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A REVIEW ON RECENT METHODS TO CONTROL EARLY BLIGHT OF TOMATO (*Solanum lycopersicum* L.)

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Review Article

ABSTRACT

The present review paper is focused on bringing forth the different methods used in controlling early blight disease of tomato (*Solanum lycopersicum* L.). It is a well-known fact that tomato is a main fruit consumed as a vegetable globally which provides important minerals, vitamins, fibres and antioxidants. However, tomato is susceptible to an array of diseases, of which early blight is the most destructive instigated by *Alternaria solani*, affects fruits and foliage resulting in a loss of 80% yields. Therefore, it becomes imperative to discuss the various strategies applied in controlling early blight of tomato. A number of researchers have used diverse methods to regulate early blight disease of tomato ranging from use of fungicides, plant extracts to several biological organisms. Nevertheless, it is equally important to develop and apply the most efficient management systems and good agricultural practices to rescue the plant of interest.

Keywords: *Alternaria solani*; biocontrol; fungicides; plant extracts; *Solanum lycopersicum*.

INTRODUCTION

Tomato is the utmost important and popular vegetable crop grown round the world [1,2]. Tomato belongs to the genus *Lycopersicon* and Family Solanaceae [3]. China is the leading country in production of tomato (31%), followed by India and the United States with the second and third highest producer in the world [4]. The consumption of tomato stands second after potato being rich in vitamins (K, C and A), minerals (Fe, Ca and P), amino acids, sugars, dietary fibres and antioxidant and contains 95.3% of water [5,6]. The production of tomato suffered huge loss in production due to the attack by various bacterial, viral and fungal diseases [7]. The main diseases are fusarium wilt, early blight, damping off, late blight, tomato mosaic virus, verticillium wilt, and bacterial wilt [8,9,10]. Out of all, the most damaging disease caused by pathogenic fungus *A. solani* is early blight, which results in major loss both in quantity and quality of fruit yield [11,12]. The disease symptoms appear on stems, leaves and fruits of tomato [13]. Small and dark lesions appear on the leaves of tomato plant [13]. Necrotic and concentric rings on leaves give a target like appearance on the surface of leaf. Lesions appeared on leaf surface are bound by yellow rings [4]. Older leaves are firstly infected by *A. solani* followed by stems, petioles, twigs and fruits of tomato plant. Control of this disease is very difficult due to wide host range and active and prolonged life cycle of *A. solani*.

DIFFERENT STRATEGIES FOR MANAGING EARLY BLIGHT

Different methods have been used for the control and better management of this disease. Methods used include cultural practices, through resistant varieties, biological control, use of chemicals and disease free planting material [14]. The use of fungicide is considered as effective method for managing early blight. The usage of resistant and tolerant varieties is also an important method to control this disease. Resistant varieties increase effect of fungicides, extend fungicide spray intervals and maintain disease. Different fungicides for combating early blight disease are available in market. Azoxystrobin, ziram, pyraclostrobin, mancozeb, copper products and potassium bicarbonate are name of some fungicides used for the same.

Use of Fungicides

The early blight of tomato is considered as the most devastating disease resulting in pre and post-harvest stages resulting in a drop in yields of 35 to 78% [4,15]. The use of fungicides is considered as the most effective approach for controlling early blight, as stated by several workers [16,17,18,14,19,20,15]. The fungicide mancozeb has been widely used since the last two decades to control early blight, reducing the severity of the disease and enhances tomato yield [4]. Farooq et al. [15] stated that hexaconazole and pyraclostrobin are the best fungicides to reduce the occurrence of the disease by inhibiting maximum growth of mycelium. While, according to Bais et al. [4], sanchar followed by mancozeb and carbendazim were superior for controlling the disease. Rani et al. [18] reported that tebuconazole and difenoconazole were the most effective fungicides in controlling early blight of tomato.

However, due to concerns about cost, toxicity risks and dangers of its residues, the use of fungicides cannot be seen as a long-term solution. In addition, the production of pathogenic fungi resistance to synthetic pesticides is a major problem, which can have a noteworthy impact on the efficacy of chemical fungicides [18,12,9]. Inappropriate use of chemicals lead to serious human health hazards and possible harmful effects on non-target organisms and the environment [21]. Therefore, proper concentration of fungicides at proper intervals should be mandatory [16]. The use of fungicides can be altered to be in a safer range by combining with other relatively safer alternative methods [14]. An overview of the different works published in different journals in this area is presented in Table 1.

Use of Biocontrol Agents

The worldwide trend towards safe environment methods for controlling plant diseases in sustainable agriculture practice needs reduced usage of synthetic chemicals [4]. Due to this, there is an increasing interest to acquire alternative antimicrobial agents (biocontrol agents) for controlling plant diseases [22,15]. Biocontrol agent is the effective and ecological alternative approach for managing early blight. Several researchers have shown the use of biological agents as a best alternative method for the control of early blight (Table 2).

Biocontrol bacterial strains viz. *Pseudomonas fluorescens* [4], *P. aeruginosa* [39], and *P. putida* [38] have resulted in low disease severity index. A very well-known and effective biocontrol fungal strain, *Trichoderma viride* has also been used for control of early blight. *T. viride* with *Pseudomonas* strains is another effective biocontrol strategy used for disease management. Owing to strong mycoparastism of fungal pathogens and rapid growth potential, *Trichoderma* species are considered as effective control agents [37,39]. *Trichoderma* antagonism is owed to the development of non-volatile and volatile metabolites, space, food, nutrient rivalry, the ability to secrete enzymes that degrade cell wall and antibiosis [14]. As a result, there is a growing interest in acquiring alternative antimicrobials (bio-control agents) for use in plant disease control systems. Bio control agents are found to be effective and eco-friendly. Furthermore, they are easily biodegradable, nonphytotoxic, systemic and safe to environment [7]. Various biocontrol agents including *Pseudomonas* spp., *Bacillus* spp. and *Serratia* spp. may induce plant protection responses which are directly related to the pathogenesis related proteins (PR) such as phenylalanine ammonia-lyase, superoxide dismutase, peroxidase, and β-1,3 glucanase defence enzymes [40].

Table 1. Different fungicides used to control early blight

S. no.	Fungicides	Method of treatment	Results	References
1	Carbendazim Mancozeb Copper oxychloride Iprodione Chorothalonil	Poisoned food technique	-Mancozeb was most effective fungicide inhibiting sporulation and growth of mycelium of *A. solani.*	Pandey; [23]
2	Fungicides	Poisoned food technique	-Mancozeb (0.2%) and hexaconazole (0.1%) showed mycelial growth inhibition by 87.21% and 88.88% respectively. -In combination hexazconazole and zineb showed maximum inhibition of mycelial growth.	Roopa *et al*. [24]
3	Onestar Ergon Amistar	RCBD	-Onestar 23% SC and amistar 23% SC showed maximum reduction in disease (69-71%).	Saxena et al. [25]
4	Duter Mancozeb Carbendazim Thiophanate methyl Zineb Iprodione Captafol Copper oxychloride	RCBD	-Mancozeb (0.2%) recorded minimum percent disease incident (22.18) and 32.2% maximum disease control, which was superior to other fungicides. -Carbendazim (0.1%) showed 28.22% and copper oxychloride (0.25%) showed 24.85% disease control.	Walke et al. [26]
5	Mancozeb	RCBD	-As compared to control, disease intensity was reduced by mancozeb with foliar spray (15.43%, 17.90% and 20.47%).	Zghair et al. [27]
6	Ridomil gold Agrolaxyl Mancozeb	RCBD	-Mancozeb was most effective in controlling the disease by 47.75%.	Desta and Yesuf; [28]
7	Carbendazim Copper sulphate Copper oxychloride Captan Mancozeb Thiram Zineb	Poison food technique	-At concentration 1500 ppm, mancozeb reduced mycelial growth by 86.4%, which was followed by carbendazim (33.7%).	Sadana and Didwania; [29]
8	Mancozeb Chlorothalonil	Randomized complete block design (RCBD)	-*In vivo* results validated decline in disease control with the reduced-sensitivity isolates related to the sensitive ones.	Abu-El Samen et al. [30]
9	Propineb Thiophanate methyl Chlorothalonil Mancozeb Copper oxychloride	Poison food technique	-Mancozeb (89.83%) showed maximum mycelial growth inhibition followed by propineb (87.40%), thiophanate-methyl (87.10%) and copper oxychloride (79.21%). -Least inhibition shown by chlorothalonil (70.40%).	Ghazanfar et al. [16]
10	Mancozeb Chlorothalonil Propineb Hexaconazole Azoxystrobin Difenoconazole Tebuconazole Propiconazole Carbendazim	Poisoned food technique	-Mancozeb, hexaconazole and combi fungicide carbendazim + mancozeb recorded maximum inhibition of 88.42%, 90.58% 88.07% mycelial growth respectively.	Mahantesh et al. [17]
11	Tebuconazole Hexaconazole Difenoconazole Carbendazim Mancozeb	Poisoned food technique	-The most effective fungicide was tebuconazole followed by difenoconazole.	Rani *et al*. (2017)

S. no.	Fungicides	Method of treatment	Results	References
12	Trigger Solex Dew Amistar Top Corel Reflex	Poisoned food technique	-Reflex and corel showed better inhibitory effect on *A. solani*. -Solex showed no inhibitory effect.	Sarfraz et al. [18]
13	Carbendazim Mancozeb Difenoconazole Propiconazole Mancozeb Propineb Copper-oxy chloride	Poisoned food technique	-Carbendazim and mancozeb showed lowest percent disease intensity, which was followed by difenoconazole and propiconazole.	Sharma et al. [19]
14	Mancozeb RokoCarbendazim Companion Blitox 50 Sanchar	Poison food technique	-The significant maximum growth inhibition was recorded in sanchar followed by mancozeb and carbendazim.	Bais et al. [4]
15	Badge X2 Prestop Serenade Sil-Matrix Opti Regalia Oxidate Sustane	RCBD	-Badge X2 and prestop reduced disease significantly both in field and green house trails. -Sil-Matrix, regalia, oxidate and sustane were ineffective in controlling disease.	Egel et al. [20]
16	Pyraclostrobin Hexaconazole Carbendazim Mancozeb Ridomil	Poisoned food technique	-At 500 ppm, the maximum inhibition of mycelial growth was shown by pyraclostrobin (97.7%), followed by hexaconazole (91.1%), carbendazim (90%) and ridomil showed inhibition i.e, 42.2%.	Farooq et al. [15]
17	Indofil Bavistin Sulcox Tall Mancozeb	Poisoned food technique	-The most effective fungicide was Tall 25EC which showed maximum mycelial inhibition.	Roy et al. [10]

Table 2. Bio control agents used against early blight

S. no.	Biocontrol agents	Method of treatment	Result	References
1	*Bacillus* species	Dual culture technique	-Out of 45 *Bacillus* isolated, 27 showed antagonistic effects against pathogen *in vitro* and four among them showed highest effect.	Abdalla et al. [31]
2	*T. harzianum* *T. virens*	Dual culture technique	-*T. virens* displayed better inhibitory effect on radial growth and sporulation of mycelium.	Pandey, [23]
3	*T. harzianum,* *T. viride, T. virens*	Dual culture technique	-*T. harzianum* inhibits mycelial growth by 77.50% followed by *T. viride* 75.14%.	Roopa et al. [24]
4	*T. harzianum* *T. viride*	Dual culture technique	-Three sprays of *T. viride* (0.5%) were most effective against mycelial growth (31.47%), when compared to control (80.90%).	Yadav; [32]
5	*T. harzianum* *P. fluorescens*	Dual culture technique	-*T. harzianum* and *P. fluorescens* were effective in reducing the disease intensity.	Zghair et al. [27]
6	*Pseudomonas fluorescens* *Trichoderma viride* *Bacillus subtilis* *T. harzianum*	Dual culture technique	-*Bacillus subtilis* was most effective against mycelial growth (52.77%) of the fungus *A. solani.* -*P. fluorescens* isolates showed 47.22% and 45.55% mycelial growth inhibition. -*T. harzianum and* isolates *of T. viride* showed less than 40% growth inhibition.	Koley et al. [33]
7	*Pseudomonas aeruginosa*	RCBD	-*In vitro* studies suggested that, this bacterial strain produces a biosurfactant that inhibits the growth of pathogen at concentration of 3.0 g/l by 73%.	Lahkar et al. [34]

S. no.	Biocontrol agents	Method of treatment	Result	References
			-Concentration of crude biosurfactant in field conditions i.e, 1.50 g/l was adequate for full inhibition of *A. solani*.	
8	Rhizobacteria	Dual culture technique	-Almost all isolates shown antifungal activity against *A. solani*. -Best result observed with treatment 22 which inhibited 53.28% colony followed by treatment 25 (36.25%). -Minimum% inhibition was found in treatment 24 (19.94%).	Maurya et al. [35]
9	*Trichoderma spp.*	Dual culture technique	-*Trichoderma* isolates reduced mycelial growth of *Alternaria solani*.	Selim; [36]
10	*P. fluorescens* *H. armigera*	RCBD	-Both biocontrol treatments were found better than untreated control in reducing the occurrence of early blight in tomatoes.	Kaur et al. (2016)
11	*T. harzianum* *T. hamatum* *T. viride* *Penicillium glabrum* *Penicillium citrinum*	Dual culture technique	-*A. solani* completely overgrown (100%, class I) by the antagonists *T. harzianum* and *T. hamatum* while *T. viride* colonized half of the growth of fungus (50% overgrowth, Class III). -*Penicillium citrinum* and *P. glabrum* could not overgrow the fungus.	Devi et al. [7]
12	*T. viride* *P. fluorescens*	RCBD	-The early blight incidence was reduced by 93.4% and 88.8% over control when infected lower leaves were removed, staking of tomato plants, seed priming with *T. viride* followed by foliar spraying with *T. viride* and *Pseudomonas fluoroscens.* -The *T. viride* and *P. fluoroscens* foliar spray with priming of seeds also reduced the disease by 78.0% and 73.0% respectively.	Dhal et al. [37]
13	*T. harzianum* *T. viride* *P. fluorescens*	RCBD	-Minimum disease intensity recorded in treatment *Trichoderma viride* (31.44%) as compared to control (49.16%).	Jaiswal et al. (2017)
14	*P. aeruginosa* *P. putida* *P. fluorescens* *P. cepacia*	Dual culture technique	-*P. aeruginosa* showed maximum effect *on* early blight. -*P. putida, P. cepacia* and *P. fluorescens* showed no significantly different effects.	Joseph et al. [38]
15	*T. harzianum* *T. viride* *P. fluorescens* *B. subtilis*	Dual culture technique	-*T. harzianum* (UAHS 1) most effective in inhibiting the mycelial growth (80.36%) followed by *T. harzianum* (UAHS 2) (78.33%).	Mahantesh et al. [17]
16	*T. viride* *P. fluorescens* *T. harzianum* *B. subtilis*	Dual culture technique	-Maximum mycelial growth inhibition was shown by *T. harzianum* (65.93%). -*B. subtilis* showed growth inhibition of pathogen by 58.22% followed by *T. viride* (41.67%) and *P. fluorescens* (38.89%).	Rani et al. [18]
17	*P. aeruginosa* *S. aureus* *B. subtilis*	Dual culture technique	-*S. aureus* showed highest inhibitory effect. -*P. aeruginosa, B. subtilis* and *S. aureus* also inhibit the hyphal growth of *A. solani*.	Chanthini et al. [39]
18	*T. harzianum* *T. viride* *T. hamatum*	Dual culture technique	-Under *in vitro* conditions, *T. hamatum* showed highest inhibition, followed by *T. hazianum* and *T. viride.*	Sarfraz et al. [14]
19	*Serratia proteamaculans*	Dual culture technique	-*S. proteamaculans* significantly suppress the disease severity compared with control. -Bacterial therapy improved plant defense enzyme function and the protein associated with pathogenesis.	Youssef et al. [40]
20	*B. subtilis*	RCBD	-Early blight disease was reduced significantly by 67–83% by foliar application of *B. subtilis* either alone or in combination with the plant nutrients.	Awan and Shoaib; [5]
21	*T. harzianum* *T. viride* *P. fluorescens*	Dual culture technique	-*P. fluorescens* showed maximum inhibition (56.03%) followed by *T. harzianum* (51.58%) and *T. viride* (47.78%).	Bais et al. [4]

S. no.	Biocontrol agents	Method of treatment	Result	References
22	*Streptomyces puniceus* strain L75	Dual culture technique	-Co-inoculation of *A. solani* with L75 EA extracts reduced induced diseased areas by approximately 48, 90 and 98% respectively relative to the control after 5 days.	Hao et al. [41]
23	*Macrolepiota* sp.	Dual culture assay	-The cultural fluid of *Macrolepiota* sp. CS185 against early blight under greenhouse environment inhibit disease up to 46.6%.	Hernández-Ochoa et al. [42]
24	*T. viride* *T. harzianum*	Dual culture method	-*T. viride* was most effective against *A. solani*.	Roy et al. [10]

Use of Plant Extracts

Several researchers have recently exploited higher plant products as novel chemotherapists in plant defence, which are important sources of new agrochemicals for plant disease control [7]. The natural products are considered to be the best as alternative to synthetic chemicals due to less negative environmental impact [43]. There are number of plants species with natural constituents which are harmful to several plant pathogens [44]. Plant extracts have antimicrobial activity for controlling early blight and other plant diseases [9]. Raza et al. [43] reported that the extract of *Eucalyptus camaldulensis*, *Azadirachta indica*, *Parthenium hysterophorus* and *Datura stramonium* reduced the early blight in the laboratory conditions. Similarly, *Lantana camara* shows effect on the decline of early blight of tomato [45]. Several authors have also documented plants extract effect against early blight disease [46,44,7,3,14,12,9]. *A. sativum* also showed promising results against *A. solani* causing EB [43,1,7]. Seed and leaf extracts of neem exhibit anti-fungal property and are used as insecticides for controlling agricultural insect pests [43]. Secondary toxic metabolites, such as coumarins, flavonols, tannins, quinones, phenolics and saponins are produced by plants [14], which are significant compounds acknowledged for their activities against a variety of microbes [1]. Because of their essential characteristics such as high molecular diversity, high bioactivity, variability and short durability of climate, essential plant oils from plants show great potential against plant disease [46]. Hong et al. [47] had noteworthy results in essential oils from cinnamon oil and origanum oil vapours against *A. solani* at 6 hours post inoculation. The use of plant extract is environmentally safe, easily biodegradable, cheaper, long-lasting and ideal for organic farming, as well as efficient biocontrol methods for plant disease management. Phytochemicals have been researched for this purpose and used to establish alternatives to chemical pesticides to control plant diseases with a lower risk to the environment and health [7,48]. The various plant extracts used for the control of early blight are presented in Table 3.

Table 3. Plant extracts used against early blight

S no.	Plant extracts	Method of treatment	Result	References
1	*Azadirachta indica* *Ocimum sanctum*	Poison food technique	-Tulsi extract reduced disease severity by 40% which is better than neem extract.	Dheeba et al. [49]
2	*S. liebmannii* *C. sertularioides* *U. lactuca* *P. gymnospora*	Poison food technique	-All sea weed extracts reduced necrotic lesions induced by *A. solani.* -*U. lactuca and P. gymnospora* showed better results.	Hernández-Herrera et al. [42]
3	*Azadirachta indica*	RCBD	-Under field trails, neem extract was observed effective against early blight (55.12%).	Nahak and Sahu, (2014)
4	*Azadirachta indica* *Zingiber officinale Rosc* *Ocimum sanctum* *Phyllanthus niruri* *Artemisia vulgaris* *Lantana camera*	Food poisoned technique	-*Zingiber officinale* showed better inhibitory effect on sporulation and radial growth of mycelium of *A. solani*.	Pandey; [23]

S no.	Plant extracts	Method of treatment	Result	References
5	Botanicals	Poisoned food technique	-The most effective plant extract against mycelial growth of *A. solani* was found to be Jatropa (62.78%).	Roopa et al. [24]
6	Plant extracts	Food poison technique	-*Datura stramonium, Azadirachta indica* and *Withania somnifera* showed noteworthy antifungal activities. - *W. somnifera* showed maximum inhibition of *A. solani* (62.56%), which was followed by *D. stramonium* (34.65%) and *A. indica* (25.27%).	Sahu and Patel, [50]
7	*C. gigentea* *A. indica* *D. alba* *A. cepa* *O. sanctum* *A. sativum*	Poisoned food technique	-Garlic bulb extract (10%) was observed most effective against mycelial growth (35.16%) in controlling disease intensity followed by neem leaf extract (35.68%), datura leaf extract (36.25%) and onion bulb extract (36.71%).	Yadav; [32]
8	*Glycyrrhiza glabra* *Syzygium aromaticum,* *Hemidesmus indicus* *Cinnamomum zeylanicum* *Inula racemosa,* *Rubia cordifolia,* *Ferula foetida, Saussurea lappa*	Poison food technique/RBD	-At dosage of 3 ml/lit, *C. zeylanicum* extract exhibited whole inhibition of *A. solani in vitro* conditions. - At dosage of 2 ml/lit *C. zeylanicum* was effective against *A. solani* infesting tomato in shade house trails.	Yeole et al. [51]
9	Plant extracts	Poison food technique	-Out of fifteen plant extracts, eight showed better inhibitory effect on mycelial growth of *A. solani*. -*Tephrosia purpurea* (72%) showed best results followed by *Capsicum annum* (70%) and *Gliricidia sepium* (70%).	Zafar et al. [52]
10	*D. stramonium* *A. indica* *L. camara*	Poisoned food technique	-*D. stramonium* (57.03%) was most effective against mycelial growth followed by *A. indica (*51.35%) and *L. camara* (48.02%).	Koley et al. [33]
11	*Coleus forskohlii*		-*Coleus forskohlii* roots showed inhibitory effect on spore germination of *A. solani.* -*C. forskolin* exhibit dose dependent effect on spore germination.	Nidiry et al. [53]
	Solanaceous phylloplane	Poison food technique	-*S. phylloplane* significantly controlled early blight in a dose-dependent manner.	Pane and Zaccardelli; [54]
12	Plant extracts	Poison food technique	-*E. obliqua* was the most effective plant extract inhibiting mycelial growth by 88%. -*P. daemia, C. viscose* and *P. amarus* showed minimum inhibition.	Sadana and Didwania; [29]
13	*Eucalyptus citriodora* *Cymbopogon citratus* *Rosmarinus officinalis* *Cymbopogon martinii* *Citrus sinensis* *Syzygium aromaticum* *Piper hispidinervum* *Melaleuca alternifolia* *Cinnamomum zeylanicum* *Mentha piperita*	Poison food technique/RCBD	-*C. citratus, S. aromaticum and C. zeylanicum* oils at concentration of 750 µL/L, *M. alternifolia* and *E. citriodora* at 2000 µL/L and *Mentha piperita* in 5000 µL/L inhibited *in vitro* conidia germination and mycelial growth completely. -Under greenhouse conditions, *C. citratus*, *C. martinii, C. zeylanicum and S. aromaticum* at 750 µL/L inhibited early blight in leaf of tomato. - *E. citriodora* oil at 5000 µL/L showed similar effects inhibiting early blight of tomato.	Abreu et al. [46]
14	Cinnamon extract	Poison food technique	-Cinnamon extract (42.5%) significantly reduced mycelial growth of *A. solani.*	Attia et al. [44]
15	*Tithonia diversifolia, Azadirachta indica, Euphorbia heterophylla, Carica papaya, Chromolaena odorata*	Poison food technique	-*C. papaya* showed maximum inhibition of mycelial growth. -*C. odorata, E. heterophylla* and *A. indica* showed *n*o significant difference in disease severity -High yield was also significantly obtained with *C. papaya.*	Joseph et al. [38]
16	*Carica papaya* *Ricinus communis*	Poison food Technique/	-At 50% concentration, *P. juliflora* showed 88.9% inhibition of early blight disease.	Kalpashree and Raveesha; [55]

S no.	Plant extracts	Method of treatment	Result	References
	Prosopis juliflora *Polyalthia longifolia*	Dry Mycelial weight method	-The inhibition of disease shown by *Carica papaya was* 77.84% which was followed by *Ricinus communis* (70.5%) and *Polyalthia longifolia* (63%) by Poisoned Food Technique. -*P. juliflora* showed 90.7% inhibition, *C. papaya* (89.47%), *Ricinus communis* (86.1%) and *P. longifolia* (79.2%) by Dry mycelial weight method.	
17	*Lantana camara* *Eucalyptus globulus* *Azadirachta indica* *Allium cepa* *Zingiber officinale* *Allium sativum* *Parthenium hysterophorus*	Poison food technique	-*Allium sativum* plant extracts recorded lowest colony diameter of *Alternaria solani* with 87.3% inhibition of growth of fungus over control.	Kumar and Barnwal[45]
18	*Allium sativum* *Parthenium hysterophorus* *E. camaldulensis* *Datura stramonium* *Azadirachta indica*	Poison food technique	-Maximum mycelial inhibition was shown by *Azadirachta indica* plant extract (69.65%). -*Allium sativum* plant extract showed (66.15%) followed by *Parthenium hysterophorus (*59.94%), *Datura stramonium (*49.46%) and *Eucalyptus camaldulensis* (49.31%).	Raza et al. [43]
19	*Eucalyptus globus* *Datura alba* *Zingiber officinale* *Curcuma longa* *Allium sativum* *Melia azedarach*	Poison food technique	-At 20% concentration, *A. sativum* extract was most effective against *A. solani.* -*Datura alba* and *Eucalyptus globus* were ineffective, remaining plants extract significantly reduced *A. solani* growth on PDA.	Ahmad et al. [1]
20	*Vitex trifolia* *Allium sativum* *Azadirachta indica* *Acorus calamus* *Lantana camara*	Poison food technique	-*Allium sativum* showed 82.2%, 94.4% at 1, 2% and 100% at 3 and 4% concentrations. -The other plant extracts showed less than 35% inhibition on growth of the fungus.	Devi et al. [7]
21	Parthenium Lantana Water hyacinth, Pongamia Marigold,Neem, Tulsi, Onion, Garlic	Poison food technique	-Pongamia leaf extract inhibit the mycelial growth of *A. solani* (54.76%), followed by neem leaf extract (48.27%), lantana leaf extract (47.42%), and garlic bulbs (46.42%). -Least inhibition recorded in water hyacinth (36.75%).	Mahantesh et al. [17]
22	*Moringa oleifera* chloroform extract and aqueous extract	Poison food Technique	-Relatively high inhibitory effects on the germination of conidia from the lowest to the highest concentration were observed by two plant extracts.	Mvumi et al. [56]
	Clove Sesame Eucalyptus Cinnamon Castor Lemon Mustard Ginger	Poison food technique	-The castor, lemon and ginger at 3% concentration showed maximum radial growth inhibition of *A. solani* by 27, 29 and 29.6% respectively. -The inhibition shown by lemon oil was 27%, cinnamon oil, 21.6%, mustard oil 21.6%, jojoba 21%, sesame 21% and garlic 20%. -The disease was reduced by 34.9% by clove oil, 34.3% by eucalyptus and 34.2% by garlic, respectively.	Rahmatzai et al. [48]
23	*Gelidium serrulatum* *Ulva lactuca* *Sargassum filipendula*	RCBD	-Sea weed extracts reduced early blight disease efficiently. -Among weeds *G. serrulatum* showed best results.	Ramkissoon et al. [57]
24	*D. stramonium* *Cannabis sativa* *Ocimum sanctum* *A. indica*	Poison food technique	-*Lantana camara* (65.07%) showed maximum mycelial inhibition followed by *D. stramonium* (63.33%) and *A. indica* (61.33%). -Minimum mycelial growth inhibition was shown by *C. sativa* (32.59%).	Rani et al. [18]
25	Garlic bulb extract Datura leaf extract	Poisoned food technique	-The garlic bulb extract and Datura leaf extract at 5% concentration reduced disease intensity by 23.17% and 24.86% respectively.	Bhagat and Zacharia; [3]

S no.	Plant extracts	Method of treatment	Result	References
26	*Nigella sativa* *Trachyspermum ammi* *Azadirachta indica* *Eucalyptus globulus* *Lantana camara*	Poison food Technique	-Mycelial growth inhibition follows the order *Azadirachta indica* (46.66%)>*Eucalyptus globulus* (40.00%)>*Lantana camara* (32.78%) under *in-vitro* conditions. -Minimum disease intensity was recorded with *Azadirachta indica* (26.99%) and *Eucalyptus globulus* (27.25%) under *in-vivo* conditions.	Bhanage et al. [6]
27	*A. indica* *Ociumum sanctum* *D. stramonium* *Zingiber officinale* *Allium sativum* *Eucalyptus sp.*	Poison food Technique	-Significant inhibition of mycelial growth was shown by *Allium sativum* followed by *Azadirachta indica.*	Bais et al. [4]
28	*Azadirachta indica* *Ocimum sanctum* *Allium sativum*	RCBD	-Plant extracts were effective when applied to plants grown in greenhouse and field. -Highest reduction in disease incidence was shown by *A. sativum* (77.42%) and *A. indica* (62.32%).	Chohan et al. [12]
29	Ashwagandha Nithya Kalyani Tulsi Ginger Garlic Coleus Bougainvillea Eruku Sea weeds	Poisoned food technique	-Garlic extract showed highest inhibition over other treatments followed by bougainvilleas (77.4%), eruku (57.4%) and coleus (55.2%) percent inhibition over control. -Ashwagandha (24.2%) and sea weeds (0%) showed least inhibition.	Gowsik et al. [58]
30	*Azadiracta indica* *Prosopis juliflora* *Allium cepa* *Eucalyptus obliqua* *Pongamia pinnata* *Murraya koenigii* *Allium sativum* *Lawsonia inermis* *Curcuma longa* *Zingiber officinale*	Poisoned food technique	-Turmeric showed maximum inhibition i.e, 89.44% over control, which was followed by garlic (85.77%) and eucalyptus (73.03%). -*C. longa, A. cepa* and *E. obliqua* extracts reduced conidial germination to 91.11, 84.44 and 80.06 per cent respectively over control.	Rex et al. [9]
31	*Allium sativum* *Azadirachta indica* *Zingiber officinale* *Ocimum sanctum* *Adhatoda vasica* *Datura metel*	Poison food technique	-The *Allium sativum* plant extract was most effective against *A. solani*, followed by *Azadirachta indica*.	Roy et al. [10]

CONCLUSION

Tomato is one of the most important vegetable crops economically produced and consumed worldwide. However, tomato is susceptible to a range of biotic agents including a fungus, *A. solani* that causes early blight of tomato. This widespread disease can incur a loss of yields upto 80% of the crop. Hence, it is vital to use various strategies and control measures to control the disease in tomato. A myriad of methods and strategies have been developed and used to control early blight disease in tomato ranging from use of chemicals such as fungicides, application of plant extracts to use of several biological organisms. A number of researchers have successfully evaluated and shown the efficacy of different fungicides with different concentrations against the disease. However, improper use of chemicals, such as fungicides pollutes the environment and becomes toxic to humans. In recent years, research is focused more on using biological plant extracts and organisms for a toxic free environment. It is important to develop good agricultural practices and efficient management systems to restraint the disease and thus, contribute to economy.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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