagonistic microorganisms offer a long-term alternative to chemical pesticides (Pautasso *et al*. 2012).

Precision agricultural technology, like as remote sensing and predictive modelling, are also critical for mitigating the effects of climate change on root crop diseases. These tools offer early diagnosis and appropriate intervention, allowing farmers to adapt to the changing disease landscape. Furthermore, adaptive methods, such as the creation of climate-resilient crops and the implementation of climate-informed agricultural policy, are critical for minimizing the consequences of climate change on root crop disease management (Pautasso *et al.*, 2012). To ensure the sustainability and productivity of root crop agriculture in the face of climate change, governments, researchers, and agricultural stakeholders must conduct continual research, educate farmers, and collaborate.

15.6 Future Prospects:

Climate change has a major impact on root crop diseases, posing significant challenges to world food security. As temperatures rise, viruses' geographic distribution shifts, causing diseases to emerge in previously unaffected areas. This spread is compounded by changes in rainfall patterns, which create ideal circumstances for the proliferation of soil-borne diseases like Phytophthora and Fusarium. These fungi, which cause catastrophic illnesses such as potato late blight and root rot, flourish in warm, moist settings, increasing infection rates and crop losses (Garrett, Karen A. 2006).

Climate change is also impacting agricultural phenology and physiology, as well as the infections that affect them. Elevated CO_2 levels can affect plant growth, rendering crops more prone to illness. Warmer temperatures can speed up the life cycles of many diseases, resulting in more frequent and severe outbreaks. For example, *Rhizoctonia solani*, a significant pathogen that affects potatoes and other root crops, is projected to have a shorter lifetime, resulting in more disease pressure (Garrett, K. A. 2020). Future prospects are worrying, as the combined effects of climate change and global trade are likely to introduce new viruses into sensitive areas. This will necessitate the creation of integrated disease management strategies, such as breeding disease-resistant varieties, improving soil health, and implementing precision agriculture technologies to monitor and control disease spread (Garrett, Karen A. 2006). To offset these problems, worldwide collaboration in research and policymaking is vital, and strengthening the resilience of root crops to climate change through sustainable farming methods will be critical in guaranteeing food security in an uncertain future.

15.7 Conclusion:

The impact of climate change on root crop diseases is profound, with far-reaching consequences for global food security. Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events create favorable conditions for the proliferation of plant pathogens. Warmer climates can extend the growing seasons of pests and diseases, leading to more frequent and severe outbreaks.

Changes in humidity and soil moisture also affect the spread and survival of pathogens, making some regions more vulnerable to diseases that were previously rare or non-existent. Additionally, climate change can disrupt the natural balance between pests, pathogens, and their natural predators, further exacerbating disease pressures on root crops. This leads to increased reliance on chemical control measures, which may not always be effective and can contribute to environmental degradation.

The overall effect is a reduction in crop yields, increased production costs, and a greater risk of food shortages, particularly in regions already vulnerable to food insecurity. Addressing these challenges requires integrated approaches that combine improved crop management practices, breeding for disease-resistant varieties, and policies that mitigate climate change impacts, ensuring sustainable root crop production in the face of a changing climate.

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