ISBN: 978-81-974990-4-3

16. Impact of Crop Diseases on the Water Footprint of Root and Tuber Crops

Afreen Fatima, Sadanand Yadav,
Brijlesh Tiwari, Deepa Srivastava

Department of Chemistry, Ecological Footprint Lab,
CMP Degree College, University of Allahabad,
Prayagraj, Uttar Pradesh, India.

Abstract:

This chapter investigates the impact of crop diseases on the water footprint of key root and tuber crops, including potatoes, cassava, sweet potatoes, and yams. It explores how diseases contribute to increased water use by reducing crop yields, impairing plant water uptake, and necessitating more frequent irrigation. The chapter provides a detailed analysis of the effects of specific diseases, such as late blight in potatoes, cassava mosaic virus, and anthracnose in yams, highlighting their role in exacerbating water consumption. Disease management practices, including increased irrigation and the application of water-intensive pesticides and fungicides, further elevate the water footprint. The chapter recommends strategies to mitigate this impact, such as the development of disease-resistant crop varieties, adoption of water-efficient irrigation systems, and implementation of integrated pest and disease management. Additionally, it identifies future research priorities, including advancements in breeding disease-resistant crops, innovations in irrigation technology, and understanding the effects of climate change on crop health and water use. The chapter emphasizes the importance of sustainable agricultural practices in reducing the water footprint and ensuring long-term water resource sustainability and food security

Keywords:

Crop Diseases, Water Footprint, Management, Disease Resistance

16.1 Introduction:

The total amount of water utilised, both directly and indirectly, in the production of goods and services is measured as the water footprint (Kumar, and Janet, 2019). This idea is important to agriculture since the production of crops uses a large number of freshwater resources worldwide. The three primary components of the water footprint are green water, which is rainwater absorbed by crops, blue water, which is surface and groundwater utilised for irrigation, and grey water, which is water used to dilute pollutants coming from agricultural activities (Maite *et al*., 2020; John *et al*., 2019 a). It is easier to evaluate the sustainability of farming operations when one is aware of the water footprint in agriculture. Reduced water footprint crops typically use water more effectively, reducing strain on nearby water supplies (Lakhiar *et al*., 2024). Conversely, crops with large water footprints can put a pressure on water supplies, particularly in areas where water is scarce.

This idea is essential for creating plans that strike a balance between water conservation and food production, guaranteeing farming's long-term sustainability (McLaughlin and Kinzelbach 2015; John *et al*., 2019 b).

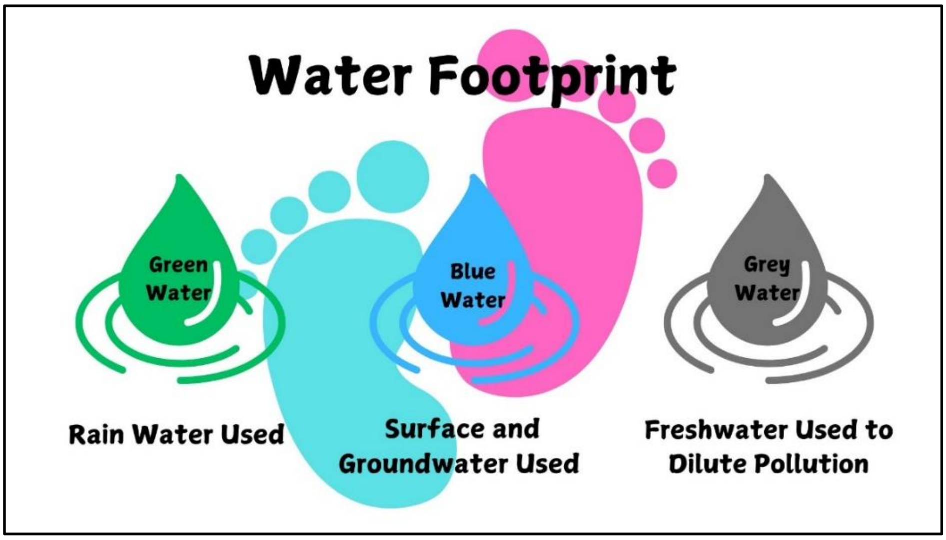

Figure 16.1: Different types of water footprint

- **Vulnerability of Root and Tuber Crops to Diseases:**

In many parts of the world, root and tuber crops such as potatoes, cassava, sweet potatoes, and yams are vital staple foods. These crops, however, are extremely susceptible to a variety of illnesses, such as bacterial, viral, and fungal infections (Chandrasekara *et al*., 2016). Cassava mosaic virus and potato blight, for instance, can seriously impair crop quality and drastically lower production.

Compared to above-ground crops, root and tuber crops are more difficult to detect and manage diseases because of their underground nature (Bodah, 2017). In addition, environmental factors that contribute to disease susceptibility include high levels of wetness, inadequate soil drainage, and temperature fluctuations. Disease outbreaks have the potential to destroy local food supplies and agricultural economies in regions where these crops are essential for food security (Maurya *et al*., 2023 a).

- **How Diseases Affect Water Use in Agricultural Systems:**

In numerous ways, diseases can have a major impact on how much water agricultural systems consume. First, more frequent irrigation is frequently needed for diseased crops to lessen the impacts of disease-induced stress, which increases water consumption. For example, diseases affecting the function of the roots might lower a plant's capacity to absorb water, requiring more irrigation to keep the crop from failing (John, 2006; Maurya *et al*., 2023 b). Furthermore, treating illnesses frequently entails applying more chemical treatments, such fungicides, which raises the water footprint of crop production.

Certain diseases can be made worse by using overhead irrigation techniques, which are frequently employed to control diseases (Mishra *et al.*, 2019; Maurya *et al*., 2020). This is because the moisture they provide encourages the disease to spread deeper. Furthermore, illnesses that lower crop yields can increase the amount of water consumed per unit of output. The same amount of water provides less food when yields are lower owing to illness, hence increasing the amount of water consumed per kilogramme of crop (Ali *et al*., 2008). Long-term effects may result from this in areas with limited water resources, where sustainable farming depends on effective water use.

16.2 Pathways through Which Illnesses Boost Crop Water Use:

- **Lower Yields Leading to Increased Water Use Per Unit of Output:**

Crop yields generally decrease dramatically when they are impacted by illness. Consequently, less is produced with the same amount of water that would normally support a healthy, full crop. Because of this inefficiency, more water is required to harvest each unit of produce. For instance, the production of a root crop like cassava may be halved yet the water need may stay roughly the same if the crop is afflicted with a disease like cassava mosaic virus (Jones and Roger 2021; Maurya *et al.*, 2018). An imbalance between water uses and agricultural productivity results from this, as the water footprint per kilogramme of crop rises. This has significant effects on the management of water resources, especially in areas that already experience drought or water scarcity.

- **Disruption of Plant Water Uptake and Physiology Due to Disease:**

Diseases in crops can disrupt normal physiological processes, including water uptake and nutrient absorption. Many root and tuber diseases affect the root system directly, impairing the plant's ability to absorb water efficiently (Ray, 2024). For example, diseases like root rot can damage the roots, reducing their capacity to transport water to the plant. This forces the plant into a state of stress, where it requires more water to maintain basic physiological functions. Additionally, diseases can alter the plant's water regulation mechanisms, such as stomatal function, which affects transpiration rates (Wu 2022). These disruptions lead to inefficient water use, with plants demanding more water while yielding less, thereby worsening the water footprint.

- **Disease-Induced Stress and Increased Irrigation Requirements:**

Crops that are disease-stressed frequently need more watering to offset the detrimental impacts. Plants suffering from diseases may experience physiological stress, which manifests as symptoms including wilting, reduced leaf area, and slower growth (Beck 2019). In response, even though the plants would not fully recover or yield normally, farmers might boost irrigation in an effort to keep the plants alive and hydrated. Since irrigation is used to reduce disease-induced stress rather than to promote growth, this method has the potential to dramatically increase water consumption (Harun-Ur-Rashid *et al*., 2023). The crop's water footprint may increase even more in severe disease outbreak situations when the amount of water needed is out of proportion to the yield.

16.3 Impact of Specific Diseases on Water Footprint in Major Root and Tuber Crops:

- **Potato (*Solanum tuberosum*): Water Footprint of Managing Late Blight (*Phytophthora infestans):***

Potato late blight, or *Phytophthora infestans*, is a destructive disease that, if left unchecked, can result in significant crop losses. The water footprint is increased by late blight in a number of ways. In an effort to preserve crop health, farmers first tend to irrigate more frequently when crops are stressed as a result of the illness. Additionally, the illness compels farmers to employ fungicides, many of which require a lot of water to apply, increasing the amount of water used (Plappally and Lienhard 2012).

Source: https://www.thompson-morgan.com

Figure 16.2: Late Blight of Potato

Moreover, lower yields from infected plants usually translate into an increased water requirement per kilogramme of harvested potatoes. This is particularly problematic in regions where groundwater and surface water sources play a major role in agriculture (Ierna 2023). Potato farming can have a significantly larger water footprint if late blight is not controlled, which would put a pressure on water supplies and agricultural production (Reay and Reay (2019).

- **Cassava (*Manihot esculenta*): Effects of Cassava Mosaic Disease on Water Footprint:**

A virus that drastically lowers cassava yields is the source of cassava mosaic disease (CMD), which sharply raises the water footprint per unit of production. CMD hinders the growth of the plant by lowering photosynthesis and slowing the development of leaves, which lowers biomass and root output (Ewa 2021). Farmers cultivating cassava in CMD-affected locations may compensate by increasing the area under cultivation or intensifying irrigation measures to counter production losses, both of which contribute to a greater water footprint (Hoekstra 2017; Maurya *et al*., 2023 c).

Since cassava is frequently farmed in rainfed systems, the illness mainly impacts how well rainwater (green water) is used. However, treating CMD frequently necessitates additional water input in areas where irrigation is used, which can exhaust already limited water resources (Hoekstra 2017). Furthermore, when cassava yields are reduced due to CMD, more water is needed overall per kilogramme of the crop, which reduces the crop's water efficiency when disease pressure increases.

- **Sweet Potato (*Ipomoea batatas*): Impact of Viral Diseases on Water Efficiency:**

A number of viral infections, including the most serious one, Sweet Potato Virus Disease (SPVD), can infect sweet potatoes. Viral infections impede the plant's growth and development, leading to a notable decrease in yields. Viral infections cause more water to be wasted because they make it more difficult for plants to generate the desired biomass with the same amount of water, which reduces the crop's capacity to absorb and use water (Farooq *et al*., 2019; Pandey *et al.*, 2022 a). Viral infections can cause overcompensation in irrigation techniques, which increases the crop's water footprint in areas where irrigation is required. Furthermore, the total resource inputs, including water, increase because viral infections frequently call for extra chemical treatments or the planting of disease-free tissue cultures. Viral infections reduce the number of sweet potatoes that can be harvested per unit of water consumed, which reduces water usage efficiency and increases the water footprint.

- **Yams (*Dioscorea* spp.): How Anthracnose Affects Water Use in Yam Cultivation:**

Anthracnose, caused by the fungus *Colletotrichum spp.*, is a significant disease affecting yams, leading to reduced leaf area, stunted growth, and lower tuber yields. As anthracnose weakens the plant’s overall health, yams become less efficient in water uptake and use (Coffie 2013). This means that even under optimal irrigation or rainfall, infected plants produce smaller tubers, effectively increasing the water footprint of the crop. When yams are grown in areas where supplemental irrigation is used, anthracnose can cause farmers to consume excessive amounts of water in an effort to offset the stress caused by the disease. Moreover, anthracnose frequently causes secondary problems including heightened susceptibility to other pests and illnesses, which calls for more water-intensive therapies like the use of pesticides (Pandey *et al*., 2022 b). When anthracnose affects yam production over time, more water is needed to produce the same number of tubers—or perhaps less—than before, which results in a noticeable rise in the water footprint (Tuyishimire *et al*., 2022).

16.4 Water-Intensive Disease Management Practices:

Increased Irrigation to Compensate for Disease-Related Stress:

- Diseases often damage the root systems of crops, reducing their ability to absorb water effectively (Passioura (2006; Pant *et al*., 2023).

- To combat this, farmers increase irrigation to maintain plant health and prevent further yield loss.
- The additional water used often leads to wastage, as diseased plants are less efficient in using the water (Rajasulochana and Preethy 2016).
- Despite increased irrigation, yields may still be reduced, resulting in a higher water footprint per unit of output (Ravishankar *et al.*, 2023).
- This practice contributes to water resource depletion, especially in water-scarce areas (Alotaibi *et al*., 2023).

Water Use in Pesticide and Fungicide Applications:

- Managing crop diseases with pesticides and fungicides often requires large amounts of water for mixing and spraying.
- Frequent chemical applications are necessary for crops highly susceptible to diseases, increasing overall water consumption (Dixon 2015).
- Fungicide treatments often require repeated applications throughout the growing season, compounding water usage.
- This practice raises the water footprint of crops and can lead to runoff, causing water contamination in surrounding areas (Fatima *et al*., 2024).

The Role of Overhead Irrigation in Disease Spread and Water Wastage:

- Overhead irrigation systems can lead to significant water wastage through evaporation before the water reaches the soil.
- The moist environment created by water droplets on plant foliage encourages the growth and spread of fungal diseases (Jain *et al*., 2019).
- This can result in a cycle where overhead irrigation worsens disease outbreaks, requiring even more water for disease management.
- The inefficiency of overhead irrigation systems increases the crop's overall water footprint and poses sustainability challenges in agriculture.

16.5 Conclusion:

There is a substantial correlation between crop diseases and the water footprint of root and tuber crops. By lowering crop yields and decreasing plants' ability to absorb water, diseases directly raise the water footprint by requiring more water per unit of production. Water consumption is also increased by the need for additional watering that infected crops frequently require to reduce disease-induced stress. Furthermore, the situation can be made worse by disease management techniques including the use of water-intensive insecticides and fungicides as well as overhead irrigation systems, which can inadvertently waste water and promote the spread of disease. Crop diseases in root and tuber crops, in general, increase the water footprint and strain already limited water supplies.

16.5.1 Recommendations for Reducing Water Footprint through Disease-Resistant Crops and Sustainable Practices:

- **Development and Use of Disease-Resistant Varieties:** Planting disease-resistant varieties of root and tuber crops can significantly reduce the water footprint by minimizing the need for excessive irrigation and chemical treatments. Resistant varieties can maintain higher yields under disease pressure, improving water use efficiency.
- **Adoption of Water-Efficient Irrigation Systems:** Switching from overhead irrigation to more efficient systems like drip or subsurface irrigation can help reduce water wastage and prevent the spread of diseases by minimizing moisture on plant leaves.
- **Integrated Pest and Disease Management (IPDM):** Implementing IPDM practices that combine biological control, cultural practices, and minimal chemical use can reduce water-intensive disease management approaches. For example, rotating crops, improving soil health, and using biological control agents can limit disease outbreaks, decreasing the need for excessive water use.
- **Precision Agriculture:** Using technology like remote sensing, drones, and soil moisture sensors can help farmers target irrigation and disease control measures more efficiently. This ensures that water and treatments are applied only when and where they are needed, improving overall water conservation.
- **Improved Soil Health:** Maintaining healthy soils through organic amendments and proper crop rotations can help crops resist diseases naturally, reducing the need for water-intensive interventions.

16.5.2 Future Research Directions on the Nexus of Crop Health and Water Use in Root and Tuber Crops:

- **Creating More Disease-Resistant Varieties:** The key to lowering the water footprint of these crops will be to carry out more research on breeding or genetically modifying root and tuber crops to make them resistant to a wider range of diseases. These crops ought to be adjusted to various climates and levels of water availability.
- **Innovations in Irrigation and Disease Detection Technologies:** Upcoming studies should concentrate on creating and improving precision agricultural instruments that can reliably identify early illness symptoms and offer up-to-date information on water requirements. This may result in focused, water-saving measures that reduce the burden of disease and water use.
- **Recognising How Climate Rise Affects Disease and Water Use:** Crop disease prevalence is expected to rise as a result of rising temperatures and altered precipitation patterns brought on by climate change. The main goals of research should be to create adaptive strategies and to comprehend how the relationship between diseases and water use in root and tuber crops will change as a result of climate change.

16.6 References:

1. Ali, M.H. and Talukder, M.S.U. (2008). Talukder, Increasing water productivity in crop production—A synthesis. *Agricultural Water Management*. 95 (11):1201-1213. ISSN 0378-3774, https://doi.org/10.1016/j.agwat.2008.06.008
2. Alotaibi, B. A., Baig, M. B., Najim, M. M., Shah, A. A. and Alamri, Y. A. (2023). Water scarcity management to ensure food scarcity through sustainable water resources management in Saudi Arabia. *Sustainability*, 15(13):10648.
3. Beck, K. D. (2019). *Evaluating the use of hyperspectral remote sensing and narrow band spectral vegetation indices to diagnose onion pink root at the leaf and canopy level*. University of Idaho.
4. Bodah, E. T. (2017). Root Rot Diseases in Plants: A Review of Common Causal Agents and Management Strategies. *Agri Res & Tech: Open Access J.,* 5(3): 555661. DOI:10.19080/ARTOAJ.2017.04.555661
5. Chandrasekara, Anoma, J. K. and Thamilini, (2016). Roots and Tuber Crops as Functional Foods: A Review on Phytochemical Constituents and Their Potential Health Benefits, *International Journal of Food Science*, 3631647: 15. https://doi.org/10.1155/2016/3631647.
6. Coffie, S. A. (2013). *Aetiology, Importance and Control of a Vine-Browning and Die-back Disease of Water Yam (Dioscorea Alata L.) in the Volta Region of Ghana* (Doctoral dissertation, University of Ghana).
7. Dixon, G. R. (2015). Water, irrigation and plant diseases. *CABI Reviews*.1-18.
8. Ewa, F. (2021). *Genetic mapping and evaluation of cassava (manihot esculenta crantz) for drought tolerance and early bulking in marginal Savannah ecology of Nigeria* (Doctoral dissertation).
9. Farooq, M., Hussain, M., Ul-Allah, S. and Siddique, K. H. (2019). Physiological and agronomic approaches for improving water-use efficiency in crop plants. *Agricultural Water Management*. 219: 95-108.
10. Fatima, A., Yadav, S. and Srivastava, D. (2024). Sustainable millet-based ethanol production in India: a comprehensive analysis of water footprint and environmental impact. *Discov Water* **4**, 65. https://doi.org/10.1007/s43832-024-00117-6
11. Harun-Ur-Rashid, Mohammad, Israt Jahan, Tahmina Foyez, and Abu Bin Imran (2023). "Bio-Inspired Nanomaterials for Micro/Nanodevices: A New Era in Biomedical Applications.*Micromachines.* 14, 9: 1786. https://doi.org/10.3390/mi14091786.
12. Hoekstra, A. Y. (2017). Water footprint assessment: evolvement of a new research field. *Water Resources Management*, 31(10): 3061-3081.
13. https://doi.org/10.1016/B978-0-12-822429-8.00002-9.
14. Ierna, A. (2023). Water management in potato. In *Potato Production Worldwide* (pp. 87-100). Academic Press.
15. Jain, A., Sarsaiya, S., Wu, Q., Lu, Y. and Shi, J. (2019). A review of plant leaf fungal diseases and its environment speciation. *Bioengineered*. 10(1): 409-424.
16. John, P. (2006). Increasing crop productivity when water is scarce—from breeding to field management. *Agricultural Water Management*, 80 (1–3): 176-196. ISSN 0378-3774, https://doi.org/10.1016/j.agwat.2005.07.012
17. John, V., Zacharia, S., Maurya, A.K., Kumar, A. and Simon, S. (2019 a). *In-vitro* Efficacy of Botanical and Selected Bio-Agents in the Management of Fusarial wilts of Tomato (*Lycopersicon esculentum* L.). *Int. J. Curr. Microbiol. App. Sci.* 8(6): 1821-1826.

18. John, V., Zacharia, S., Maurya, A.K., Murmu, R. and Simon, S. (2019 b). Field Experiment on Efficacy of Selected Bio-agents and Botanical in the Management of Fusarial Wilt of Tomato (*Lycopersicon esculentum* L.). *Biotech Today,* 9 (2): 42-46. DOI: 10.5958/2322-0996.2019. 00019.X
19. Jones and Roger, A. C. (2021). "Global Plant Virus Disease Pandemics and Epidemics" *Plants* 10 (2): 233. https://doi.org/10.3390/plants10020233.
20. Kumar, P. S. and Janet, J. G. (2019). Water Footprint of Agricultural Products. In: Muthu, S. (eds) Environmental Water Footprints. Environmental Footprints and Eco-design of Products and Processes. *Springer, Singapore*. https://doi.org/10.1007/978-981-13-2508-3_1.
21. Lakhiar, I. A., Yan, H., Zhang, C., Wang, G., He, B., Hao, B., Han, Y., Wang, B., Bao, R., Syed, T.N. (2024). A Review of Precision Irrigation Water-Saving Technology under Changing Climate for Enhancing Water Use Efficiency, Crop Yield, and Environmental Footprints. *Agriculture*, 14:1141. https://doi.org/10.3390/agriculture1407114.
22. Maite, M. A., Corina, I., Rodriguez, Alex Fernandez-Poulussen, Daniel, M., Maria, J. B., Ramon, L. (2020). Grey water footprint as an indicator for diffuse nitrogen pollution: The case of Navarra, Spain, *Science of The Total Environment*, 698:134338. ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2019.134338.
23. Maurya, A. K., Aditya, John, V., Pant, H., Sharma, S. P., El Refaey, D. Z., Sami, R., Helal, M., Fadi Baakdah, and Ahmed, N. (2023 b). Unveiling Oil Seed Cakes Ability to Suppress Fusarium Wilt (*Fusarium udum* Butler) in Pigeonpea (*Cajanus cajan* L. Millsp.). *Journal of Biobased Materials and Bioenergy*, 17(6): 790–796. Doi: doi:10.1166/jbmb.2023.2319
24. Maurya, A. K., John, V., Murmu, R. and Pant, H. (2023 a). "Rice brown spot disease (*Helminthosporium oryzae*): ecology, epidemiology and identification measures. Fungal Diseases of Rice and their Management. Vol-II to be published by Apple Academic Press, CRC group, a Taylor and Francis group, 223-234. ISBN hard: 978-1-77491-247-8.
25. Maurya, A. K., John, V., Murmu, R., Simon, S. and Pant, H. (2020). An Overview of *Fusarium udum* and *Heterodera cajani* interactions in Pigeonpea (*Cajanus cajan*). Current Research and Innovations in Plant Pathology. *Akinik Publications* New Delhi. 9(6): 98-112. ISBN: 978-93-90217-71-7. DOI: https://doi.org/10.22271/ed.book.793
26. Maurya, A. K., Simon S., John, V. and Lal, A. A. (2018). Survey of Pigeon Pea Wilt Caused by Cyst Nematode (*Heterodera cajani*) in Trans Yamuna and Ganga Taluks of Allahabad District. *Int. J. Curr. Microbiol. App. Sci.,* **7**(6): 799-802.
27. Maurya, A.K., John, V., Pant, H., Raghav, R. and Kumar, M. (2023 c). Eco-friendly management of Pigeon pea wilt caused by *Fusarium udum*. *Pest Management Strategies in Pulses and Cereal crops*, 157-166. ISBN: 978-81-19149-06-3.
28. McLaughlin, D. and Kinzelbach, W. (2015). Food security and sustainable resource management. *Water Resour. Res*., 51:4966–4985. doi: 10.1002/2015WR017053.
29. Mishra, J. S., Kumar, R., Saurabh, K. and Bhatt, B. P. (2019). Conservation Agriculture for Climate Resilient Farming & Doubling Farmers' Income, 246p. ICAR Research Complex for Eastern Region, Patna.
30. Pandey, M., Maurya, A. K. and John, V. (2022 a). Fusarium wilt of chick pea and its management: present and future. Emerging Sustainability Trends in Agricultural, Rural & Environmental Development. *Society of Biological Sciences and Rural Development*, 229-237. ISBN: 978-81-923535-8-6.

31. Pandey, M., Maurya, A. K., John, V. and Kumar, M. (2022 b). Evaluation of different isolates of *Pseudomonas fluorescens* against *Fusarium oxysporum* f. sp. *ciceri*, causing wilt of chickpea (*Cicer arietinum* L.). *Annals of Phytomedicine*: *An International Journal*,11 (2): 806-813.
32. Pant, H., Maurya, A. K. Aditya, Singh, M. K., John, V., Mehra, M., Sami, R., Baakdah, F. and Helal, M. (2023). Ecofriendly Management of Root Knot Nematode (*Meloidogyne incognita*) in Okra (*Abelmoschus esculentus* (L.) Moench). *Journal of Biobased Materials and Bioenergy*, 17: 311–317. Doi:10.1166/jbmb.2023.2286
33. Passioura, J. (2006). Increasing crop productivity when water is scarce—from breeding to field management. *Agricultural water management*, 80(1-3): 176-196.
34. Plappally, J.H., and Lienhard, V. (2012). Energy requirements for water production, treatment, end use, reclamation, and disposal. *Renewable and Sustainable Energy Reviews*.16 (7):4818-4848, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2012.05.022.
35. Rajasulochana, P. and Preethy, V. (2016). Comparison on efficiency of various techniques in treatment of waste and sewage water–A comprehensive review. *Resource-Efficient Technologies*, *2*(4):175-184.
36. Ravishankar, L. V., Pandey, M.K., Dey, T., Singh, A., Rasool, B., Diskit, S., Dar, N.A., Maurya, A.K., John, V., Sami, R., Shami, A. A., Al Kashgry, N. A. T., Althaqafi, M. M. and Algopishi, U. B. (2023). Phenotyping and Molecular Characterization of Durable resistance in Bread Wheat for Stripe Rust (*Puccinia striiformis* f.sp. *tritici*). *Journal of Biobased Materials and Bioenergy*, 18:1-11.
37. Ray, R. V. (2024). Effects of pathogens and disease on plant physiology, Editor(s): Richard P. Oliver, Agrios' Plant Pathology (Sixth Edition). *Academic Press*. 63-92. ISBN 9780128224298,
38. Reay, D., and Reay, D. (2019). Climate-Smart Potatoes. *Climate-Smart Food*, 151-163.
39. Tuyishimire, A., Liu, Y., Yin, J., Kou, L., Lin, S., Lin, J. and Simbi, C. H. (2022). Drivers of the increasing water footprint in Africa: The food consumption perspective. *Science of the Total Environment*. 809, 152196.
40. Wu, J., Jingyan, W., Wenkai, H., Feiyan, Z., Peiyun, W., Chengyi, S., and Wei, G. (2022). "Physiology of Plant Responses to Water Stress and Related Genes: A Review" *Forests.* 13, 2: 324. https://doi.org/10.3390/f13020324.