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Bacterial wilt control of tomato by using locally available plants and their extracts: A brief review

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ABSTRACT

Bacterial wilt is one of the major and serious diseases of tomato and other solanaceous plants caused by *Ralstonia solanacearum*, one of the most important gram negative, aerobic, motile, rod-shaped, and soil borne bacteria. The disease is more prevalent in tropical, subtropical and warm temperate region of the world and the yield losses by *this disease* vary from 0 to 91% in the tomato. Thus, this paper intended to review the bacterial wilt control of tomato by using naturally and locally available plants and their products which have been carried out to date so as to find out gap for future research. More than 30 research and technical paper were studied and reviewed. Review focuses on plant-derived natural bactericides and their possible applications in agriculture to control tomato bacterial wilt that has been intensified as huge potential to inspire and influence modern agro-chemical research. Alcoholic leaf extract of *Lantana camara*, incubation of fresh organic matter of *Cajanus cajan* and *Crotalaria juncea*, rhizome extract of *Cucurma longa*, aqueous extracts of *Adathoda vasica* and *Tagetes patula* and essential oil of extracted from *Thymol spp* and *Cymbopogon martini* strongly inhibited the growth of bacterial pathogen *Ralostonia solanacearum*. This shows that phytobiocides are good alternatives to replace the chemicals in managing the bacterial wilt of tomato. The possible mechanisms of action of the plant residues are mainly considered to be antimicrobial activities followed by the indirect suppression of the pathogen through improved physical, chemical, and biological soil properties.

INTRODUCTION

Bacterial wilt is one of the major and serious diseases of tomato and other solanaceous and ornamental plants (Kucharek 1998). The disease is more prevalent in the wet tropics, subtropics and warm temperate regions of the world (Hayward 1991; Kelman 1953; Champoiseau and Momol 2009). The disease is caused by the bacterium *Ralstonia solanacearum*, previously known as *Pseudomonas solanacearum* which is an important and destructive soil borne bacterial pathogen (Sharma and Kumar 2004; Allen et al. 2005; Chaudhry and Rashid 2011) with a worldwide distribution and strains of this pathogen affect more than 200 plant species in over 50 families throughout the world, including a wide range of crop plants, ornamentals and weeds (Hayward 1995). The disease is difficult to control (Kucharek 1998) because pathogen can survive within a large temperature range (10^0C to 41^0C) and in diverse environmental conditions (Muthoni et al. 1995; Fajinmi and Fajinmi, 2010). The pathogen infects the host plant primarily through roots and enter into vascular bundles through wound formed by lateral roots caused by soil borne organisms especially insects and nematodes (Adebayo and Ekpo 2005). The disease can also transmitted through mechanical damages when carrying out intercultural operations (Champoiseau and Momol 2009).

Infected tomatoes plants may be stunted or completely wilted, resulting in poor fruit quality such as small sized fruits and significant loss of yield. The first visible symptoms of bacterial wilt are usually seen on the foliage of plants at early stage of disease infection. These symptoms consist of wilting of the youngest leaves at the ends of the branches during the hottest part of the day. At this stage, only one or half a leaflet may wilt, and plants may appear to recover at night, when the temperatures are cooler. As the disease develops under favorable conditions, the entire plant may

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wilt quickly and desiccate although dried leaves remain green, leading to general wilting and yellowing of foliage and eventually plant death. Another common symptom that can be associated with bacterial wilt in the field is stunting of plants. These symptoms may appear at any stage of plant growth, although in the field it is common for healthy-appearing plants to suddenly wilt when fruits are rapidly expanding (Champoiseau and Momol 2009). The yield losses by *R. solanacearum* vary from 0 to 91% in the tomato, 33 to 90% in the potato, 10 to 30% in tobacco, 80 to 100% in the banana, and up to 20% in the groundnut depending upon host, cultivar, climate, soil type, cropping pattern, and strain. (Elphinstone 2005). It is very difficult to control this pathogen as its abilities to grow endophytically, survive in soil, especially in the deeper layers, travel along water, and its relationship with weeds (Wang and Lin 2005).

The control of R. solanacearum is challenging once the pathogen has infested the soil (Jone 2008). Integrated disease management strategies such as cultural practices, crop rotation and use of resistant cultivars adopted by farmers have been found ineffective (Mbaka et al. 2013). However, various control strategies including host plant resistance (Dalal et al. 1999), transgenic resistance plant (Jia et al. 1999), cropping system (Dalal et al. 1999), soil amendments (Vincent and Mew 1998), integrated control (Katayama and Kimura 1987) and biological control (Khalequzzaman et al. 2002) have been developed. Different control methods including cultural, biological and chemical control methods have been adopting in Nepal also to control bacterial wilt problem in tomato. But the use of locally available plants and their extracts are very low.

The natural plant products derived from plant species has the capacity to control diseases caused by viruses, bacteria and fungal pathogens. Research focused on plant-derived natural bactericides and their possible applications in agriculture to control plant bacterial diseases has intensified as this approach has huge potential to inspire and influence modern agro-chemical research. Many reports revealed that, plant metabolites and plant based pesticides appear to be one of the better alternatives as they are known to have minimal environmental impact and danger to consumers in contrast to synthetic pesticides (Gottlieb et al. 2002). During the recent decades, many herbal extracts have been extensively tested and a myriad of reports have been documented outlining the uses of plant extracts to control the animal and plant diseases (Opara et al. 2010). A good number of reports outlined the antimicrobial effects of some medicinal plants for plant disease control. Some plant extracts were documented as effective inhibitors of phytopathogenic bacteria (Leksomboon et al. 2000). Plants produce antimicrobial agents by secondary metabolism to protect themselves from pathogen attack, and therefore many plant species possess substantial antimicrobial activity (Macdonald 2008).

MATERIALS AND METHODS

This paper was prepared by collecting the information from all available resources i.e. books, journals, annual reports, proceedings etc published by different Authors, Researchers, Professors as well as research centers and stations. A total of 30 research papers were collected and intensive review was made. Collected information's were systematically arranged into different subheadings namely; Use of Lantana *(Lantana camara)*, Use of Pigeon pea (*Cajanus cajan)* and Crotolaria (*Crotalaria juncea)*, Use of Turmeric (*Cucurma longa*), Use of White cedar (*Melia azedarach)*, Garlic (*Allium sativum)*, Malbar nut (*Adhatoda vasica)*, Marigold (*Tagetes patula)* and Nerium *(Nerium oleander)* and Use of Thymol (*Thymus spp*.) and Palmarosa oil (*Cymbopogon martinii*).

DISCUSSION

Control of bacterial wilt in infested soils is very difficult. It is generally considered that crop rotation with a non-host crop is of minimal value because of the wide range of crop and weed hosts of the pathogen (Hayward 1991). At present no conventional bactericides are known to provide effective control of this soil borne pathogen. Management of disease using bactericides causes environment pollution and the bactericide residues are harmful to human health. In addition, the intensive and indiscriminate use of pesticides in agriculture has caused many problems to the environment such as water, soil, animals and food contagion; poisoning of farmers; elimination of non-target organisms and selection of phytopathogens, pest and weed insensitive to certain active ingredients (Stangarlin et al. 1999). Soil treatments with traditional general-purpose fumigants such as methyl bromide did not provide satisfactory control of the disease (Chellemi et al. 1997).

.Natuarl plants products are important source of new agrochemicals for the control of plant diseases (Abdel-Monaim et al. 2011; Hassan et al 2009; Ji et al. 2005; Regnault et al. 2005).Use of biological control measures including phytobiocides for various soil borne pathogen has gained popularity in recent years due to concern of environmental and ecological hazards created by use of chemical products in disease control (Haas and De fago 2005). Plant products are safe, non-phytotoxic, systemic and biodegradable (Tripathi & Dubay 2004). Plant products can be used as green manures, dried powders (Naz et al. 2015a,b) and aqueous or organic solvent extracts (Yesmin et al. 2008; Balestra et al. 2009). Some plants, including medicinal plants, have larger amounts of anti-microbial secondary metabolites. When dried powders of such plants are used as soil organic amendments, the powders get mixed with soil water, get decomposed and release water-soluble anti-microbial secondary metabolites which protect host plants against pathogens (Naz et al. 2015b). Bacterial Wilt, a hard-to-control disease, cannot be sustainably managed by any single control method. Various strategies have been developed to control bacterial wilt include the use of host-plant resistance and cropping systems (Dalal et al. 1999), transgenic resistant plant (Jia et al. 1999) and biological control includes Vesicular-arbuscular Mycorrhizae (VAM) (Halos and Zorilla 1979), a virulent mutants of *R. solanacearum* (Dong et al. 1999), genetically engineered antagonistic bacteria (Kang et al. 1995), some naturally occurring antagonistic rhizobacteria such as *Bacillus* spp. (Da Silveira et al. 1995) or integration of these strategies (Anith et al. 2004). Exploitation of naturally available chemicals from plants, which retards the reproduction of undesirable microorganisms, would be a more realistic and ecologically sound method for plant protection and will have a prominent role in the development of future commercial pesticides for crop protection strategies, with special reference to the management of plant diseases (Gottlieb et al. 2002).

Several studies reported that bacterial wilt was suppressed and controlled by plant residues derived from, *e.g.* chili (*Capsicum annum*) (Teixeira et al. 2006), Chinese gall (*Rhus chinensis*) (Yuan et al. 2012), clove (*Syzygyum aromaticum*) (Amorim et al. 2012), cole (*Brassica* sp.) (Arthy et al. 2005), eggplant (*Solanum melongena*), (Almeida et al. 2007), eucalyptus (*Eucalyptus globules*) (Paret et al. 2010), geranium (*Geranium carolinianum*) (Ooshiro et al. 2004), guava (*Psidium guajava* and *P. quineense*) (Acharya and Srivastava 2009), Japanese cedar (*Cryptomeria japonica*) (Hwang et al. 2005), lemongrass (*Cimbopogon citratus*) (Paret et al. 2010), marigold (*Tagetes patula*) (Terblanche and Villiers 1998), neem (*Azadirachta indica*) (Pontes et al. 2011), palmarosa (*Cimbopogon martint*) (Paret et al. 2010), pigeon pea (*Cajanus cajan*), sunn hemp (*Crotalaria juncea*) (Cardoso et al. 2006), thyme (*Thymus* spp.) (Ji et al. 2005 and Pradhanang et al. 2003) and wood wax tree (*Toxicodendron xylvestre*) (Yuan et al. 2012). The possible mechanisms of action of the plant residues are mainly considered to be antimicrobial activities, followed by the indirect suppression of the pathogen through improved physical, chemical, and biological soil properties (Cardoso et al. 2006).

The antibacterial activity of *Ralstonia* with plant extracts have been reported earlier (Lopez et al. 2005; Larkin et al. 2007). Though most of the botanicals have anti-bacterial effect on most of the plant pathogenic bacteria and other microorganisms (Chethana et al. 2012). Green plants have been shown to represents a reservoir of effective chematherapeutants and can provide valuable sources of natural pesticides (Dorman et al. 2000). Green plants are found to be an effective reservoir for the bioactive molecules and can provide valuable sources for the discovery of natural pesticides (Akhtar et al. 1997). Green manure of above-ground parts of pigeon pea (*Cajanus cajan*) and crotalaria (*Crotalaria juncea*) completely suppressed tomato bacterial wilt in 45 days (Cardoso et al. 2006). Field application of thymol oil (derived from thyme plant) at the rate of 0.72% reduced bacterial wilt of tomato by 65-82% (Ji et al. 2005). Similalry, Hong et al. (2011) reported that combination of thymol and acibenzolar-S-methyl (ASM) significantly reduces the incidence of bacterial wilt and increased the yield of tomato. . Garlic extract and clove oil shown to have high potential against several microorganisms (Jeyaseelan et al. 2010) including *R. solanacearum*. The antibacterial effect of crude medicinal plant extract of *Curcuma longa*, *Brassica oleracae* and *Ipomoea batatas* on *Ralstonia solanacearum* were also reported (Wagura 2011).. Essential oil extracted from the lemon grass (*C. citratus*) at concentration of 0.14% completely inhibited R. solanacearum race 4 pathogen in ginger (Paret et al. 2010). Pradhanang et al. (2003) demonstrated that 100 percent tomato seedlings are free from *R. solanacearum* when inoculated with soil treated with lemon grass (700 ml/liter). Similarly, essential oil extracted from aromatic plants (*M. piperata*, palmarosa, geranium, *M. arvensis*, citronella, *M. spicata* and lemon grass) were found effective against R. solanacearum at 1 mg concentration (Khan et al. 2007)Phytobiocides are good alternatives to replace the chemicals in managing the bacterial wilt of tomato caused by *Ralstonia solanacearum*. They are locally available plant materials that are found to be effective for the management of bacterial wilt disease of tomato. Some of identified and tested phytobiocides are:

Use of Lantana *(Lantana camara)*

A study carried out by Banerjee and Chatterjee (2012) reported that *Lantana camara* is effective to control the bacterial wilt of tomato. Evaluation of antibacterial activity in the alcoholic leaf extract of *Lantana camara* was done by bactericidal bioassay method. The antibacterial effect was tested and interpreted in terms of the enzyme activities; catalase, peroxidase and polyphenol oxidase content in the healthy, extract treated and bacteria infected tomato plants. They reported that there was significant increased in the activities of all the enzymes in infected sets whereas enzymes activities were decreased in the sets which are treated with 50% alcoholic leaf extract of *Lantana camara*. The MIC (Minimum Inhibitory Concentration) was measured by using *Lantana camara* crude leaf extract. This shows that *Lantan camara* has potentiality to control the biochemical changes in the enzyme caused by bacterial infection in tomato plants.

Use of Pigeon pea (*Cajanus cajan)* and Crotolaria (*Crotalaria juncea)*

A fresh organic matter of pigeon pea and crotalaria were incubated in soil for 30 and 60 days before planting. Tomato seedlings of cv. Santa Clara were transplanted into polyethylene bags with 3 kg of the planting substrate (infested soil + organic matter). The wilting symptoms and percentage of flowering plants were evaluated for 45 days. All evaluated concentrations with incorporation and incubation for 30 days of aerial parts of pigeon pea and crotalaria controlled 100% tomato bacterial wilt. With 60 days of incubation, only the 10 % concentration of pigeon pea and crotalaria did not control the disease. These results suggest that soil incorporation of fresh aerial parts of pigeon pea and crotalaria is an effective method for bacterial wilt control (Cardoso et al. 2006).

Use of Turmeric (*Cucurma longa*)

A study conducted to analyze the in vitro antibacterial potential of turmeric plant against ten highly virulent isolates of *R. solanacearum*. The antibacterial activity of the extracts was assayed by agar well diffusion method on Tryptone Soya agar. The result revealed that the average zone of inhibition of the rhizome extract was ranging at 20-26 mm against *R. solanacearum*. Various concentrations of the extracts were prepared by dissolving extracts in DMSO. The minimum inhibitory concentration (MIC) was determined by two-fold micro broth dilution method for the tested pathogens. The MIC of the turmeric extract was 2-20 µg ml^{-1}. The activities of the solvent extract are remarkable when compared with the water extracts. Hence, solvent extract will enhance the efficacy of turmeric in the activity of *R. solanacearum* infections. This shows that Turmeric has antimicrobial property against the *R. solanacearum* (Narasimha et al. 2015).

Use of White cedar (*Melia azedarach)*, Garlic (*Allium sativum)*, Malbar nut (*Adhatoda vasica)*, Marigold (*Tagetes patula)* and Nerium *(Nerium oleander)*

Finely ground powders of widely available medicinal and weed plant species *viz., Melia azedarach* (White cedar), *Allium sativum* (Garlic), *Adhatoda vasica* (Malabar nut), *Tagetes patula* (Marigold) and *Nerium oleander* (Nerium) were assessed for their antimicrobial activity, both *in vitro* (10% w/v) and *in-vivo* (10, 20, 30, 40 g/kg of potted soil) against *R. solanacearum*. Aqueous extracts (prepared as 10% w/v, soaking for 48-72 hours and filtering) of *A. vasica* and *T. patula* inhibited the in-vitro growth of the bacterial pathogen over 60% of that produced by the standard antibiotic streptomycin while *A. sativum* and *N. oleander* extracts were less effective against *R. solanacearum*. Using agar well diffusion assay, Jeyaseelan et al. (2010) found out that both organic solvents and aqueous extracts of *A. sativum* bulbs restricted the *in-vitro* growth of plant pathogenic bacteria ***i.e***., *X. axonopodis* and *R. solanacearum*. The higher dose (40 g/kg of soil) of *A. vasica* and *T. patula* decreased disease severity and increased yield and plant growth characters as much as the standard antibiotic did. In additional to this, no phytotoxicity was observed in tomato plant as well. Abo-Elyousr et al. (2009) reported *A. sativum* extract reduced *R. solanacearum* population in in vitro tests and incidence of bacterial wilt in field also. Similarly, study conducted by Deberdt et al. (2012) shows that *Allium fistulosum* (50% and 100%) significantly reduced and controlled the population of *R. solanacearum* in in vitro as well as in field condition.

Garlic exhibited the strongest antibacterial activity against bacterial wilt *in vitro* and *in vivo* followed by Datura and then Nerium. Cold water extracts of these plant species were more effective than hot water extract in the development of the disease *in vivo*. In greenhouse experiments, the application of the tested plant extract to soil at the time of inoculation, two days before inoculation and two days after inoculation the pathogen, significantly reduced the disease index of wilt on Super Marmande tomato cultivars. The application of plant extracts at the same time as inoculation resulted in the highest reduction of disease index (Din et al. 2016).

Use of Thymol (*Thymus spp*.) and Palmarosa oil (*Cymbopogon martinii*)

The essential oil extracted from thymol and palmarosa, used at a concentration of 0.7%, were evaluated under field conditions for control of bacterial wilt of tomato caused by *Ralstonia solanacearum*. The experimental fields were artificially infested with the bacterial pathogen. The plant essential oils were applied after two hours and then the plots were sealed with plastic mulch for 3 days. Tomato seedlings (cv. Equinox) were transplanted into the field 7 days later. This study reported that 92.5% of tomato plants (cv. Equinox) wilted in the untreated control plots in fall of 2002 compared to 33.1% and 48.1% in case of thymol and palmarosa treated plots respectively in final assessment. Similarly, only thymol was evaluated in 2003 (cv. Solar Set.) in which disease incidence in untreated plots reached 65.5%, while in treated plots only 12% of plants were wilted (Ji et al. 2005). In addition, tomato plants grown in soils treated with thymol or palmarosa oil did not develop wilt symptoms under greenhouse experimental conditions (Pradhanang et al. 2003). Modes of action of the antibacterial property of thymol appeared to include disruption of bacterial cell membrane integrity by altering protein reactions (Juven et al. 1994). Paret et al. (2010) evaluated the effect of essential oil derived from palmaroa on *R. solanacearum* race 4 in edible ginger and reported that palmarosa oil at concentration of 0.07% completely inhibit the pathogen. Similarly, study conducted by Pradhanang et al. (2003) reported that tomato seedlings are free from *R. Solanacearum* when inoculated with soil treated with thymol (700 mg liter^{-1}) and palamrosa oil (700 ml liter^{-1}).

CONCLUSIONS

Bacterial wilt is one of the major limiting factor of solanaceous vegetables production. The disease is caused by the bacterium *Ralstonia solanacearum* which is an important soil borne bacterial pathogen with a worldwide distribution and the disease is difficult to control because pathogen can survive within a wide temperature range (10^{0}C to 41^{0}C) and in diverse environmental conditions. Infected tomatoes plants may be stunted or completely wilted, resulting in poor fruit quality such as small sized fruits and significant loss of yield. Different treatments, control measures and strategies have been developed and adopted till now but none of these practices have seems to perfect and complete package for the control of disease. But nowadays very cost effective locally available plant materials and their extracts have been used and the results were also found quite satisfactory compared to chemical treatments in terms of cost, control and environmental perspective. Use of different plant products such as *Lantana camara, Crotolaria juncea, Cajanus cajan, Allium sativum, Curcuma longa, thymus spp. Cymbopogon spp.* etc have been found to be effective against the control of bacterial wilt of tomato.

REFERENCES

Abdel-Monaim M.F. Abo-Elyousr K.A.M. Morsy K.M (2011). Effectiveness of plant extracts on suppression of damping-off and wilt disease of lupine (*Lupinus termis* Forsik). Crop Protection, 30:185-191.

Abo-Elyousr K.A.M. Asran M.R. (2009) Antibacterial activity of certain plant extracts against bacterial wilt of tomato. Archives of Phytopathology and Plant Protection, 42:573-578.

Acharya S. Srivastava R.C. (2009) Bactericidal properties of the leaf extracts of *Psidium guajava* and *Psidium guineense* against *Ralstonia solanacearum* by two analytical methods. Vegetos, 22:33–37.

Adebayo O.S. Ekpo E.J.A. (2005) *Ralstonia Solanacearum* Causing Bacterial Wilt of Tomato in Nigeria. American Phytopathological Society, APS Press, St. Paul, 15(12): 1129-1130

Allen C. Prior P. Hayward A.C. (2005). Bacterial wilt disease and the RS species complex. APS, St. Paul, MN, USA. pp.1.

Almeida H.O. Mattos E.C. Barbosa M.O. Teixeira F.R. Magalhaes R.D. Romeiro R.S. Fontes F.P.B. Baracat-Pereira M.C. (2007) Peptide fraction inhibiting plant pathogen growth predominant in cell wall extracts from young plants or in soluble fraction from expanded leaves from eggplants. Journal of Phytopathology, 155:735–737.

Amorim E.P.D. De Andrade F.W.R Moraes E.M.D. Da Silva J.C. Lima R.D. De Lemos E.F.P. (2011) Antibacterial activity of essential oils and extractions of the development of *Ralstonia solanacearum* in banana seedlings. Revista Brasileira de Fruticultura, 33:392–398.

Anith K.N. Momol M.T. Kloepper J.W. Marios J.J. Olson S.M. Jones J.B. (2004) Efficacy of plant growth-promoting rhizobacteria, acibenzolar-s-methyl and soil amendment for integrated management of bacterial wilt on tomato. Plant Disease, 88: 669-673.

Arthy J.R. Akiew E.B. Kirkegaard J.A. Trevorrow P.R. (2005) Using *Brassica* spp. as biofumigants to reduce the population of *Ralstonia solanacearum*. *In*: Allen C, Prior P, Hayward AC, editors. Bacterial Wilt Disease and the *Ralstonia solanacearum* Species Complex. American Phytopathological Society Press; St Paul, pp. 159–165.

Balestra G.M. Heydari A. Ceccarelli D. Ovidi E. Quattrucci A. (2009) Antibacterial effect of *Allium sativum* and *Ficus carica* extracts on tomato bacterial pathogens. Crop protection, 28: 807-811.

Banerjee N. Chatterjee P. (2012). Control of bacterial wilt of tomato by *Lantana camara* L. Proceeding of International Seminar on "Multidisciplinary Approaches in Angiosperm Systematics", 2: 812-818.

Bhowmik D.C. Sampath Kumar K.P. Chandira M. Jayakar B. (2009) Turmeric: A Herbal and traditional medicine. Archives of Applied Science Research, 1 (2): 86-108.

Cardoso S.C. Soares A.C.F. Brito A.D.S. Laranjeira F.F. Ledo C.A.S. Dos Santos A.P. (2006) Control of tomato bacterial wilt through the incorporation of aerial part of pigeon pea and crotalaria to soil. Summa Phytopathologica, 32 (1):27–33.

Champoiseau G.P. Momol T.M. (2009) Bacterial Wilt of Tomato. University of Florida. Retrieved 10th May, 2018, from: http://plantpath.ifas.ufl.edu/rsol/Trainingmodules/BWTomato_Module.html

Chaudhry Z. Rashid H. (2011) Isolation and characterization of *Ralstonia solanacearum* from infected tomato plants of soan skesar valley of Punjab. Pakistan Journal of Botany, 43 (6): 2979- 2985.

Chellemi D.O. Anderson P.C. Brodbeck B. Dankers W. Rhoads F.M. (1997) Correlation of chemical profiles of xylem fluid of tomato to resistance to bacterial wilt. *In*: Prior Ph, Allen C, Elphinstone J, editors. Bacterial wilt disease. Molecular and ecological aspects. Reports of the Second International Bacterial Symposium held in Gossier, Guadeloupe, France, 22–27 Jun 1997. Berlin: Springer; 1998, 225–232.

Chethana B. S. Ganeshan G. Rao S. Bellishree K. (2012) In vitro evaluation of plant extracts, bioagents and fungicides against Alternaria porri (Ellis) Cif., causing purple blotch disease of onion. Pest Management in Horticultural Ecosystems, 18(2): 194- 198.

Da Silveira. E.B. De Mariano R.L.R. Michereff S.J. Menezes M. (1995) Antagonism of *Bacillus* spp. against *Pseudomonas solanacearum* and effect on tomato seedling growth. Fitopatologia Brasileira (Brazil), 20: 605-612.

Dalal N. Dalal S. Golliwar V. Khobragade R. (1999) Studies on grading and pre-packaging of some bacterial wilt resistant brinjal (*Solanum melongena* L.) Varieties. Journal of Soils and Crops, 9: 223-226.

Deberdt P. Perrin B. Coranson-Beaudu R. Duyck P.F. Wicker E. (2012) Effect of *Allium fistulosum* extract on *Ralstonia solanacearum* populations and tomato bacterial wilt. Plant Disease, 96:687-692.

Din N. Ahmad M. Siddique M. Ali A. Naz I. Ullah N. Ahmad F. (2016) Phytobiocidal management of bacterial wilt of tomato caused by *Ralostonia solanacearum* (Smith) Yabuuchi. Spanis Journal of Agricultural Research, 14 (3): 1006.

Dong C. Zeng X. Liu Q. (1999) Biological control of tomato bacterial wilt with avirulent bacteriocinogenic strain of *Ralstonia solanacearum*. JOURNAL OF SOUTH CHINA AGRICULTURAL UNIVERSITY, 20: 1-4.

Eigner D. Scholz D. (1999) Ferula asa-foetida and Curcuma longa in traditional medicinal treatment and diet in Nepal. Journal of Ethnopharmacology, 67:1–6.

Elphinstone J.G. (2005) The current bacterial wilt situation: a global overview. In: Allen C, Prior P, Hayward AC, editors. Bacterial Wilt Disease and the *Ralstonia solanacearum* Species Complex. American Phytopathological Society Press; St Paul, pp. 9–28.

Fajinmi A.A. Fajinmi O.B. (2010) An overview of bacterial wilt disease of tomato in Nigeria, Agricultural journal, 5: 242-247.

Gottlieb O.R. Borin M.R. Brito N.R. (2002) Integration of ethnobotany and phytochemistry: dream or reality?. Phytochemistry, 60:145-152.

Haas D De fago G (2005) Biological control of Soil-borne pathogens by *fluorescent Pseudomonas*. Review of Microbiology, 3: 307–319.

Hassan M.A.E. Bereika M.F.F. Abo-Elnaga H.I.G. Sallam M.A.A. (2009) Direct antimicrobial activity and induction of systemic resistance in potato plants against bacterial wilt disease by plant extracts. The Plant Pathology Journal, 25:352-360.

Hayward A.C. (1991) Biology and epidemiology of bacterial wilt caused by *Pseudomonas solanacearum*. Annual Review of Phytopathology, 29: 65–87.

Hayward A.C. (1995) *Pseudomonas solanacearum*. In: Singh, U.S., Singh, R.P. and Kohmoto, K. (eds.), *Pathogenesis and Host specificity in Plant Disease: Histopathological, Biochemical, Genetic and Molecular Bases,* Elsevier, Tarrytown, 1: 139-151.

Hong J.C. Momol M.T. Pingsheng J. Stephen S.M. Colee J. Jones J.B. (2011) Management of bacterial wilt in tomatoes with thymol and acibenzolar-S-methyl. Crop Protection, 30: 1340-1345.

Hwang Y.H. Matsushita Y.I. Sugamoto K.. Matsui T. (2005) Antimicrobial effect of the wood vinegar from *Cryptomeria japonica* sapwood on plant pathogenic microorganisms. Journal of Microbiology and Biotechnology, 15:1106–1109.

Jeyaseelan E. Pathmanathan M. Jeyadevan J. (2010) Inhibitory effect of different solvent extracts of *Vitex negundo* L. and *Allium sativum* L. on phytopathogenic bacteria. Archives of Applied Science Research, 2: 325-331.

Ji P. Momol M.T. Olson S.M. Pradhanang P.M. (2005) Evaluation of thymol as biofumigant for control of bacterial wilt of tomato under field conditions. Plant Disease, 89:497–500.

Jia S. Qu X. Feng L. Tang T. Tang Y. Liu K. Zheng P. Zhao Y. Cai M. (1999) Expression of antibacterial peptide gene in transgenic potato confers resistance to bacterial wilt. *In*: *Chinese Agricultural Science*, Beijing, China.

Jones, J.B. 2008: Tomato plant culture: In the field greenhouse and garden. Taylor and Francis Group, USA. 55.

Juven B.J. Kanner J. Schved F. Weisslowicz H (1994) Factors that interact with the antibacterial action of thyme essential oil and its active constituents. Journal of Applied Bacteriology, 76:626-631.

Kang Y. Mao G. Lu C. He L. (1995) Biological control of bacterial wilt of tomato by extracellular protein defective mutant of *Pseudomonas solanacearum*. Acta Phytopathology, 22: 287-288.

Katayama K. Kimura S. (1987) Ecology and protection of bacterial wilt of potato. 2. Some control methods and their integration. Nagasaki Agriculture and Forestry Experiment Station, 15: 29-57.

Kelman A. (1953) The bacterial wilt caused by Pseudomonas solanacearum: A literature review and bibliography. North Carolina Agricultural Experiment Station, Tech. Bull. No. 99.

Khalequzzaman K.M. Jinnah M.A. Rashid M.A.A.M. Chowdhury M.N.A. Masud Alam M. (2002) Effect of Pseudomonas fluorescens in Controlling Bacterial Wilt of Tomato. The Plant Pathology Journal, 1: 71-73.

Khan M.R. Pundhir V.S. Rahman S.M.A. Singh V.P. (2007) Effect of some essential oil and methanol extract of Aromatic medicinal plants on bacterial wilt pathogen *Ralstonia solanacearum,* Progressive Agriculture*.,* 7 (1/2): 8-11.

Kucharek T. (1998) Bacterial Wilt of Row Crops in Florida. Circ-1207. University of Florida, IFAS, Coop. Ext. Serv.

Leksomboon C. Thaveechai N. Kositratana W. Paisooksantivatana Y. (2000) "Antiphytobacterial activity of medicinal plant extracts," Science, 54:91–97.

Lopez P. Sanchez C. Battle R. Nerin R. (2005) Journal of Agriculture Food Chemistry, 53: 6939-6949.

Macdonald M.M. (2008) Evaluation of alien invasive weedy plants for activity against plant pathogenic fungi. Pretoria: University of Pretoria.

Mbaka J.N. Gitonga J.K. Gathambari C.W. Mwangi B.G. Githuka P. Mwangi M. (2013) Identification of knowledge and technology gaps in high tunnels tomato production in Kirinyaga and Embu counties. Retrieved 8th June, 2018 from: https://www.google.com/#q=bacterial+wilt+tomato+kirinyaga

Muthoni J. Shimelis H. Melis R. (2012) Management of bacterial wilt (*Rhalstonia solanacearum* Yabuuchi et al. 1995) of potatoes: opportunity for host resistance in Kenya." The Journal of Agricultural Science, 4(9): 64–78.

Narasimha Murthy K. Soumya K. Srinivas C. (2105) Antibacterial Activity of *Curcuma longa* (Turmeric) Plant Extracts Against Bacterial Wilt of Tomato Caused by *Ralstonia solanacearum*. International Journal of Science and Research (IJSR), 4 (1): 2136-2141.

Naz I.S. Palomares-Rius J.E. Block V. Khan S.M. Ali S. Baig A. (2015b) Sustainable management of Southern root-knot nematode, *Meloidegyne incognita* (Kofoid and Yesmin, M.N., S.N. Uddin, S. Mubassara, M.A. Akond. 2008. Antioxidant and Antibacterial activities of *Calotropis procera* L. American-Eurasian Journal of Agricultural and Environmental Sciences, 4: 550-553.

Naz I.S. Palomares-Rius J.E. Khan S.M. Ali S. Ahmad M. Ali A. Khan A. (2015a) Control of Southern root- knot nematode, *Meloidegyne incognita* (Kofoid and White) chitwood on tomato using green manure of *Fumaria parviflora* Lam (Fumariaceae). Crop Protection, 67: 581-587.

Ooshiro A. Takaesu K. Natsume M. Taba S. Nasu K. Uehara M. Muramoto Y. (2004) Identification and use of a wild plant with antimicrobial activity against *Ralstonia solanacearum*, the cause of bacterial wilt of potato. Weed Biology and Management, 4:187–194.

Opara E.U. Obani F.T. (2010) "Performance of some plant extracts and pesticides in the control of bacterial spot diseases of solanum." Agricultural Journal, 5(2):45–49.

Paret M.L. Cabos R. Kratky B.A. Alvarez A.M. (2010) Effect of plant essential oils on *Ralstonia solanacearum* race 4 and bacterial wilt of edible ginger. Plant Disease, 94:521–527.

Paret M.L. Cabos R. Kratky B.A. Alvarez A.M. (2010) Effect of plant essential oils on *Ralstonia solanacearum* race 4 and bacterial wilt of edible ginger. Plant Disease, 94: 521-527. http://dx.doi.org/10.1094/PDIS-94-5-0521

Pontes N.D. Kronka A.Z. Morases M.F.H. Nascimento A.S. Fujinawa M.F. (2011) Incorporation of neem leaves into soil to control bacterial wilt of tomato. Journal of Plant Pathology, 93:741–744.

Pradhanang P. M. Momol M.T. Olson S.M. Jones J.B. (2003) Effects of plant essential oils on *Ralstonia solanacearum* population density and bacterial wilt incidence in tomato. Plant Disease, 87:423-427.

Regnault Roger C. Philogène B.J.R. Vincent C. (2005) Biopesticides of Plant Origin. Lavoisier, Paris.

Sharma J.P Kumar S. (2004) Effect of crop rotation on population dynamics of *Ralstonia solanacearum* in tomato wilt sick soil. Indian Phytopathology, 57(1): 80-81.

Stangarlin J.R. Schwan-Estrada K.R.F. Cruz M.E.S. Nozaki M.H. (1999) Medicinal plants and alternative control of phytopathogens. Biotecnologia Ciência & Desenvolvimento, 11:16-21.

Teixeira F.R. Lima M.C.O.P. Almeida H.O. Romeiro R.S. Silva D.J.H. Pereira P.R.G. Fontes E.P.B. and Baracat-Pereir M.C. (2006) Bioprospection of cationic and anionic antimicrobial peptides from bell pepper leaves for inhibition of *Ralstonia solanacearum* and *Clavibacter michiganensis* sp. *michiganensis* growth. Phyt opathology, 154:418–421.

Terblanche J. De Villiers D.A. (1998) The suppression of *Ralstonia solanacearum* by marigolds. In: Prior PH, Allen C, Elphinstone J, editors. Bacterial Wilt Disease: Molecular and Ecological Aspects. Springer; Heidelberg, New York: 1998. pp. 325–331.

Tripathi P. Dubey N.K. (2004) Exploitation of natural products as an alternative strategy to control post-harvest fungal rotting of fruits and vegetables. Postharvest Biology and Technology, 32: 235-245.

Vincent V.M. Mew T.W. (1998) Effect of a soil amendment on the survival of *Ralstonia solanacearum* in different soils. Phytopathology 88: 300-305.

Wagura, A.G. Wagai S.O. Manguro L. Gichimu B.M. (2011) Plant Pathology.

Wang J.F Lin C.H (2005) Integrated management of tomato bacterial wilt. AVRDC-The world vegetable center; Taiwan.

Yuan G-Q. Li Q-Q. Qin, J. Ye Y-F. Lin W. (2012). Isolation of methyl gallate from *Toxicodendron sylvestre* and its effect on tomato bacterial wilt. Plant Disease, 91:1143–1147.