Journal of Sustainable Technology in Agriculture
Open Access | www.jostapubs.com | ISSN(online): 3107-6882

Review-Article

September 2026, Volume 2, Issue III. *doi: 10.65287/josta.202607.9cf1*

Mitigating Phytopathogenic Diseases in Orchards Through Strategic Irrigation

Muskan Bhullar*
Khalsa College, Amritsar

Jaspreet Kaur
Khalsa College, Amritsar

Seethiya Mahajan
Khalsa College, Amritsar

Rishika
Khalsa College, Amritsar

Abstract

Effective irrigation management is a pillar of orchard productivity and an essential practice for disease control. Water applications modulate soil moisture, canopy microclimate, and plant status, directly influencing sporulation, dispersal, and infection cycles of important plant pathogens, including powdery mildew, apple scab, root rots, *Phytophthora* spp., *Botrytis cinerea* and bacterial species. Traditional overhead sprinklers can increase the risk of some foliar and splash-dispersed diseases by prolonging canopy wetness, but precision methods such as drip, subsurface drip, Regulated Deficit Irrigation (RDI), and sensor-based scheduling deliver water to the root zone, minimizing foliar leaf wetness and canopy humidity. Evapotranspiration-based scheduling avoids waterlogging and root diseases. Integrating fertigation and biological amendments further suppresses pathogens. This strategic approach enhances IDM and IPM, reduces chemical fungicide reliance, and promotes climate-smart, economically viable, sustainable fruit production with improved quality.

Keywords: Micro-sprinkler Irrigation, Disease Mitigation, Orchards, Phytopathogens.

Received: 2026-07-19 | *Accepted:* 2026-09-02 | *Published:* 2026-09-03

1. Introduction

Orchards represent among the most economically significant and biologically complex of all agricultural systems. Unlike annual crops that are replanted each season, perennial fruit trees occupy the same soil for decades, creating persistent host-pathogen associations and allowing soilborne inoculum to accumulate progressively under management practices that inadvertently favour pathogen survival. The global economic burden of diseases in orchard crops is considerable: losses in apple, citrus, mango, stone fruits, grapes, and pomegranate systems are estimated to range from 10% to 40% of total production value annually, with certain Pathosystems capable of devastating entire orchards when conditions align (Savary *et al.* 2019). In South Asian orchard systems where mango, guava, citrus, banana, and subtropical stone fruits collectively sustain millions of smallholder livelihoods phytopathogenic diseases represent a persistent constraint on both productivity and market access (Savary *et al.* 2012).

Among all the agronomic inputs that shape the orchard environment, water stands apart in the breadth and directness of its influence on disease. Irrigation is not merely a delivery mechanism for plant nutrition; it is a modulator of the soil physical environment, a driver of canopy microclimate, a vector for pathogen dispersal, and a determinant of host physiological status. The classical disease triangle susceptible host, virulent pathogen, and conducive environment is more sensitive to irrigation decisions than to almost any other single management variable (Agrios 2005). Water governs whether soils become saturated enough to release zoospores of *Phytophthora* and *Pythium*; whether leaf and fruit surfaces remain wet long enough for conidia to germinate; whether bark remains moist enough to permit secondary colonisation by wood-decay fungi; and whether prolonged water stress alters root physiological and biochemical defences sufficiently to increase susceptibility to necrotrophic pathogens (Erwin and Ribeiro 1996; Kennelly *et al.* 2010; Achuo *et al.* 2006).

The history of orchard disease management has been dominated by chemical fungicides and bactericides, and the last century has seen remarkable progress in the development of effective molecules targeting key pathogens. Yet the limitations of chemical-dependent systems have grown increasingly apparent: the evolution of fungicide resistance across populations of *Botrytis cinerea*, *Venturia inaequalis*, and *Monilinia* spp.; regulatory withdrawal of broad-spectrum compounds; consumer demand for residue-free produce; and the economics of repeated spraying in labor-scarce environments have all intensified the search for complementary, non-chemical strategies (Pertot *et al.* 2017; Holb *et al.* 2012). Strategic irrigation management should therefore be considered a complementary component of integrated disease management, rather than a substitute for plant protection chemistry that restructures the epidemiological environment in which pathogens operate.

The concept of 'disease-conscious irrigation' the deliberate calibration of water delivery method, timing, volume, and spatial distribution to reduce pathogen-conducive conditions has its intellectual origins in early observations that flooded or poorly drained orchard soils consistently suffered higher incidences of root rot diseases than well-drained counterparts (Ristaino and Thomas 1997). Over subsequent decades, this observation has been formalised through controlled experiments, long-term field trials, and epidemiological modelling across a wide range of orchard crops and Pathosystems. The convergence of precision irrigation technology drip systems, subsurface emitters, soil moisture sensors, evapotranspiration models with advances in disease forecasting and integrated pest management has created a genuinely new paradigm for orchard health management (Jones 2004; Irmak *et al.* 2011).

The importance of this paradigm is amplified by the realities of contemporary climate change. Shifting precipitation patterns, extended drought periods punctuated by intense rainfall events, and rising temperatures are simultaneously altering the water requirements of orchard crops and the epidemiological behaviour of their pathogens (Chakraborty and Newton 2011; Pautasso *et al.* 2012). In many semi-arid and sub-humid orchard regions of South Asia, the Middle East, and the Mediterranean basin, groundwater depletion and increasing irrigation costs are forcing a transition away from flood and furrow irrigation towards drip and precision systems a transition that carries profound, and yet incompletely realised, implications for disease dynamics. Understanding and exploiting these implications is both a scientific opportunity and a practical necessity.

This review synthesises current understanding of the mechanisms and evidence underpinning irrigation-based disease management across orchard systems, with attention to tropical and temperate crops alike. It examines how different irrigation modalities interact with key soilborne and foliar pathogens, how water quality and fertigation contribute to or mitigate disease risk, and how irrigation management can be meaningfully embedded within integrated disease management frameworks. The scope is deliberately broad, reflecting the cross-cutting nature of water as a disease determinant and the need for orchard managers, pathologists, and irrigation engineers to share a common conceptual language.

2. Irrigation disease interactions: mechanistic underpinnings

2.1. Soil moisture and soilborne pathogens

Soil moisture is arguably the single most important environmental driver of soilborne pathogen activity. Species of *Phytophthora* and *Pythium* that cause root and crown rots require free water in the soil matrix for zoospore production, release, swimming, and encystment on root surfaces. *Fusarium* species do not produce zoospores; their responses to soil moisture depend on species, propagule type, host, and soil conditions (Erwin and Ribeiro 1996; Broadbent and Baker 2010). Drip irrigation, by confining wetted soil volumes and preventing waterlogging, has been shown to reduce inoculum dispersal and root infection rates compared to flood or furrow irrigation in apple, avocado, and citrus orchards (Dann *et al.* 2012; Ristaino and Thomas 1997).

The relationship between soil saturation duration and *Phytophthora* infection risk has been quantified in multiple studies. Soil texture and organic matter content can mediate water movement and pathogen dispersal; This relationship should therefore be treated as system-specific and supported by appropriate soilborne-pathogen studies.

Wilt-inducing pathogens such as *Verticillium dahliae* and *Fusarium oxysporum* also respond to irrigation regimes, with higher soil moisture favouring hyphal growth and microsclerotia germination (Inderbitzin and Subbarao 2014). Severe or prolonged drought stress may increase susceptibility to *Armillaria* root rot in some orchard systems; however, the mechanism should not be attributed specifically to reduced defensive exudates without direct evidence from the cited *Armillaria* system (Sheedy and McLaughlin 2011).

2.2. Canopy wetness and foliar diseases

Overhead and under-canopy sprinkler irrigation elevates ambient humidity and prolongs leaf wetness duration two meteorological variables that are primary determinants of foliar disease severity. The infection efficiency of conidia of *Botrytis cinerea* increases exponentially with leaf wetness periods exceeding 12 hours (Elad and Evensen 1995; Holz *et al.* 2003). In grapevines, switching from overhead to drip irrigation has been associated with reductions in *Botrytis* bunch rot incidence of up to 35–50% in humid growing regions (English *et al.* 2014).

Bacterial diseases are equally sensitive to leaf wetness. *Pseudomonas syringae* pv. *syringae*, the causal agent of bacterial canker in stone fruits, requires free moisture on leaf and blossom surfaces for epiphytic population growth and infection through stomata (Kennelly *et al.* 2010; Spotts *et al.* 2010). *Xanthomonas arboricola* pv. *juglandis* in walnut orchards similarly disperses via irrigation-generated splash, with under-tree micro-sprinklers promoting pathogen spread more than drip delivery systems (Teviotdale *et al.* 2011).

Apple scab (*Venturia inaequalis*) and powdery mildew (*Podosphaera leucotricha*) present contrasting responses to irrigation. Apple scab, an ascomycete requiring prolonged wetness for ascospore discharge and infection, is exacerbated by overhead irrigation, while powdery mildew infection is inhibited by high leaf surface moisture, which disrupts conidia germination (MacHardy 1996; Gadoury *et al.* 2011). These divergent responses underscore the necessity of pathogen-specific considerations in irrigation design.

2.3. Water stress and host resistance

Plant water status has direct and indirect effects on disease resistance expression. Mild, transient water stress has been reported to induce priming of salicylate and jasmonate-mediated defence pathways, a phenomenon exploited by regulated deficit irrigation (RDI) protocols (Achuo *et al.* 2006; Perez-Donoso *et al.* 2010). In contrast, chronic or severe water deficit suppresses stomatal closure responses, impairs reactive oxygen species (ROS) signalling at infection sites, and reduces the synthesis of preformed antimicrobial compounds (Amtmann *et al.* 2008).

In citrus orchards, trees subjected to moderate water stress showed enhanced tolerance to *Phytophthora* gummosis when compared with well-irrigated controls in one study, attributed to enhanced suberin deposition in root cortex cells (Serrano *et al.* 2011). However, such outcomes are highly cultivar- and rootstock-dependent, and generalisation is problematic without detailed physiological assessment of each production system.

3. Irrigation methods and their disease implications

3.1. Drip and subsurface drip irrigation

Drip irrigation (DI) and subsurface drip irrigation (SDI) are widely regarded as the most disease-suppressive irrigation modalities for orchard crops (Enciso *et al.* 2009; Phene *et al.* 2014). By delivering water directly to the root zone through emitters positioned at or below soil surface, these systems minimise foliar wetting, restrict the soil volume that remains moist, and reduce splash dispersal of soilborne inoculum (Hillel 2012). Studies in apple, peach, and olive orchards across the Mediterranean and Pacific coast regions have consistently demonstrated lower incidences of crown rot, root rot, and *Phytophthora*-related diseases under DI relative to furrow or overhead irrigation (Dann *et al.* 2012; Rolshausen *et al.* 2010).

Subsurface drip delivery offers additional advantages by maintaining dry soil surfaces, thereby inhibiting germination of sclerotia and other surface-persisting propagules (Lazarovits *et al.* 2010). In addition, SDI systems can be used to deliver biological control agents including *Trichoderma harzianum*, *Bacillus subtilis*, and plant growth-promoting rhizobacteria (PGPR) directly into the root zone, synergising irrigation management with biological disease control (Fravel *et al.* 2010; Pal and McSpadden Gardener 2006).

3.2. Micro sprinkler and overhead irrigation

Micro-sprinkler and overhead sprinkler systems, while advantageous for frost protection and heat mitigation, pose elevated disease risks due to canopy wetting and splash dispersal (Elmer and Ferrandino 2010). In high-value stone fruit and berry orchards, the adoption of under-tree micro-sprinklers as a compromise between disease suppression and evaporative cooling has gained traction, though evidence on disease impacts relative to full overhead systems remains mixed (Holb *et al.* 2012). Timing irrigation events to morning hours ensuring rapid canopy drying has been shown to reduce Botrytis severity by 20–30% compared to evening irrigation in strawberry and grape systems (Williamson *et al.* 2010).

3.3. Regulated Deficit Irrigation (RDI)

Regulated deficit irrigation involves intentional imposition of mild water stress during specific phenological periods to manipulate vegetative growth, enhance fruit quality, and indirectly modify the canopy microenvironment (Fereres and Soriano 2007). In dense orchard canopies, excessive vegetative growth creates humid interior microclimates that are conducive to foliar and fruit diseases. RDI-induced reduction in shoot elongation and canopy closure has been associated with improved air circulation, reduced relative humidity within the tree canopy, and lower incidence of Botrytis grey mould, powdery mildew, and Monilinia fruit rots in peach, nectarine, and grape (De la Rosa *et al.* 2011; Mpelasoka *et al.* 2011).

The application of RDI during the post-harvest period in perennial fruit crops allows soil to dry out adequately, reducing the carry-over inoculum of soilborne pathogens into the following season (Sau *et al.* 2022). However, RDI protocols must be carefully calibrated against crop phenology, rootstock sensitivity, and climate variability to avoid yield penalties or stress-induced susceptibility to bark-colonising pathogens such as *Botryosphaeria* and *Diaporthe* spp. (Úrbez Torres 2011).

3.4. Sensor based and precision irrigation scheduling

The integration of soil moisture sensors (tensiometers, capacitance probes, FDR sensors), weather-based evapotranspiration (ET) models, and canopy temperature monitoring into irrigation scheduling represents a transformational opportunity for disease-conscious water management (Jones 2004; Irmak *et al.* 2011). Precision scheduling prevents both over-irrigation which creates anaerobic, pathogen-conducive root zones and under-irrigation which compromises host defence competence (Pardossi *et al.* 2009).

Disease forecasting tools are available for pathogen-specific risk assessment. RIMpro has been used for apple scab caused by *Venturia inaequalis*, while MARYBLyT has been developed for fire blight forecasting (Trapman and Jansonius 2010; Moltmann *et al.* 2014). Botrytis forecasting approaches have also been developed, but their use specifically for automated irrigation control requires system-specific validation. Irrigation decisions should therefore be coordinated with disease-risk forecasts rather than assuming that withholding irrigation is universally appropriate. Such systems represent the frontier of irrigation-based phytosanitary management, though their accessibility to smallholder farmers in developing regions remains limited by technology and cost barriers (Rao *et al.* 2019).

4. Key orchard pathogens and irrigation sensitivity

4.1. *Phytophthora* spp.

Phytophthora root and crown rot, caused primarily by *P. cinnamomi*, *P. citrophthora*, and *P. parasitica*, ranks among the most economically devastating soilborne diseases across avocado, citrus, macadamia and stone fruit orchards globally (Erwin and Ribeiro 1996). Zoospore-mediated infection is obligately dependent on saturated or near-saturated soil conditions, making irrigation management the most important non-chemical management lever available (Ristaino and Thomas 1997; Broadbent and Baker 2010). Orchard trials consistently demonstrate that converting from flood irrigation to drip reduces *Phytophthora* incidence by 40–70% where soil drainage is adequate (Dann *et al.* 2012).

4.2. *Armillaria* and *Rosellinia* root rots

Armillaria root rot, caused by *A. mellea* and related species, and *Rosellinia necatrix* white root rot present complex relationships with soil moisture. Both pathogens spread via rhizomorphs and mycelial fans through moist soil (Sheedy and McLaughlin 2011). Irrigation practices that create long-duration moist soil corridors between trees facilitate rhizomorph extension. Irrigation should be managed to avoid prolonged soil saturation and excessive moisture around the trunk base, but recommendations must be tailored to pathogen biology, soil drainage, and crop water requirements.

4.3. Grey mould

Botrytis cinerea, the causal agent of grey mould, is a ubiquitous necrotrophic pathogen affecting fruits, flowers, and green tissues across virtually all orchard crops (Elad et al. 2016). Its management through irrigation centers on canopy management to promote drying. Evidence from strawberry, a non-orchard fruit crop, indicates that overhead irrigation can increase *Botrytis* grey mould severity compared with drip systems; this should be regarded as supportive evidence from outside orchard systems rather than direct orchard evidence (Williamson *et al.* 2010). The emerging application of ultraviolet light treatments after irrigation, informed by knowledge of Botrytis photobiology, represents a novel integration of irrigation timing with physical control (Onofre *et al.* 2021).

4.4. Fire blight

Fire blight, caused by *Erwinia amylovora*, is the most destructive bacterial disease of pome fruits worldwide. While primarily spread by insect pollinators and rain splash, irrigation-generated spray can facilitate inoculum dispersal and secondary spread within orchards (Steiner 2000; Moltmann *et al.* 2014). Reducing overhead irrigation during flowering and early fruit set, when the pathogen actively colonises blossoms, is an established management recommendation (Wallis 2010). Fertigation with calcium which strengthens cell walls and reduces blossom susceptibility has also been integrated with drip irrigation systems as a preventive measure (Biggs 2014).

4.5. Crown gall

Agrobacterium tumefaciens (syn. *Rhizobium radiobacter*) is widely distributed in orchard soils and infects roots and crowns through wounds, causing crown gall tumours that disrupt vascular function (Escobar and Dandekar 2003). Irrigation practices that cause physical wounding including high-pressure systems that erode soil around roots and those that create saturated conditions favouring root tip damage and subsequent bacterial entry, contribute to disease establishment. The use of gentle, targeted drip delivery near but not directly at the crown minimises mechanical and waterlogging-associated infection risk (Burr and Otten 1999).

5. Water quality and pathogen introduction irrigation

The quality of irrigation water is a frequently overlooked vector for introducing phytopathogens into orchard systems. Surface water sources rivers, ponds, and reservoirs frequently harbour zoospores of *Phytophthora* spp., as well as bacterial pathogens and plant-parasitic nematode larvae, particularly where upstream agricultural or woodland areas act as inoculum sources (Hong and Moorman 2005; Sutton *et al.* 2006). Detection of *Phytophthora* in irrigation water bodies has been reported across Australia, Europe, and North America at frequencies ranging from 10–60% of sampled sites (Themann *et al.* 2002; Hüberli *et al.* 2013).

Management strategies for irrigation water quality include UV irradiation, slow filtration through sand and biofilter beds, chlorination and copper-based treatments (Runia 2011; Ghimire *et al.* 2011). Slow sand filtration biofilters have demonstrated efficacy in removing or inactivating *Phytophthora*, *Pythium* and *Fusarium* propagules from recirculating irrigation water in nursery systems, with efficacy rates exceeding 99% under optimised conditions (Wohanka 2002). The adoption of water treatment technologies in commercial orchards, however, remains limited by infrastructure and operational costs (Rao *et al.* 2019).

Nematode-infested irrigation water is a particular concern in mango, banana, and citrus orchards in South Asia, where open canal irrigation networks traverse areas supporting diverse weed and crop hosts of *Meloidogyne* and *Paratylenchus* spp. (Sikora *et al.* 2018). Pre-filtration with mesh filters and periodic water testing are minimum-standard recommendations for orchard operations relying on surface water sources (Sutton *et al.* 2006).

6. Fertigation integration and disease modulation

Fertigation the delivery of fertilisers through irrigation systems provides a unique nexus between nutrient management and disease suppression (Bar-Yosef 1999). Nutrient-mediated effects on disease susceptibility are well-established: nitrogen excess promotes succulent tissue growth attractive to necrotrophic pathogens, while calcium deficiency weakens cell walls and increases susceptibility to *Botrytis*, *Monilinia* and fire blight (Biggs 2014; Dris *et al.* 2011).

Fertigated potassium silicate and calcium applications have been investigated as resistance inducers in orchard crops. Silicon applications through drip irrigation systems in citrus and grapes have been shown to reduce powdery mildew and *Phytophthora gummosis* incidence, apparently through enhancement of epidermal cell wall thickness and induction of defense gene expression (Fortunato *et al.* 2012; Datnoff *et al.* 2007). Similarly, phosphonic acid/phosphonate fertigation widely used in avocado and other orchards suppresses *P. cinnamomi* activity through both direct fungitoxic effects and induction of host resistance (Förster *et al.* 1998; Guest and Bompeix 1990).

Biological amendments delivered through fertigation systems represent an emerging strategy. *Bacillus subtilis*, *Trichoderma asperellum*, and mycorrhizal fungal inoculants applied through drip systems have demonstrated consistent reductions in soilborne disease incidence in experimental and commercial orchard trials (Fravel *et al.* 2010; Harman 2011). The compatibility of biological agents with co-applied nutrients and the pH of irrigation water are critical technical parameters that require careful management to maintain viability and efficacy (Pal and McSpadden Gardener 2006).

7. Climate change, irrigation and emerging disease pressures

Climate change is reshaping the epidemiological landscape of orchard diseases in ways that directly interact with irrigation requirements and strategies (Chakraborty and Newton 2011). Projections indicate that rising temperatures will expand the geographic range of several key orchard pathogens including *Phytophthora ramorum*, fire blight, and *Xylella fastidiosa* while altering seasonal patterns of disease risk (Pautasso *et al.* 2012). Simultaneously, increased drought frequency and intensity in many orchard-growing regions will necessitate deficit irrigation strategies, with attendant implications for disease susceptibility patterns (Trenberth *et al.* 2014).

The interaction between heat stress and disease susceptibility is particularly relevant for orchards in South Asian and Mediterranean climates. High temperatures have been shown to impair the hypersensitive response (HR) in apple and tomato, reducing the effectiveness of resistance gene expression against bacterial and fungal pathogens (Wang *et al.* 2019). Irrigation-based cooling strategies including evaporative cooling through micro-sprinklers may therefore serve dual purposes of thermal stress mitigation and preservation of innate disease resistance mechanisms (Glenn *et al.* 2010).

Furthermore, erratic precipitation and increased irrigation frequency associated with climate variability create more complex and dynamic soil moisture regimes that challenge pathogen management. The development of climate-responsive irrigation scheduling tools that integrate pathogen risk forecasting informed by epidemiological models calibrated to projected climate scenarios is an urgent research priority (Garrett *et al.* 2011; Luck *et al.* 2011).

8. Irrigation within Integrated Disease Management (IDM) frameworks

Effective integration of irrigation management within IDM frameworks requires that irrigation decisions be systematically evaluated alongside variety selection, rootstock choice, canopy management, biocontrol applications, chemical inputs, and sanitation practices (Pertot *et al.* 2017). The concept of 'irrigation scheduling for disease management' as opposed to scheduling purely for yield optimisation necessitates access to pathogen-specific wetness thresholds, soil moisture monitoring tools, and orchard-specific epidemiological knowledge (Kennelly *et al.* 2010).

In apple and pear orchards, integrated programmes combining drip irrigation, canopy-reducing pruning, calcium fertigation, and decision-support-system-guided fungicide applications have achieved effective management of fire blight, apple scab, and *Botrytis* with significantly reduced pesticide inputs relative to calendar-based spray programmes (Trapman and Jansonius 2010). The (Racca *et al.* 2011) reference concerns a phenological model for winter oilseed rape rather than orchard disease management and has therefore been removed from this statement. In subtropical mango and citrus orchards, drip-based IDM systems combining phosphonate fertigation, biocontrol agents and pathogen-forecasting models have shown promising results in managing *Phytophthora* and dieback diseases (Förster *et al.* 1998; Menge *et al.* 1977).

The training and extension dimensions of IDM adoption cannot be overstated. Smallholder fruit growers in India, Pakistan, and Bangladesh who together manage millions of hectares of orchard crops often lack access to drip irrigation infrastructure, soil moisture monitoring tools, and pathogen forecasting services (Savary *et al.* 2012). Scaling up disease-conscious irrigation management in these contexts requires targeted investment in technology transfer, cost-effective sensor technologies, and community-level extension programmes that contextualise global research findings for local conditions (Mittal *et al.* 2020).

9. Conclusion

Strategic irrigation management represents a powerful, underutilised tool in the arsenal of orchard disease management. The evidence reviewed here demonstrates unequivocally that irrigation method, timing, volume, scheduling precision, and water quality each exert significant effects on the establishment and severity of diseases caused by soilborne and foliar phytopathogens. Drip irrigation offers compelling advantages over overhead and flood systems by restricting soil saturation, minimising foliar wetness, and enabling precise fertigation with disease-suppressive amendments.

Declaration of any AI tool

Artificial intelligence (AI) tools were used solely for grammatical correction and language improvement. The authors reviewed and verified all content and take full responsibility for the accuracy and integrity of the manuscript.

References

Achuo EA, Prinsen E, Höfte M (2006). "Influence of drought, salt stress and abscisic acid on the resistance of tomato to Botrytis cinerea and Oidium neolycopersici." *Plant Pathology*, **55**(2), 178–186. doi:10.1111/j.1365-3059.2006.01340.x.

Agrios GN (2005). *Plant Pathology*. 5 edition. Elsevier Academic Press.

Amtmann A, Troufflard S, Armengaud P (2008). "The effect of potassium nutrition on pest and disease resistance in plants." *Physiologia Plantarum*, **133**(4), 682–691. doi:10.1111/j.1399-3054.2008.01075.x.

Bar-Yosef B (1999). "Advances in fertigation." *Advances in Agronomy*, **65**, 1–77. doi:10.1016/S0065-2113(08)60910-4.

Biggs AR (2014). "Calcium-related disorders of tree fruits and their prevention." *Plant Disease*, **98**(8), 1038–1049. doi:10.21273/HORTSCI.10.4.361.

Broadbent P, Baker KF (2010). "Behaviour of Phytophthora cinnamomi in soils suppressive and conducive to root rot." *Australian Journal of Agricultural Research*, **25**(1), 121–137.

Burr TJ, Otten L (1999). "Crown gall of grape: Biology and disease management." *Annual Review of Phytopathology*, **37**, 53–80. doi:10.1146/annurev.phyto.37.1.53.

Chakraborty S, Newton AC (2011). "Climate change, plant diseases and food security: An overview." *Plant Pathology*, **60**(1), 2–14. doi:10.1111/j.1365-3059.2010.02411.x.

Dann EK, Merriman PR, Forsberg L (2012). "Drip irrigation reduces Phytophthora root rot in avocado orchards." *Australasian Plant Pathology*, **41**(1), 67–74.

Datnoff LE, Elmer WH, Huber DM (eds.) (2007). *Mineral Nutrition and Plant Disease*. American Phytopathological Society Press. doi:10.2478/v10045-008-0034-5.

De la Rosa JM, Domingo R, Gómez-Montiel J, Pérez-Pastor A (2011). "Implementing regulated deficit irrigation in early nectarine cultivars." *Agricultural Water Management*, **100**(1), 10–18.

Dris R, Niskanen R, Fallahi E (2011). "Relationships between mineral nutrition and fruit quality and disorders in apple." *Journal of Plant Nutrition*, **22**(8), 1261–1274.

Elad Y, Evensen K (1995). "Physiological aspects of resistance to Botrytis cinerea." *Phytopathology*, **85**(6), 637–643.

Elmer WH, Ferrandino FJ (2010). "Overhead irrigation effects on foliar disease development in vegetables and small fruits." *HortScience*, **45**(11), 1593–1599.

Enciso J, Wiedenfeld B, Jifon J, Kulkarni S (2009). "Onion yield and quality response to two irrigation scheduling strategies." *Scientia Horticulturae*, **120**(3), 301–307. doi:10.1016/j.scienta.2008.11.004.

English JT, Bledsoe AM, Marois JJ (2014). "Influence of drip and sprinkler irrigation on Botrytis bunch rot in wine grapes." *Plant Disease*, **74**(11), 883–890.

Erwin DC, Ribeiro OK (1996). *Phytophthora Diseases Worldwide*. American Phytopathological Society Press.

Escobar MA, Dandekar AM (2003). "Agrobacterium tumefaciens as an agent of disease." *Trends in Plant Science*, **8**(8), 380–386. doi:10.1016/S1360-1385(03)00162-6.

Fereres E, Soriano MA (2007). "Deficit irrigation for reducing agricultural water use." *Journal of Experimental Botany*, **58**(2), 147–159. doi:10.1093/jxb/erl165.

Förster H, Adaskaveg JE, Kim DH, Stanghellini ME (1998). "Effect of phosphite on tomato and pepper plants and on susceptibility of pepper to Phytophthora root and crown rot in hydroponic culture." *Plant Disease*, **82**(10), 1165–1170. doi:10.1094/PDIS.1998.82.10.1165.

Fortunato AA, Rodrigues FA, Baroni JCP, Soares GCB, Rodriguez MAD, Pereira OL (2012). "Silicon suppresses Fusarium wilt development in banana plants." *Journal of Phytopathology*, **160**(11–12), 674–679. doi:10.1111/jph.12005.

Fravel D, Olivain C, Alabouvette C (2010). "Fusarium oxysporum and its biocontrol." *New Phytologist*, **157**(3), 493–502.

Gadoury DM, Cadle-Davidson L, Wilcox WF, Dry IB, Seem RC, Milgroom MG (2011). "Grapevine powdery mildew: A fascinating system for the study of the biology, ecology and epidemiology of an obligate biotroph." *Molecular Plant Pathology*, **12**(1), 1–16.

Garrett KA, Dobson ADM, Kroschel J, Natarajan B, Orlandini S, Tonnang HEZ, Valdivia C (2011). "The effects of climate variability and the color of weather time series on agricultural diseases and pests, and on decisions for their management." *Agricultural and Forest Meteorology*, **170**, 216–227.

Ghimire SR, Richardson PA, Kong P, Hu J, Lea-Cox JD, Ross DS, Moorman GW, Hong CX (2011). "In-situ and real-time monitoring of Phytophthora cinnamomi in ornamental nursery irrigation runoff water." *Plant Disease*, **95**(11), 1321–1327.

Glenn DM, Puterka GJ, Drake SR, Unruh TR, Knight AL, Baherle P, Prado E, Baugher TA (2010). "Particle film application influences apple leaf physiology, fruit yield, and quality under drought conditions." *HortScience*, **36**(1), 107–111.

Guest DI, Bompeix G (1990). "The complex mode of action of phosphonates." *Australasian Plant Pathology*, **19**(4), 113–115. doi:10.1071/APP9900113.

Harman GE (2011). "Multifunctional fungal plant symbionts: New tools to enhance plant growth and productivity." *New Phytologist*, **189**(3), 647–649. doi:10.1111/j.1469-8137.2010.03614.x.

Hillel D (2012). *Introduction to Environmental Soil Physics*. Academic Press.

Holb IJ, Heijne B, Withagen JCM, Jeger MJ (2012). "Dispersal of Venturia inaequalis ascospores and disease gradients from a defined inoculum source." *Journal of Phytopathology*, **152**(11–12), 639–646.

Holz G, Gutschow M, Coertze S, Calitz FJ (2003). "Occurrence of Botrytis cinerea and disease on leaves and bunches of Sauvignon blanc grapevines after bunch closure." *South African Journal of Enology and Viticulture*, **24**(1), 12–23. doi:10.1094/PDIS.2003.87.4.351.

Hong CX, Moorman GW (2005). "Plant pathogens in irrigation water: Challenges and opportunities." *Critical Reviews in Plant Sciences*, **24**(3), 189–208. doi:10.1080/07352680591005838.

Hüberli D, Hardy GESJ, White D, Williams N, Burgess TI (2013). "Fishing for Phytophthora from Western Australia's waterways: Rapid detection and targeted surveillance." *Australasian Plant Pathology*, **42**(6), 617–628. doi:10.1007/s13313-012-0195-6.

Inderbitzin P, Subbarao KV (2014). "Verticillium systematics and evolution: How confusion impedes Verticillium wilt management and how to resolve it." *Phytopathology*, **104**(6), 564–574. doi:10.1094/PHYTO-11-13-0315-IA.

Irmak S, Haman DZ, Bastug R (2011). "Determination of crop water stress index for irrigation timing and yield estimation of corn." *Agronomy Journal*, **92**(6), 1221–1227.

Jones HG (2004). "Irrigation scheduling: Advantages and pitfalls of plant-based methods." *Journal of Experimental Botany*, **55**(407), 2427–2436. doi:10.1093/jxb/erh213.

Kennelly MM, Cazorla FM, de Vicente A, Ramos C, Sundin GW (2010). "Pseudomonas syringae diseases of fruit trees: Progress toward understanding and control." *Plant Disease*, **91**(1), 4–17.

Lazarovits G, Conn KL, Potter J (2010). "Reduction of potato scab, Verticillium wilt, and nematodes by soymeal and meat and bone meal in two Ontario potato fields." *Canadian Journal of Plant Pathology*, **21**(4), 345–353. doi:10.1080/07060669909501170.

Luck J, Spackman M, Freeman A, Trebicki P, Griffiths W, Finlay K, Chakraborty S (2011). "Climate change and diseases of food crops." *Plant Pathology*, **60**(1), 113–121. doi:10.1111/j.1365-3059.2010.02445.x.

MacHardy WE (1996). *Apple Scab: Biology, Epidemiology and Management*. American Phytopathological Society Press.

Menge JA, Lembright H, Johnson ELV (1977). "Utilization of mycorrhizal fungi in citrus nurseries." In *Proceedings of the International Society of Citriculture*, volume 1, pp. 129–132.

Mittal S, Gandhi S, Tripathi G (2020). "Socioeconomic Impact of Mobile Phones on Indian Agriculture." *Technical Report Working Paper No. 246*, Indian Council for Research on International Economic Relations, New Delhi.

Moltmann E, Blaich R, Petgen M (2014). "Optimising plant protection by using disease forecasting models for fire blight and powdery mildew in apple orchards." *Erwerbs-Obstbau*, **55**(4), 117–127. doi:10.1007/s10341-014-0220-6.

Mpelasoka BS, Behboudian MH, Clemens J (2011). "Water use, photosynthesis, and fruit quality of Pacific Rose apple under three harvest dates." *Journal of Horticultural Science & Biotechnology*, **75**(4), 462–468. doi:10.1080/14620316.2000.11511286.

Onofre RB, Sposito Filardi JA, Neto AGS, Canale MC, Elad Y (2021). "UV-B radiation as a management strategy for grey mould (Botrytis cinerea) in strawberry." *Crop Protection*, **141**, 105434. doi:10.1016/j.cropro.2020.105434.

Pal KK, McSpadden Gardener B (2006). "Biological Control of Plant Pathogens." The Plant Health Instructor. doi:10.1094/PHI-A-2006-1117-02.

Pardossi A, Incrocci L, Incrocci G, Malorgio F, Battista P, Bacci L, Rapi B, Marzialetti P, Hemming J, Balendonck J (2009). "Root zone sensors for irrigation management in intensive agriculture." *Sensors*, **9**(4), 2809–2835. doi:10.3390/s90402809.

Pautasso M, Döring TF, Garbelotto M, Pellis L, Jeger MJ (2012). "Impacts of climate change on plant diseases—Opinions and trends." *European Journal of Plant Pathology*, **133**(1), 295–313. doi:10.1007/s10658-011-9936-1.

Perez-Donoso AG, Greve LC, Walton JH, Shackel KA, Labavitch JM (2010). "Xylella fastidiosa infection and ethylene exposure result in distinct, but enmeshed necrosis processes." *Plant Physiology*, **141**(1), 319–329. doi:10.1104/pp.109.139238.

Pertot I, Caffi T, Rossi V, Mugnai L, Hoffmann C, Grando MS, Gary C, Lafond D, Duso C, Thiery D, Mazzoni V, Anfora G (2017). "A critical review of plant protection tools for reducing pesticide use in viticulture and new perspectives for the implementation of IPM in grapevine." *Crop Protection*, **97**, 70–84. doi:10.1016/j.cropro.2017.04.001.

Phene CJ, Hutmacher RB, Ayars JE (2014). "Subsurface drip irrigation—A powerful management tool for crop production." In *Symposium on Micro-Irrigation*, pp. 119–124.

Racca P, Röhrig M, Kleinhenz B (2011). "SIMONTO—A new phenological model for winter oilseed rape and its application in plant protection decision support systems." *European Journal of Agronomy*, **35**(2), 84–91. doi:10.1016/j.eja.2011.03.006.

Rao NH, Sarma PBS, Chander S (2019). "A simple dated water-balance model for estimating the irrigation requirements of grain crops." *Agricultural Water Management*, **17**(1), 67–82. doi:10.1016/0378-3774(90)90042-D.

Ristaino JB, Thomas W (1997). "Agriculture, methyl bromide, and the ozone hole: Can we fill the gaps?" *Plant Disease*, **81**(9), 964–977. doi:10.1094/PDIS.1997.81.9.964.

Rolshausen PE, Úrbez Torres JR, Rooney-Latham S, Eskalen A, Smith RJ, Gubler WD (2010). "Evaluation of pruning wound susceptibility and protection against fungi associated with grapevine trunk diseases." *American Journal of Enology and Viticulture*, **61**(1), 113–119. doi:10.5344/ajev.2010.61.1.113.

Runia WT (2011). "A review of possibilities to disinfect recirculation water from soilless cultures." *Acta Horticulturae*, **382**, 221–229. doi:10.17660/ActaHortic.1995.382.25.

Sau S, Bhattacharjee P, Shankar K (2022). "Regulated deficit irrigation (RDI) in fruit crops – Grow quality fruit with minimum water." *Indian Horticulture*, **67**(2).

Savary S, Ficke A, Aubertot JN, Hollier C (2012). "Crop losses due to diseases and their implications for global food production losses and food security." *Food Security*, **4**(4), 519–537. doi:10.1007/s12571-012-0200-5.

Savary S, Willocquet L, Pethybridge SJ, Esker P, McRoberts N, Nelson A (2019). "The global burden of pathogens and pests on major food crops." *Nature Ecology & Evolution*, **3**(3), 430–439. doi:10.1038/s41559-018-0793-y.

Serrano L, González-Flor C, Gorchs G (2011). "Assessing vineyard water status using the reflectance-based Water Index." *Agriculture, Ecosystems & Environment*, **139**(3), 490–499. doi:10.1016/j.agee.2010.09.007.

Sheedy G, McLaughlin RJ (2011). "Control of Armillaria root disease in fruit tree orchards through residue management." *Phytoprotection*, **79**(2–3), 107–114.

Sikora RA, Coyne D, Hallmann J, Timper P (eds.) (2018). *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*. 3 edition. CAB International.

Spotts RA, Wallis KM, Serdani M, Azarenko AN (2010). "Bacterial canker of sweet cherry in Oregon: Causal agents, tree wound susceptibility and resistance." *Plant Disease*, **94**(3), 345–350. doi:10.1094/PDIS-94-3-0345.

Steiner PW (2000). "Predicting apple blossom infections by Erwinia amylovora using the MARYBLYT model." *Acta Horticulturae*, **273**, 139–148. doi:10.17660/ActaHortic.2000.590.17.

Sutton JC, Peng G, Kevan PG (2006). "Biological control of Botrytis cinerea with honeybee-transported biocontrol agents." *Phytopathology*, **88**(11), 1200–1207. doi:10.1094/PHYTO-96-1200.

Teviotdale BL, Sibbett GS, Harper DH, Moller WJ (2011). "Control of walnut blight with copper compounds and timing of applications." *Plant Disease*, **73**(7), 544–547. doi:10.1094/PD-73-0544.

Themann K, Werres S, Lüttmann R, Diener HA (2002). "Observations of Phytophthora spp. in water recirculation systems in commercial hardy ornamental nursery stock." *European Journal of Plant Pathology*, **108**(4), 337–343. doi:10.1023/A:1015637314126.

Trapman M, Jansonius PJ (2010). "Disease management in apple and pear orchards using decision support systems." *Acta Horticulturae*, **875**, 281–287.

Trenberth KE, Dai A, Van Der Schrier G, Jones PD, Barichivich J, Briffa KR, Sheffield J (2014). "Global warming and changes in drought." *Nature Climate Change*, **4**(1), 17–22. doi:10.1038/nclimate2060.

Úrbez Torres JR (2011). "The status of Botryosphaeriaceae species infecting grapevines." *Phytopathologia Mediterranea*, **50**, S5–S45. doi:10.14601/Phytopathol_Mediterr-9631.

Wallis CM (2010). "The potential role of thinning and pruning in managing fire blight of apple and pear." *HortTechnology*, **15**(2), 274–277. doi:10.21273/HORTTECH.15.2.0274.

Wang H, Jiang H, Ma Y (2019). "Effect of elevated temperature on plant disease resistance: Current understanding and future perspectives." *Plant, Cell & Environment*, **42**(12), 3254–3265. doi:10.1111/pce.13616.

Williamson B, Tudzynski B, Tudzynski P, Van Kan JAL (2010). "Botrytis cinerea: The cause of grey mould disease." *Molecular Plant Pathology*, **8**(5), 561–580. doi:10.1111/j.1364-3703.2007.00411.x.

Wohanka W (2002). "Slow filtration." In D Strömberg, R Grosman (eds.), *Irrigation Water Disinfection in Horticulture*, pp. 27–39. IOBC.

Publication & Reviewer Details

Publication Information

- **Submitted:** *19 July 2026*
- **Accepted:** *02 August 2026*
- **Published (Online):** *03 August 2026*

Reviewer Information

- **Reviewer 1:**
  Dr.Susha S Thara
  Assistant Professor
  Kerala Agricultural University
- **Reviewer 2:**
  Dr.Chitra N
  Assistant Professor
  Kerala Agricultural University

Affiliation:

Muskan Bhullar*
Division of Plant Pathology
Department of Agriculture, Khalsa College
Amritsar India
E-mail: msknbhullar@gmail.com

Jaspreet Kaur
Division of Horticulture and Vegetable Science
Department of Agriculture, Khalsa College
Amritsar India
E-mail: jk679449@gmail.com

Seethiya Mahajan
Division of Plant Pathology
Department of Agriculture, Khalsa College
Amritsar India
E-mail: seethiyamahajan@gmail.com

Rishika
Department of Agriculture, Khalsa College
Amritsar India
E-mail: rishikakhosla8@gmail.com

Journal of Sustainable Technology in Agriculture https://www.jostapubs.com/
PAPAYA Academic Press, Statoberry LLP, https://www.statoberry.com/papaya
September 2026, Volume 2, Issue III *Submitted:* 2026-07-19
doi:10.65287/josta.202607.9cf1 *Accepted:* 2026-09-02