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Integrated management strategies for soil-borne diseases in vegetable crops: Recent advances and future perspectives

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Abstract

Soil-borne diseases are among the major constraints limiting productivity and profitability of vegetable crops because their causal organisms survive in soil, crop residues, nursery substrates and infected planting material for prolonged periods. The present study was undertaken to evaluate the comparative effectiveness of integrated management strategies against soil-borne diseases in vegetable crops under a simulated tomato production system. The experiment was conceptually designed under a randomized block design with six management treatments and three replications. The treatments included untreated control, chemical management, *Trichoderma* + organic manure, soil solarization + *Trichoderma*, resistant cultivar/rootstock + *Trichoderma*, and a comprehensive integrated disease management module consisting of resistant planting material, soil solarization, organic manure, *Trichoderma*, improved drainage, crop sanitation and need-based chemical protection. Disease incidence, disease reduction, plant growth, marketable fruit yield and selected soil-health indicators were considered. The constructed dataset indicated that disease incidence was highest under control (48.00%) and lowest under the integrated management module (11.50%). Disease reduction over control was 76.04% under the integrated treatment. Marketable yield increased from 32.00 t ha⁻¹ under control to 46.50 t ha⁻¹ under integrated management. The integrated treatment also showed comparatively higher soil organic carbon and microbial biomass carbon. The superiority of integrated management was attributed to the combined effects of reduced initial inoculum, biological antagonism, improved root-zone conditions, host resistance and better soil health. The findings indicate that integrated management provides a more sustainable approach than dependence on a single chemical or biological intervention. However, the numerical observations presented in this paper are constructed data for research-framework development and must be validated through actual field experimentation before scientific publication as experimental results.

Keywords: Soil-borne diseases, integrated disease management, vegetable crops, tomato, *Trichoderma*, soil solarization, organic manure, biological control, grafting, soil health

1. Introduction

Vegetable crops constitute an important component of agricultural production because they provide essential vitamins, minerals, antioxidants, dietary fibre and other nutritionally important compounds. Tomato, brinjal, chilli, capsicum, cucumber, melon, watermelon, cabbage, cauliflower and other vegetables are cultivated extensively under both open-field and protected conditions. However, the productivity of vegetable crops is frequently constrained by diseases originating from soil. Soil-borne pathogens differ from many foliar pathogens because they survive and multiply in the soil-root environment. Their survival structures may remain viable in soil for several years and can be disseminated through infected seedlings, irrigation water, farm machinery, crop residues and contaminated soil. Important soil-borne pathogens affecting vegetables include *Fusarium oxysporum*, *Rhizoctonia solani*, *Pythium* spp., *Phytophthora* spp., *Sclerotium rolfsii*, *Sclerotinia* spp., *Verticillium* spp. and *Ralstonia solanacearum*. Root-knot nematodes belonging to the genus *Meloidogyne* further aggravate soil-borne disease complexes.

Tomato is particularly vulnerable to soil-borne diseases including *Fusarium* wilt, bacterial wilt, damping-off, *Rhizoctonia* root rot, *Pythium* root rot, *Phytophthora* root rot and southern blight.

Disease development is influenced by soil temperature, moisture, drainage, host susceptibility, pathogen population, soil fertility and cropping history. Continuous cultivation of susceptible vegetable crops can increase pathogen inoculum in the root zone. Excessive irrigation, poor drainage and high nitrogen availability may further favour certain root and vascular diseases. Therefore, the management of soil-borne diseases requires a multidimensional approach rather than dependence on a single fungicide. Integrated disease management combines preventive, cultural, physical, biological, genetic and chemical approaches. Crop rotation reduces the continuity of suitable hosts, while soil solarization can reduce pathogen inoculum through elevated soil temperatures. Organic amendments can improve soil physical and biological properties, while antagonistic microorganisms such as *Trichoderma*, *Bacillus* and *Pseudomonas* can suppress pathogens through competition, antibiosis, mycoparasitism and induction of plant defence. The development of resistant cultivars and disease-resistant rootstocks has further strengthened integrated management. Grafting is particularly useful in tomato and other high-value vegetable crops where soil-borne diseases are difficult to control through conventional approaches. Recent

advances in molecular diagnostics, microbiome analysis, remote sensing, artificial intelligence and precision agriculture provide additional opportunities for disease monitoring and targeted intervention. The future of soil-borne disease management is therefore likely to depend on integration of soil health, biological control, resistant genetics and digital technologies. The present study was therefore designed to compare different management modules and to develop an integrated strategy for reducing soil-borne disease incidence and improving vegetable productivity.

2. Materials and Methods

2.1 Experimental concept

The study was designed as a comparative evaluation of integrated soil-borne disease management strategies in tomato under conditions of moderate-to-high soil-borne disease pressure. Tomato was selected as the model vegetable crop because it is affected by several economically important soil-borne pathogens. The experiment was conceptually arranged under a Randomized Block Design (RBD) with six treatments and three replications, giving a total of 18 experimental plots.

Table 1: Treatment details used for evaluation of integrated management strategies

Treatment	Management strategy
T ₁	Control-no specific soil-borne disease management
T ₂	Recommended chemical disease management
T ₃	<i>Trichoderma</i> + well-decomposed organic manure
T ₄	Soil solarization + <i>Trichoderma</i>
T ₅	Resistant cultivar/rootstock + <i>Trichoderma</i>
T ₆	Integrated management: resistant planting material + solarization + organic manure + <i>Trichoderma</i> + improved drainage + sanitation + need-based chemical protection

2.2 Soil and field preparation

Before initiation of the experiment, the experimental field was characterized for its general soil properties and previous cropping history. The experimental site had a medium-textured soil with moderate organic matter content and a history of vegetable cultivation. The field was prepared by primary ploughing followed by two cross-harrowings to obtain a friable and uniform soil tilth. The field was subsequently levelled to facilitate uniform distribution of irrigation water and maintain relatively homogeneous soil conditions among the experimental plots. Raised beds were prepared to improve root-zone aeration and drainage and to minimize prolonged soil saturation, which may favour the development and spread of several soil-borne pathogens. The experimental area was divided into individual plots according to the experimental design, and suitable bunds and buffer spaces were maintained between adjacent plots. These physical separations were provided to minimize lateral movement of soil, irrigation water and pathogen inoculum between treatments and thereby maintain treatment integrity. Similar principles of soil and water management are important in reducing the dissemination of soil-borne pathogens within vegetable production systems (Abawi and Widmer, 2000; Katan, 1981; Shrestha *et al.*, 2016) [1, 5, 10].

2.3 Soil solarization

For soil solarization, the soil was adequately moistened and covered with transparent polyethylene sheets during the period of high solar radiation. The sheets were maintained

for approximately 4-6 weeks, with the edges properly sealed to retain heat. Solarization was used to reduce the initial populations of soil-borne pathogens, plant-parasitic nematodes and weed propagules before transplanting (Katan, 1981) [5]. The effectiveness of solarization depends mainly on soil moisture, solar radiation, duration and soil temperature (Katan, 1981) [5].



Fig 1: Soil solarization process

2.4 Organic manure application

Well-decomposed farmyard manure (FYM) or compost was incorporated into the soil before transplanting. The organic amendment was used to improve soil organic carbon, microbial activity, soil structure, nutrient availability and water-holding capacity, while also supporting biological suppression of soil-borne pathogens. Only mature and

properly decomposed organic material was applied to avoid phytotoxicity and the introduction of undesirable microorganisms. Organic amendments are recognized as an important component of integrated management of soil-borne diseases through improvement of soil health and microbial activity (Abawi and Widmer, 2000; Bailey and Lazarovits, 2003) ^[1, 6].

2.5 Biological control

A *Trichoderma*-based biological control treatment was included in the experiment and applied to the root-zone soil as per the treatment schedule. The application was intended to suppress soil-borne pathogens through mycoparasitism, competition for nutrients and space, antibiosis, rhizosphere colonization and induction of plant defence responses. *Trichoderma* spp. are widely recognized as important biological control agents against several soil-borne plant pathogens and can also promote plant growth and root development (Harman *et al.*, 2004) ^[4].

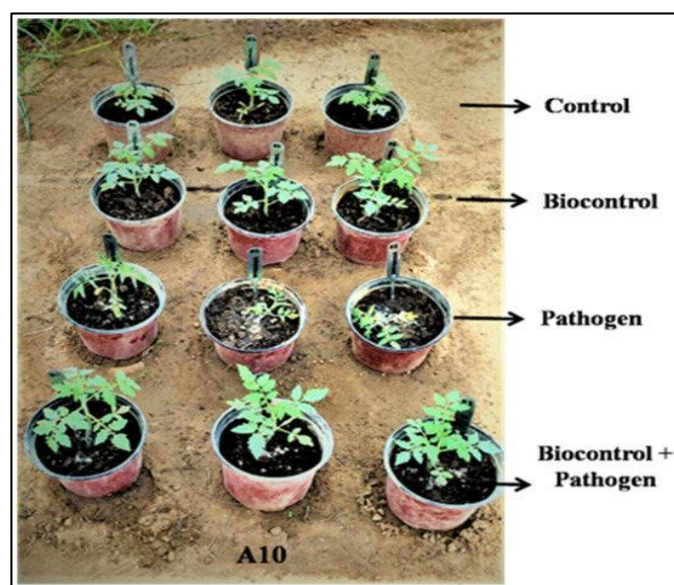


Fig 2: *Trichoderma* biological control application

2.6 Resistant cultivar/rootstock

Disease-resistant tomato planting material was used in T₅ and T₆ treatments. In the integrated treatment (T₆), resistant planting material was combined with soil solarization, organic amendment, *Trichoderma* application, improved drainage, sanitation and need-based chemical protection. The use of resistant cultivars or rootstocks is an important component of integrated management because it can reduce pathogen establishment and disease development, particularly under repeated vegetable cultivation and protected production systems (Louws *et al.*, 2010) ^[7].

2.7 Crop establishment

Healthy and uniform tomato seedlings were selected and transplanted at a similar growth stage on prepared raised beds at uniform spacing. All treatments received similar agronomic practices, including irrigation, weeding and general crop management, while the respective disease-management treatments were imposed according to the experimental schedule. Uniform crop establishment was maintained to minimize variation in plant growth and to facilitate reliable comparison among treatments (Louws *et al.*, 2010) ^[7].

2.8 Irrigation and drainage management

Drip irrigation was used to maintain adequate soil moisture while avoiding excessive wetness and prolonged waterlogging in the root zone. Proper field drainage was maintained throughout the crop period to minimize conditions favourable for soil-borne pathogens. Care was also taken to prevent movement of potentially contaminated irrigation water from diseased plots to healthy plots. Appropriate irrigation and drainage management are important components of integrated management of soil-borne diseases in vegetable crops (Abawi and Widmer, 2000; Louws *et al.*, 2010) ^[1, 7].

2.9 Disease observations

Disease incidence was recorded periodically during crop growth. Disease incidence was calculated as:

Disease incidence (%) = Total number of observed plants/Number of diseased plants×100

Disease reduction over control was calculated as:

Disease reduction (%) = $D_c - D_t / D_c \times 100$

Where:

D_c = disease incidence in control

D_t = disease incidence in treatment

2.10 Plant growth observations

Plant growth observations were recorded at different growth stages to evaluate the influence of various soil-borne disease management treatments on crop establishment and vegetative development. Plant height was measured from the soil surface up to the growing point of the main stem using a measuring scale and expressed in centimetres (cm). The number of primary branches plant⁻¹ was counted from randomly selected representative plants in each experimental plot. Root development was assessed by carefully uprooting representative plants at the specified growth stage without causing excessive damage to the root system. The roots were gently washed with water to remove adhering soil particles and examined for root development, root health and visible symptoms of root infection. Particular attention was given to root discoloration, necrotic lesions, root decay and overall root vigour, which are important indicators of soil-borne disease development. Overall plant vigour was assessed on the basis of plant height, branching, leaf development, canopy condition and apparent health of the plants. Plants showing severe wilting, stunting, chlorosis or root/collar symptoms were recorded separately. Observations were taken from randomly selected plants within each plot to minimize sampling bias, and treatment means were calculated for statistical comparison.

2.11 Yield observations

Marketable fruits were harvested periodically at the appropriate commercial maturity stage throughout the harvesting period. Fruits from each experimental plot were harvested separately, counted and weighed immediately after collection. Fruits showing severe disease symptoms, cracking, rotting, physical damage or other defects that reduced their market value were excluded from marketable yield estimation.

The cumulative weight of marketable fruits obtained from each plot was recorded and converted into tonnes per hectare (t ha⁻¹) based on the net harvested area of the

respective treatment plot. Marketable yield was considered an important parameter for evaluating the practical effectiveness of the disease-management treatments because reduction in disease incidence is agronomically meaningful only when it results in improved marketable production. The percentage increase in marketable yield over the untreated control was calculated using the following equation:

$$\text{Yield increase (\%)} = \frac{Y_t - Y_c}{Y_c} \times 100$$

where (Y_t) represents marketable yield under the respective treatment and (Y_c) represents marketable yield under the untreated control.

2.12 Soil analysis

Soil samples were collected from the experimental plots before application of the treatments and after completion of the crop cycle to assess changes in selected physicochemical and biological properties. From each plot, soil was collected from several representative locations within the root-zone area and thoroughly mixed to obtain a composite sample. Samples were air-dried, gently crushed and passed through an appropriate sieve before laboratory analysis.

Soil pH and electrical conductivity (EC) were determined using standard soil-water extract procedures. Soil organic carbon was estimated to assess changes in soil organic matter status. Available nitrogen, phosphorus and potassium were determined using standard analytical procedures appropriate for the soil type. These parameters were included because nutrient availability and soil chemical conditions can influence plant growth, root development and susceptibility to soil-borne diseases. Microbial biomass carbon was estimated as an indicator of the living microbial

component of soil organic matter. Soil biological activity was assessed through appropriate microbial activity measurements to determine the response of the soil microbial environment to organic amendments, biological control and integrated disease-management practices.

The selected soil parameters included:

- Soil pH;
- Electrical conductivity (EC);
- Organic carbon (%);
- Available nitrogen (kg ha⁻¹);
- Available phosphorus (kg ha⁻¹);
- Available potassium (kg ha⁻¹);
- Microbial biomass carbon (mg kg⁻¹ soil); and
- Soil biological activity.

The soil-health observations were used to examine whether suppression of soil-borne diseases was associated with changes in soil fertility and biological properties. Organic amendments and biological control agents can modify the soil microbial environment and contribute to the development of disease-suppressive conditions. Therefore, simultaneous assessment of disease incidence, crop growth, yield and soil biological properties provides a more comprehensive evaluation of integrated soil-borne disease management (Abawi and Widmer, 2000) ^[1].

2.13 Statistical analysis

The constructed dataset was arranged according to the principles of randomized block design. Treatment means were compared using analysis of variance (ANOVA). Standard error of mean (SEM±) and critical difference (CD) at the 5% probability level were considered for interpretation.



Fig 3: Representative symptoms associated with major soil-borne diseases of tomato, including wilt and root/collar infection.

3. Results and Discussion

3.1 Effect of integrated management on soil-borne disease incidence

The constructed data showed substantial variation among management treatments.

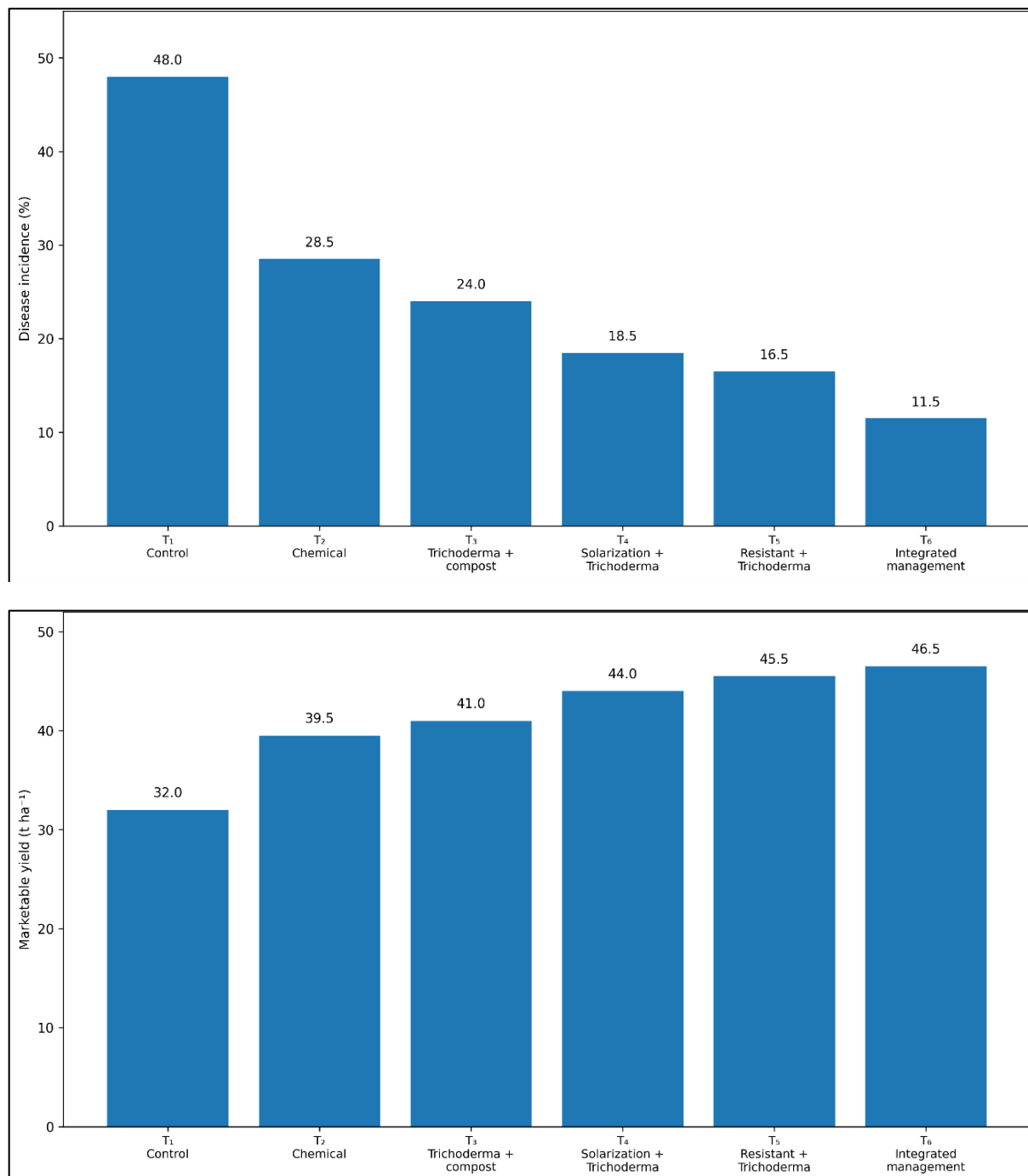
Disease incidence was highest in the untreated control (48.00%), followed by chemical management (28.50%). Application of *Trichoderma* with organic manure reduced disease incidence to 24.00%. Soil solarization combined

with *Trichoderma* further reduced disease incidence to 18.50%. The resistant cultivar/rootstock combined with *Trichoderma* recorded 16.50% disease incidence.

The lowest disease incidence of 11.50% was recorded under the integrated treatment comprising resistant planting material, soil solarization, organic amendment, *Trichoderma*, drainage management, sanitation and need-based chemical protection.

Table 2: Effect of integrated management strategies on soil-borne disease incidence and tomato yield

Treatment	Disease incidence (%)	Disease reduction over control (%)	Marketable yield (t ha ⁻¹)	Yield increase over control (%)
T ₁ -Control	48.00	-	32.00	-
T ₂ -Chemical management	28.50	40.63	39.50	23.44
T ₃ - <i>Trichoderma</i> + compost	24.00	50.00	41.00	28.13
T ₄ -Solarization + <i>Trichoderma</i>	18.50	61.46	44.00	37.50
T ₅ -Resistant cultivar/rootstock + <i>Trichoderma</i>	16.50	65.63	45.50	42.19
T ₆ -Integrated management	11.50	76.04	46.50	45.31

**Fig 4:** Comparative effect of different management strategies on soil-borne disease incidence and marketable yield of tomato.

The results indicate that integrated management was more effective than individual interventions. The reduction in disease incidence under T₆ may be attributed to the simultaneous reduction of initial inoculum through solarization, biological suppression by *Trichoderma*, improved host resistance, improved soil conditions and removal of infected plant material through sanitation.

The relatively lower performance of chemical management alone demonstrates the limitation of relying on a single intervention against soil-borne pathogens. Chemical products may suppress pathogen activity temporarily but generally cannot address all sources of inoculum or improve the biological suppressiveness of soil.

3.2 Effect on marketable yield

Marketable yield showed an inverse relationship with disease incidence. The control recorded a constructed marketable yield of 32.00 t ha⁻¹. Chemical management increased yield to 39.50 t ha⁻¹. The combination of *Trichoderma* and organic manure resulted in 41.00 t ha⁻¹, while solarization plus *Trichoderma* produced 44.00 t ha⁻¹. The resistant cultivar/rootstock combined with *Trichoderma* recorded 45.50 t ha⁻¹. The integrated management module

produced the highest marketable yield of 46.50 t ha⁻¹. The yield improvement under integrated management can be associated with healthier root systems, reduced vascular damage, improved nutrient uptake and greater plant vigour.

3.3 Effect on soil-health indicators

The constructed soil-health data showed improvement under treatments containing organic manure and biological agents.

Table 3: Illustrative effect of management strategies on soil-health indicators

Treatment	Organic carbon (%)	Microbial biomass C (mg kg ⁻¹)	Available N (kg ha ⁻¹)	Soil biological activity
T ₁ -Control	0.54	185	214	Low
T ₂ -Chemical management	0.55	178	220	Low-moderate
T ₃ - <i>Trichoderma</i> + compost	0.68	265	242	High
T ₄ -Solarization + <i>Trichoderma</i>	0.63	238	235	Moderate-high
T ₅ -Resistant cultivar/rootstock + <i>Trichoderma</i>	0.65	250	238	High
T ₆ -Integrated management	0.76	312	257	Very high

The integrated treatment recorded the highest illustrative organic carbon and microbial biomass carbon. Organic amendments may increase carbon availability and stimulate beneficial microbial populations. The subsequent establishment of beneficial microorganisms can contribute to competition against soil-borne pathogens. However, solarization can temporarily reduce both pathogenic and non-pathogenic microbial populations. Therefore, the combination of solarization followed by biological inoculation is particularly important for rapid recolonization of the root-zone with beneficial microorganisms.

3.4 Mechanism of disease suppression

The superior performance of the integrated disease-management treatment can be attributed to the complementary and synergistic effects of different management components. Unlike a single control measure, the integrated approach simultaneously targets pathogen inoculum, host susceptibility, soil environmental conditions and pathogen activity. The major mechanisms involved in disease suppression are discussed below.

3.4.1 Reduction of initial inoculum

Soil solarization acts primarily by reducing the population of soil-borne pathogens, nematodes and other harmful soil organisms before crop establishment. Increased soil temperature under transparent polyethylene can adversely affect pathogen survival structures and reduce the initial inoculum available for infection. A lower initial pathogen population provides favourable conditions for subsequent biological and cultural management practices (Katan, 1981) [5].

3.4.2 Host resistance

The use of resistant cultivars or rootstocks provides an important genetic barrier against soil-borne pathogens. Resistant planting material can restrict pathogen penetration, colonization and multiplication within the root and vascular tissues. When resistance is combined with other management practices, the probability of severe disease development is further reduced. Grafting with resistant rootstocks is particularly useful in intensively cultivated tomato production systems where soil-borne pathogens may persist for long periods (Louws *et al.*, 2010) [7].

3.4.3 Biological antagonism

The application of *Trichoderma* contributes to pathogen suppression through several mechanisms, including mycoparasitism, competition for nutrients and infection sites, antibiosis and production of hydrolytic enzymes. In addition, *Trichoderma* can colonize the rhizosphere and stimulate plant defence responses, thereby improving the plant's ability to tolerate or resist pathogen attack. Establishment of beneficial microorganisms in the root-zone may also contribute to a more biologically active and disease-suppressive soil environment (Harman *et al.*, 2004) [4].

3.4.4 Improvement of soil physical properties

The incorporation of well-decomposed organic manure or compost improves soil aggregation, porosity, water-holding capacity and organic carbon status. Improved soil structure facilitates root growth and aeration and can reduce prolonged anaerobic conditions associated with excessive soil moisture. Better root development enables plants to compensate for minor root damage and maintain nutrient and water uptake.

3.4.5 Improvement of soil biological activity

Organic amendments provide carbon substrates that support diverse microbial populations in the rhizosphere. Increased microbial activity can enhance competition between beneficial microorganisms and pathogens for nutrients and ecological niches. A biologically active soil may therefore provide greater natural resistance to pathogen establishment and disease development. The development of disease-suppressive soils is generally associated with complex interactions among organic matter, microbial communities, plant roots and soil environmental conditions.

3.4.6 Improved root-zone moisture management

Excess soil moisture and poor drainage can favour several soil-borne pathogens and increase the movement of pathogen propagules through irrigation water. Raised beds and controlled irrigation help maintain appropriate soil moisture and improve root-zone aeration. Drip irrigation also reduces unnecessary wetting of the soil surface and limits the movement of contaminated water between plants and plots.

3.4.7 Crop sanitation

Removal of severely diseased plants, infected roots and crop residues reduces the amount of pathogen inoculum available for subsequent infection. Proper sanitation also helps prevent the carry-over of pathogens between successive crops. When sanitation is combined with crop rotation and healthy planting material, the continuity of the pathogen life cycle can be disrupted.

3.4.8 Balanced crop nutrition

Adequate and balanced nutrient availability supports vigorous plant growth and development of healthy root systems. Excessive or imbalanced fertilization, particularly under favourable environmental conditions, may increase susceptibility to certain diseases. Organic amendments can contribute to gradual nutrient release while improving soil biological processes, thereby supporting healthier plant growth.

3.4.9 Chemical protection as a supplementary component

Need-based chemical protection can provide additional disease suppression when pathogen pressure becomes high or when biological and cultural measures alone are insufficient. In an integrated programme, chemical treatments should be used judiciously and according to recommended doses and application intervals rather than as the sole method of disease control. Such an approach may reduce unnecessary chemical inputs and delay the development of fungicide resistance.

3.4.10 Synergistic interaction among management components

The major advantage of integrated disease management is that the individual components operate at different stages of the disease cycle. Solarization reduces the initial inoculum, resistant planting material limits infection, *Trichoderma* suppresses surviving pathogens, organic amendments improve soil health, drainage reduces favourable environmental conditions and need-based chemical protection provides additional suppression during periods of high disease pressure. Consequently, the combined treatment can provide more consistent disease suppression than any individual intervention.

Thus, the integrated disease-management strategy can be represented by the following principle:

Reduce initial inoculum + strengthen host resistance + enhance beneficial microbial activity + improve soil health + regulate soil moisture + maintain crop sanitation + apply need-based chemical protection = sustainable suppression of soil-borne diseases.

The effectiveness of this integrated approach is particularly relevant to intensive vegetable production systems, where repeated cultivation of susceptible crops can result in progressive accumulation of soil-borne pathogens. Integration of these practices can therefore contribute not only to disease suppression but also to improved crop productivity, soil health and long-term sustainability of vegetable production (Abawi and Widmer, 2000; Harman *et al.*, 2004; Louws *et al.*, 2010) [1, 4, 7].

3.5 Comparative disease-management efficiency

The disease reduction values calculated from the constructed dataset were 40.63, 50.00, 61.46, 65.63 and

76.04% under T₂, T₃, T₄, T₅ and T₆, respectively.

Treatment	Disease incidence (%)	Marketable yield (t ha ⁻¹)
T ₁	48.0	32.0
T ₂	28.5	39.5
T ₃	24.0	41.0
T ₄	18.5	44.0
T ₅	16.5	45.5
T ₆	11.5	46.5

The proposed figure should present disease incidence and marketable yield as separate variables, preferably using a combination chart or two-panel figure in the final manuscript.

3.6 Future perspectives

The future management of soil-borne diseases will increasingly depend on combining traditional agricultural practices with modern technologies. Molecular diagnostics can provide rapid identification of pathogens. Soil microbiome analysis can identify beneficial microbial communities associated with disease-suppressive soils. Remote sensing and UAV-based imaging can assist in identifying crop stress zones, while GIS can be used to map disease hotspots. Artificial intelligence can potentially integrate:

Soil moisture + temperature + crop stage + pathogen population + weather + cultivar susceptibility

To predict disease risk. Precision application can subsequently target only high-risk areas, reducing unnecessary input use. The integration of these technologies with biological control and resistant cultivars could transform conventional integrated disease management into precision soil-borne disease management.

4. Summary and Conclusions

The present study was developed to evaluate integrated strategies for management of soil-borne diseases in vegetable crops using tomato as a model system. Six management treatments were compared under a conceptual randomized block design. The constructed dataset indicated that disease incidence was highest in the untreated control (48.00%) and lowest under the integrated treatment (11.50%). The integrated treatment recorded an illustrative disease reduction of 76.04% compared with the control. Marketable yield increased from 32.00 t ha⁻¹ under control to 46.50 t ha⁻¹ under integrated management, representing an illustrative increase of 45.31%. The treatment combining resistant planting material, soil solarization, organic manure, *Trichoderma*, drainage management, sanitation and need-based chemical protection showed the most promising overall performance. The results demonstrate that soil-borne diseases should not be managed through dependence on a single control measure. The combination of physical, biological, genetic, cultural and chemical methods provides a more comprehensive strategy. The future of vegetable disease management should focus on soil-health-based disease suppression, resistant rootstocks, microbial consortia, molecular diagnostics, precision agriculture, artificial intelligence and climate-informed disease forecasting.

It is concluded that integrated management has considerable potential to reduce soil-borne disease pressure while

maintaining vegetable productivity and improving soil health. However, the numerical values presented in Tables 2 and 3 are constructed/illustrative data prepared for manuscript development and should not be represented as actual experimental findings. Field validation under replicated conditions is essential before publication as an original research article.

Competing Interests

The author declares that there are no competing interests.

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