

Review Article

Eco-friendly Ways of Managing Fusarium Wilt of Tomato (*Fusarium oxysporum* f. sp. *lycopersici*) and Related Soil-borne Phytopathogens: A Review

ABSTRACT

Tomato is an important vegetable crop grown for its nutritional and economic values. The crop is rich in vitamins, minerals and contains anti-oxidant compounds, like vitamin C and lycopene that has significant role in human health as it has anti-cancer. Tomato production is significantly affected by a number of factors amongst which are pests and diseases, among which is Fusarium wilt. Fusarium Wilt of tomato is one of the major and widespread fungal soil borne diseases in Nigeria. Difficulty in controlling this disease is attributable to long survivability of the pathogen and its existence in diverse pathogenic races. Management of the disease has always been a major challenge. Conventional strategies, such as the use of resistant cultivars and synthetic fungicides, are not completely effective in managing tomato wilt caused by *Fusarium oxysporum* f. sp. *lycopersici* and because of unintended effects of chemicals on the environments its application is highly cautioned. This paper has examined many non-pesticide approaches such as application of bio-control agents, use of suppressive soils, composts/vermicomposts and their extracts, animal manure and urine, soil solarisation, botanical extracts, good agricultural practices and integrated disease management strategy to control Fusarium wilt and other related soil borne diseases. It is worth noting that no single method can effectively control such diseases. In order to achieve a sustainable and eco-friendly disease management strategy the use of integrated approach is highly recommended. This review will provide farmers with diverse methods to be integrated as management package for Fusarium wilt and related diseases.

Keywords: Bio-solarisation, bio-fumigation, compost, eco-friendly disease management, fungicides, Fusarium wilts, soil-borne diseases, suppressive soil, tomato

1. INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a vital component of daily food and is consumed as unprocessed fresh fruits as well as in various types of processed products [1]. It is cultivated in essentially all countries either in fields or in protected culture [2]. Fusarium wilt caused by *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) Snyder and Hansen (*FOL*) is one of the most

significant diseases affecting tomato (*Solanum lycopersicum*L.) worldwide [3, 4, 5 and 6], especially in the acidic sandy soils of tropical regions [7]. The disease has become a limiting factor to the sustainable development of tomato production due to the long-term survival of the chlamydospore in the plant debris of the soil [8].

FOL as a soil-borne pathogen can survive indefinitely in the absence of host in infested soil as chlamydospores [9], and its germination is triggered by the presence of tomato root [7]. Sequential steps involved in the infection process of *FOL* is summarized as root recognition through host-pathogen signals, attachment to surface of root hairs and hyphal propagation, invasion of the root cortex, and vascular tissue and differentiation within xylem vessels and finally oozing of toxins and virulence factors [7]. This is followed by colonization of the vascular tissues leading to disease development that led to wilting of the host plant [10, 11].

Fusarium wilt causes great losses on the susceptible varieties of tomato especially when soil and air temperature are high during the warm season [12]. The pathogen inflicts a substantial yield loss ranging from 25 to 55% [13] and up to 90% is reported under optimal infection conditions [14]. In Nigeria the disease causes serious yield losses up to of 50% [15], especially in the Northern parts of the country. The pathogen is controlled by disinfecting the soil with methyl bromide, chloropicrin or metham sodium and systemic fungicides such as benomyl, thiabendazole and thiophanate. However, sustainable use of fungicides in *FOL* management is difficult due to development of resistant isolates and damaging effects on the natural environment, the agro ecosystem and human beings [16]. This stimulated the development of alternative methods as disease management strategies. These methods are briefly summarised as Follows:

1.0 USE OF BIO-CONTROL AGENTS

Biocontrol agents had been reported to be an effective method in controlling plant diseases [17]. They have been reported to be used in the control of Fusarium wilts for many crops including tomato, cucumber, melon, strawberry, banana and carnation [18]). Bio-control agents such as non-pathogenic *F. oxysporum*[19, 20]; hypovirulent binucleate *Rhizoctonia* [21], *Gliocladium virens* *Trichoderma hamatum*,, *Burkholderiacepaci*, *Pseudomonas fluorescens* [22], *Bacillus subtilis*, *Streptomyces pulcher*[23], *Baccilluspolymayxa* [24] and *Enterobacter cloacae* [25] have been reported to control Fusarium wilt disease. Application of Mycoparasites such as *Trichodermaharziaianum*, *T. viride* and *T. hamatum* in tomato field significantly controlled tomato wilt caused by *Fusarium oxysporum* f. sp. *lycopersici* [26].

Comment [U1]: What doses are used and what technique is applied?

Suppression of Fusarium wilt using biocontrol agents has been achieved through interactions among the plant, the pathogen, the biocontrol agents, the microbial community around the plant and the physical environment [27]. Hydrolytic enzymes of antagonistic microorganisms have been considered to play an important role in the biological control of plant pathogens. Many enzymes have been isolated from various strains of *Trichoderma* Species [28], *Gliocladium vixens* [29], *Paenibacillus* and *Stroptomycetes* species [30], and their activities were assayed and found effective in controlling Fusarium wilts. Successful bio-control system employs the use of naturally occurring antagonistic microorganisms that are able to reduce the activities of plant pathogens. This is accomplished through competition; secretions of antibiotics, parasitism and induced resistance [31].

Comment [U2]: how to treat diseased plants?

2.0 USE OF SUPPRESSIVE SOILS

Soil disease suppression is the reduction in the incidence of soil-borne diseases even in the presence of a host plant and inoculum in the soil, mainly attributed to diverse microbial communities present in the soil that could act against soil-borne pathogens in multifaceted ways [32]. Many groups of microorganisms found in the soil are potential biological control agents which suppress Fusarium wilt of tomato [33]. Soil has untapped and several potential

biocontrol agents that have shown high antagonistic activity against several soil-borne pathogens [34]. The soil-inhabiting antagonists were found to be effective suppressants to Fusarium wilt of tomato and these include; non-pathogenic *F. oxysporum* [35], *Trichoderma*, *Rhizoctonia*, and *Gliocladium* [36], *Bacillus* species and *Streptomyces* species [37], *Pseudomonas* spp. [38]. Biological mechanisms through which the disease-suppressive soils control the disease development are illustrated in Figure 1.

3.0 USE OF COMPOSTS/VERMICOMPOSTS AS ORGANIC AMENDMENTS

Organic amendments showed antibacterial and antifungal activity against soil-borne and foliar pathogens. Bananomet *et al.* [39] reported that extensive application of composts controlled several soil-borne pathogens (*Rhizoctonia solani*, *Sclerotinia* spp., *Pythium* spp., *Verticillium dahliae*, *Fusarium* spp., *Phytophthora* spp., and *Thielaviopsis* sp.) which were responsible for causing wilting, damping-off and decaying in many horticultural crops. Abbasi and co-workers [40] reported increased activities of biocontrol agents in the rhizosphere of tomato due to application of animal manure composts and reduced severity of soil-borne diseases of tomato. Many types of compost were reported to have suppressed Fusarium wilts in different crops [41, 42]. The efficacy of composts in managing soil-borne disease varied according to Termorshuizen *et al.* [43], but it is still considered a suitable method of controlling soil-borne diseases [44]. Avilés *et al.* [45] attributed the ability of compost to

Comment [U3]: prescribe the recommended doses

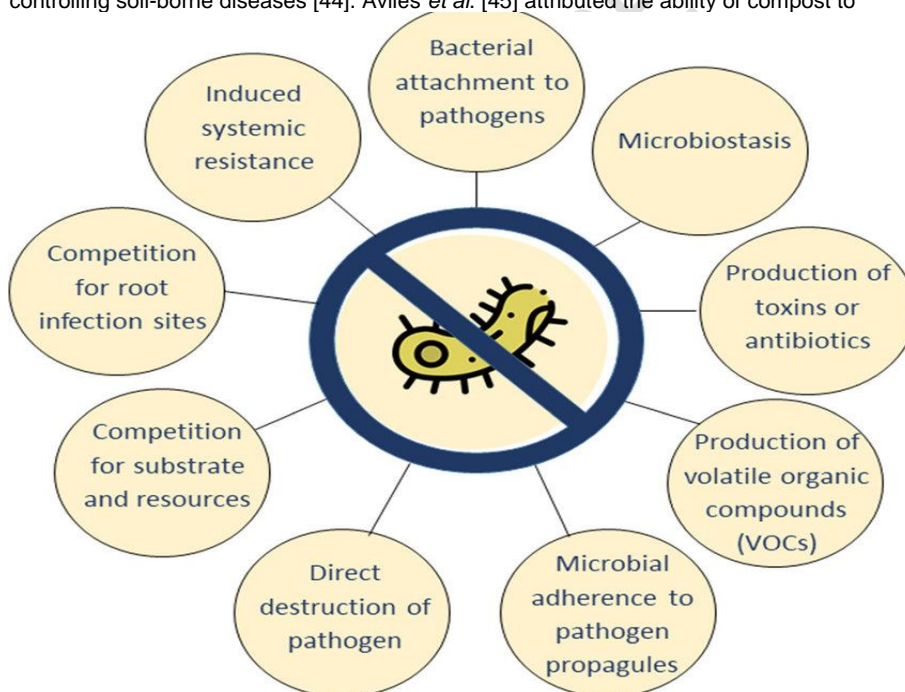


Figure 1: Possible mechanisms of disease-suppressive soil a close view
Source [Jayaraman *et al.*, 2021]

suppress plant pathogens to various roles played by microbes in composts which might be directly responsible for antagonistic interactions with pathogens and/or for the induction of systemic resistance in host plants [46]. Microbial activity during compost maturation

indirectly contributed to the formation of natural bio-stimulants and humic molecules which triggered bio-control agents to suppress soil pathogens [47].

Despite the potential of composts to suppress soil-borne pathogens in general, the success of the application of certain composts against a particular pathogen is not predictable [48], this is one of the major limitation of compost application in soil borne disease management. In an effort to increase harnessing of compost microbiomes for plant protection, Lutz *et al.* [48] proposed an integrated systems approach (Figure 2). They further reported that outcomes of the systems approach may include identification and isolation of new biocontrol strains and their mode of action, development of microbial consortia with suppressiveness superior to single strains, development of diagnostic tools to allow a targeted application of composts against soil-borne diseases, and the development of strategies to selectively promote key microbial organisms in composts. Compost application to agricultural fields is an excellent natural approach, which can be taken to fight against plant pathogens and its application is also an environmentally friendly alternative to chemical use [49] and improve the soil health and its nutrient levels.

Use of organic matter in form of vermicomposts has been recognized as having considerable potential as soil amendments for improving yield [50] and managing tomato wilt caused by *FOL* [51]. Vermicomposts which are products of organic matter degradation through interactions between earthworms and microorganisms, accelerates the rates of decomposition of the organic matter, alters the physical and chemical properties of the material, and lowers the C: N ratio, leading to a rapid humification [52]. This increases the surface area of the materials for colonization by beneficial microorganisms [53].

4.0 USE OF COMPOST/VERMICOMPOST EXTRACTS

Compost extracts are liquid extracts derived from mature composts, suitable for application to soil and/or as Foliar spray [54]. It contains organic and inorganic soluble nutrients, and a large number of organisms including fungi, bacteria, protozoa and nematodes [55]. Compost extracts are also known as compost teas [56]. Divers [57] reported that the active compounds identified in compost extracts include bacteria (*Bacillus*), yeasts (*Sporobolomycetes* and *Cryptococcus*) and fungi, as well as chemical antagonists such as phenols and amino acids. Water extracts prepared from composted organic matter had been used by farmers for many years for their perceived beneficial effects on plant health [58, 40]. Yohalem and others [59] reported that compost extract reduced the severity of Foliar diseases such as powdery and downy mildews of grapes caused by *Plasmopara viticola* and *Ulcinulanecatar* respectively, gray mould of straw berries (*Botrytis cinerea*), and late blight of potato (*Phytophthora infestans*).

Microbial populations in compost extracts are considered the most significant factor contributing to disease suppression [60]. However, there is a limited understanding of the microbial species composition, how these organisms survive on plants and the role of microbial diversity in the efficacy of the extracts. Results obtained from several studies suggested that antibiosis, which is a mechanism of suppression might be responsible, due to retention of suppressive qualities from the filter or heat sterilized extracts [59]. There is evidence that antibiotic metabolites present in compost extracts originate from the compost source [61]. Al-Dahmani and his co-workers [62] reported significant but inconsistent control of tomato bacterial spot (*Xanthomonas vesicatoria*) with cow manure; pine bark; and yard waste compost extracts. Hointink and co-workers [63] reported that the mechanisms of action exhibited by compost extracts in suppressing plant diseases appear to be antibiotic, competitive, parasitic and through induction of resistance. However, the efficacy and the suppressive ability of compost extracts depend on: age of compost, source of compost, type

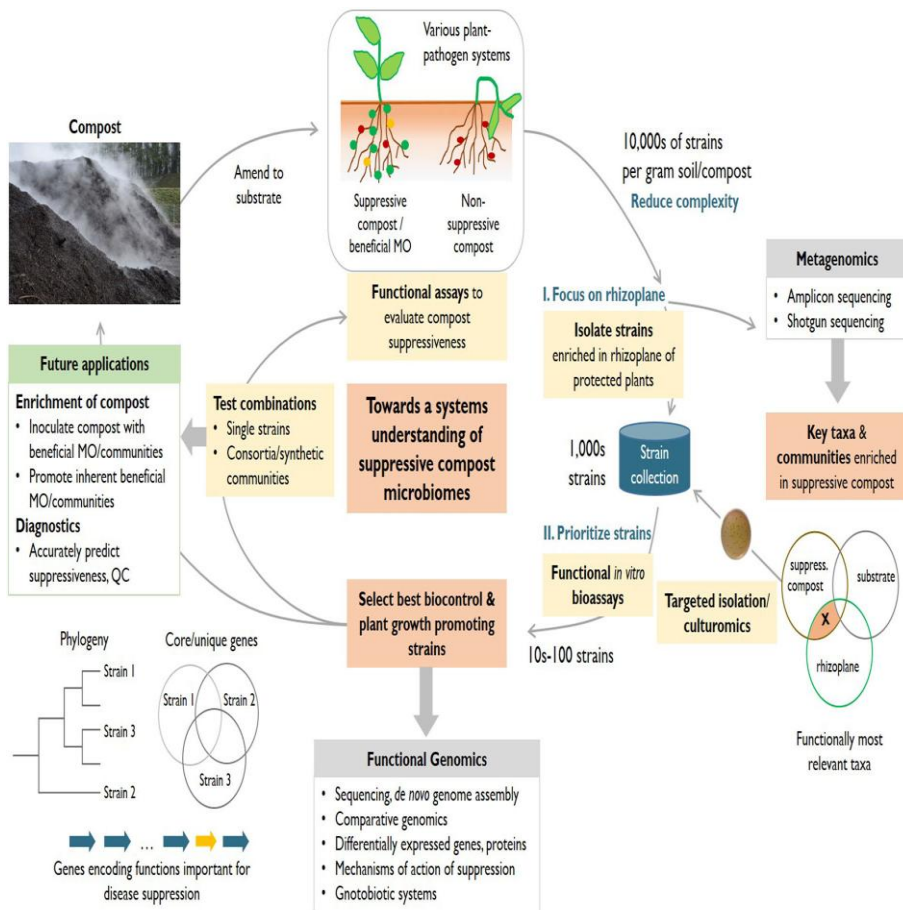


Figure 2: An integrated systems approach to enhance understanding of the microorganisms responsible for the disease-suppressive effects of compost in various plant pathogen systems. Source: [48].

of target pathogen, method of preparation, meteorological condition, timing and frequency of application [64]. Research studies showed that aqueous extracts of vermicompost and/or organic compost were effective in inhibiting mycelial growth of *Botrytis cinerea*, *Sclerotinia sclerotiorum*, *Sclerotium rolfsii*, *Rhizoctonia solani* and *Fusarium oxysporum* sp. *lycopersici* [65, 66].

5.0 USE OF ANIMAL MANURE AND URINE

Basak *et al.* [67] studied the efficacy and *in vitro* activities of cow urine and dung for controlling wilt caused by *F. oxysporum* sp. *cucumerinum* of cucumber and *F. solani* sp. *cucurbitae*. Cow dung solution and urine showed 80 - 84% and 100% inhibition of wilt pathogens, respectively. Ashlesha *et al.* [68] reported effective control of damping-off of okra and root rot of pea incited by *R. solani* using fresh cow dung, cow urine and cow milk

Comment [U4]: specify quantity or volume

based preparations. Sinha *et al.* [69] studied the antifungal properties of vermicompost and vermish against soil borne pathogens (*Pythium ultimum*, *R. solani* and *Fusarium* sp.) and recorded 51-72% inhibition in mycelial growth of the pathogens. Similarly, Sang *et al.* [70] reported the reduction in mycelial growth of *Phytophthora capsici* and *Colletotrichum coccodes* in pepper and *C. orbiculare* in cucumber by water extracts of compost. Sugha [71] evaluated the antifungal potential of panchgavya (combination of five dairy products) against *R. solani*, *S. rolfsii*, *F. solani*, *S. sclerotiorum* and *Phytophthora colocasiae* and advocated that the mycelial bits dipped for 6 h in panchgavya caused complete suppression of mycelial growth of *R. solani* and other pathogens. Dogra [72] also reported the antifungal activity of panchgavya against major soil-borne pathogens comprising *F. oxysporum* f.sp. *pisi*, *R. solani*, *S. rolfsii* and *S. sclerotiorum*.

Comment [U5]: specify quantity or volume

Comment [U6]: list the 5 dairy products

6.0 BIO-FUMIGATION

The term bio-fumigation refers to the allelopathic effects of biocidal glucosinolate (GSL) hydrolysis products, principally isothiocyanates (ITCs) on soil organisms [73]. The term "bio-fumigation" was coined to describe the suppression of soil-borne pathogens by compounds released from *Brassica* tissues, and implies a greater reduction in the load of pathogen inoculum than that resulted from the simple absence of a host. Bio-fumigation denotes the application of plant materials to treat fields infected with diseases or nematodes [74]. Trindade and Aries [75] defined bio-fumigation as the suppression of soil-borne pests by biocidal compounds of plant origin such as isothiocyanates and polyphenols. It is therefore an intentional use of bioactive plants and other organic materials that aid in reducing populations of plant pests in soil, mostly *Brassicaceae* and *Allium* species [76].

Suppression of soil-borne pests by bio-fumigation was achieved due to the presence of biocidal compounds; particularly isothiocyanates released from brassicaceous rotation and green manure crops when the glucosinolates (GSLs) in their tissues were hydrolysed in soil [77]. Some hydrolysis products, particularly the ITCs were known to have broad biocidal activity including insecticidal, nematocidal, fungicidal, antibiotic and phytotoxic effects [78]. Biofumigation also denotes the application of agronomic practices which involves the use of volatile chemicals (allelochemicals) released from decomposing plant tissues or using a specific plant species containing identified toxic molecules to suppress soil-borne pests [79]. Apart from brassicas, plants from *Caricaceae*, *Moringaceae*, *Salvadoraceae* and *Tropaeolaceae* families were also known to have bio-fumigant properties [80, 81]. Arnault *et al.* [82] reported the ability of *Brassicaceae* and *Alliaceae* family in producing many sulphur-containing volatile compounds arising via cleavage of certain S-alk(en)yl cysteine sulphoxides which could act on a variety of soil borne pests, including fungi, bacteria and nematodes.

Bio-fumigation greatly reduced pesticide application making farming cheaper and safer as it added organic matter to the soil, leading to increased soil aeration, water infiltration rates and soil water holding capacity [83]. Bio-fumigation was also reported to have increased soil porosity if used as a green manure and added more organic carbon to the soil thereby increasing the activity of soil fauna and flora [84]. Most studies on bio-fumigation have been done using brassicas [85], plant families like *Alliaceae*, *Moringaceae* and *Caricaceae* also possess bio-fumigant properties and could therefore be used in bio-fumigation [83]. The liberation of volatile compounds from decomposing crop residues generally occurs within a few days after their incorporation in moist soil following decomposition of bio-fumigant plant tissues which principally release isothiocyanates, in addition to thiocyanates, nitriles and oxazolidinethiones [86]. Isothiocyanates are released following tissue damage when endogenous myrosinase enzymes hydrolyze glucosinolates which are produced by plants as secondary metabolites [12]. Degradation of tissues of *Alliaceae* releases sulphurous volatiles such as thiosulfines which is converted into disulphides that have biocidal properties against fungi, nematodes, bacteria and other pathogens [87].

Bio-fumigant crops can be grown as cover crops or intercrops which could be slashed and ploughed under at flowering [88]. Besides growing the brassicas as green manure crops, they can be formulated into either a brassica cake or powder which can be incorporated into the soil or may be used as mulch [89]. It was also reported that bio fumigation enhanced soil saprophytic activity by microbes like *Streptomyces* sp. which act as agents for the induction of plant resistance to diseases like those caused by *Rhizoctonia* sp. [90]. Biofumigation with poultry manure and cabbage residues has been reported to control Fusarium wilt of tomato and therefore recommended to be applied as bio-pesticides and also as bio-fertilizer for improving yield on Fusarium wilt infected tomatoes [91].

7.0 SOIL SOLARIZATION

Soil solarization is hydrothermal soil disinfestations process that utilizes clear plastic mulch to trap solar radiation in moist soil during the hottest periods resulting in increased soil temperature to levels that can be lethal to soil-borne pathogens [92, 93, 94, 95, 96, and 97]. Pokharel and Hammon [98] and Siddiqi *et al.* [98] reported that high temperature generated during solarisation induced changes in soil volatile compounds that were toxic to soil pests and pathogenic organisms. This method has attracted the interest of scientists in many warm-climate countries because of its effectiveness, simplicity, and safety for humans, plants, and the environment [98]. Soil solarization as a natural hydrothermal process of disinfesting soil is accomplished through passive solar heating. Gelsomino *et al.* [100] also reported that reduction of soil-borne inoculum of plant pathogens achieved by direct thermal inactivation at soil temperatures ranging from 40°C to more than 60°C as the primary function of solarization to manage fungi, bacteria and nematodes.

Researchers have reported the use of soil solarization as eco-friendly method against fungal pathogens such as *Verticillium* spp., *Fusarium* spp. and *Phytophthora cinnamomi* and bacterial pathogens such as *Streptomyces scabies*, *Agrobacterium tumefaciens*, and *Clavibacter michiganensis* [101, 102]. Chen *et al.* [103] revealed the ability of soil solarization to increase the release of soluble nutrients such as inorganic N forms, extractable P and K, available cations, and dissolved organic matter resulting in improved vegetative plant growth and yield. Soil solarization is an attractive alternative method to replace the use of methyl bromide that was phased out in 2015. Fuentes *et al.* [104] opined that soil solarization alone might not consistently be effective to control soil-borne pathogens and pests, but its efficacy could be increased if combined with cultural, biological and/or chemical methods. The method could be used singly or in combination with other methods to effectively manage soil-borne diseases [105].

8.0 BIO-SOLARISATION

Combining solarization with the incorporation of plant residues in the soil produces a more consistently suppressive and sometimes eradicated effect on soil-borne fungi, bacteria, nematodes, weeds and pests rather than either treatment used alone [97]. Soil solarisation as reported by Eshel *et al.* [106] could be improved by combining it with other control measures. Managing *Fusarium oxysporum* sp. *lycopersici*, the causal agent of tomato wilt with solarization alone was not effective because the soil-borne pathogen was heat tolerant [108]. Several researchers have reported the potential of improving pathogen control and expansion of spectrum activity of biocontrol agents by integrating soil solarization with organic amendments [94, 107]. Integrating soil solarisation with plant residues proved to be good alternative in managing soil-borne pathogens especially under a situation where the use of organic amendment alone proved to be ineffective [109].

Many studies have demonstrated the effectiveness of combining solarization with bio-fumigation by covering and heating soil containing Brassica residues which produced deleterious effects on soil-borne fungi and nematodes far better than where the residues

were simply incorporated into natural field soil [110]. Combining soil solarization and biofumigation has been a good measure in combating diseases caused by soil-borne pathogens such as Fusarium wilt of tomato [111]. Biosolisation is also known as anaerobic soil disinfestation (ASD), described as biological process of disinfesting the soil by creating its condition anaerobic using simply decomposable amendments such as rice bran, fresh crop residues and soybean flour by covering it with polypropylene and water it to saturation [112]. The soil amendments used in ASD provide the substrate for speedy microbial growth [113]. Application of water on the organic amendment, covering with polypropylene mulch and decomposition of soil amendment restrict the gaseous exchange between the soil and atmosphere, thus creating anaerobic conditions and release of toxic substances such as acetic acid, butyric acid, and other volatiles which can be lethal to the soil-borne pathogens [114].

8.0 USE OF BOTANICALS

Mahadevan [115] reported that the presence of antifungal components in higher plants to have been recognized as an important factor for disease resistance due to their biodegradability and selective ability in their toxicity. They are considered as highly valuable in controlling some plant diseases [115]. Neem extract as one the botanicals used in managing plant diseases has been reported to show antimicrobial activity with notable effects on some fungal pathogens [116]. Significant levels of control of Fusarium wilt of tomato [117], downy mildew of grape caused by *Plasmophoraviticola*, late leaf spot incited by *Phaeoisariopsispersonata* and rust of ground nut caused by *Puccinia arachidis* has been documented [118]. Tests done by Kimaru *et al* [117] revealed that the neem cake powder contained ingredients that had fungistatic effects against *Fusarium* wilt of tomatoes. Qasem and Abu-Blan [119] studied the antifungal effect of aqueous extract of *Ranunculus* sp. against *F. oxysporum* sp. *lycopersici* *in vitro* and observed that there was a strong inhibition in the mycelial growth of the pathogen. In another study, Shivpuri *et al.* [120] reported the toxicity of ethanol leaf extracts of neem and *Datura* against *F. oxysporum* and *R. solani* under laboratory conditions.

Comment [U7]: which???

9.0 USE OF RESISTANT OR TOLERANT VARIETIES

Use of resistant or tolerant varieties is one of the most important eco-friendly and cost-effective disease management practices [121, 122] 2011). Cerkaukas [123] reported the availability of varieties that are resistance to races I and II of *Fusarium oxysporum* sp. *lycopersici* which will offers a valid alternative to the use of chemicals. However, additional pathogenic strain (Race 3) of the pathogen which affects the developed resistant varieties has been reported in several countries [22, 125, and 126]. For this reason, complementary methods of controlling the disease need be explored.

10.0 GOOD AGRICULTURAL PRACTICES (GAP)

Improvement of plant vigour through good farm management often helps in increasing resistance to pathogen attack. Earlier reports ascertained that altering of the soil pH by appropriate choice of fertilizer led to amelioration of the environment making it unfavourable for disease development [127]. Raising soil pH between 6 - 7.5 and fertilizing with nitrogenous fertilizer controlled *Fusarium* wilt of tomato and chrysanthemum [128]. Crop rotation with non-solanaceous crops such as cereals helped in reducing Fusarium wilt [129]. Use of soil amendments has been reported to be more promising than fungicides in controlling *Fusarium* wilt because it led to the reduction or elimination of inoculum of the pathogen in the soil [130] Jeff [131] and Kimaru *et al.* [117] attributed the effectiveness of soil amendment against soil-borne pathogen to enhanced host nutrition, proliferation of

antagonistic microorganisms and heat produced during decomposition. Decomposed organic materials have long been recommended in most agricultural and horticultural systems using organic farming methods as they offered possible control strategies for soil-borne diseases [117].

11.0 INTEGRATED DISEASE MANAGEMENT (IDM)

Waiganjoet *et al.* [132] recognised Integrated Pest Management (IPM) as effective approach for increasing agricultural productivity and combating environmental degradation in developing countries. The Integrated Pest Management seeks to improve the productivity of high-value marketed horticultural crops in Africa. Practices that can help to build healthy soils include crop rotation, organic matter additions or using high-residue tillage implements. A significant amount of research has been conducted on the suppression of pests and diseases through the application of compost products worldwide. The results have shown that composts can provide natural biological control of soil-borne diseases affecting collar and roots as well as plant foliage [133]. The inclusion of green manures and cover crops in a rotation is an excellent way to improve soil fertility, suppress weeds and provide a break in pest cycles [131]. A research conducted by Singh *et al.* [134] disclosed effective suppression of Fusarium wilt of tomato by integrating plant extracts with biocontrol agents and chemicals which significantly suppressed *Fusarium oxysporum* f. sp. *lycopersici*.

4. CONCLUSION

Chemical fungicides application are often not effective enough to control Fusarium wilts and other soil-borne diseases, and recently there is global outcry and public concerns about their deleterious effects. This necessitates the search for viable alternatives which are safe and eco-friendly. This review has explained the non-chemical methods that could conceivably be exploited for effective management of FOL. It also attributed difficulties in the control of FOL to the emergence of new pathogenic races, elimination of bio-control organisms as a result of indiscriminate use of fungicides and inadequate land for long-term crop rotation. Considering the adverse effects of chemicals to the environment and human health, it is therefore, necessary to find novel alternatives to control Fusarium wilt of tomato. Adoption of these methods for Fusarium wilt management and other soil-borne disease on tomatoes and vegetables may not eradicate all the pathogenic fungi from the soil. The use of integrated disease management strategies may offer solution to this where some of the eco-friendly ways outlined may be applied with/or without judicious application of fungicides. Therefore the use of integrated approach is highly recommended to achieve sustainable tomato production.

REFERENCES

1. Brookie, K.L., Best, G.L., Conner, T.S. Intake of raw fruits and vegetables is associated with better mental health than intake of processed fruits and vegetables. *Frontier Psychology*, 2018; 9, 487.
2. Houssein, A.A., Ahmed, S.M. and Ismail, A.A. Activation of tomato plant defense response against Fusarium wilt disease using *Trichoderma harzianum* and salicylic acid under greenhouse conditions. *Research Journal of Agriculture and Biological Sciences*, 2010; 6 (3):328 – 338.
3. Ajilogba, C. F. and Babalola, O. O. Integrated Management Strategies for Tomato Fusarium Wilt. *Biocontrol Science*, 2013; 18 (3):117 – 127.

Comment [U8]: Review all references in accordance with the reference system contained in the authors' guide

Comment [U9]: review references for published articles

4. Borisade, O.A., Uwaidem, Y.I., Salami, A.E. Preliminary report on *Fusarium oxysporum* f.sp. *lycopersici* (Sensulato) from some tomato producing agro ecological areas in Southwestern Nigeria and susceptibility of F1-resistant tomato hybrid (F1-Lindo) to infection. *Ann. Res. Rev. Biol.* 2017; 18 (2), 1–9.
5. Abdelaziz, A. M., Mohamed H. Kalaba, Amr H. Hashem, Mohamed H. Sharaf, and Mohamed S. Attia . Biostimulation of tomato growth and biocontrol of *Fusarium* wilt disease using certain endophytic fungi. *Botanical Studies* 2022; 63: 34. Doi: 10.1186/s40529-022-00364-7.
6. Mostafa, Y.S.; Alamri, S.A.; Alrumman, S.A.; Hashem, M.; Taher, M.A.; Baka, Z.A. In Vitro and In Vivo Biocontrol of Tomato Fusarium Wilt by Extracts from Brown, Red, and Green Macroalgae. *Agriculture* 2022; 12, 345. <https://doi.org/10.3390/agriculture12030345>
7. Srinivas, C., Nirmala Devib, K. Narasimha Murthy, Chakrabhavi Dhananjaya Mohan, T.R., Lakshmeesha, C., BhimPratap Singh , Naveen Kumar Kalagatur, S.R. Niranjana , Abeer Hashem , Abdulaziz A. Alqarawi, Baby Tabassum, Elsayed Fathi Abd Allah , S. Chandra Nayaka , Rakesh K. Srivastava. *Fusarium oxysporum* f. sp. *lycopersici* causal agent of vascular wilt disease of tomato: Biology to diversity– A review. *Saudi Journal of Biological Sciences* 2019; 26:1315–1324
8. Chang Y., DU, B., Wang, G. L., Ji, P., XIE, Y., Li, X., Li, Z., Wang, J. A study on the pathogen species and physiological races of tomato Fusarium wilt in Shanxi. *China Journal of Integrative Agriculture* 2018 ; 17(6): 1380–1390.
9. Cha, J.Y., Han, S., Hong, H.J., Cho, H., Kim, D., et al. Microbial and biochemical basis of a *Fusarium* wilt suppressive soil. *ISME Journal* 2016; 10, 119–129.
10. Di, X., Takken, F.L.W., Tintor, N., 2016. How phytohormones shape interactions between plants and the soil-borne fungus *Fusarium oxysporum*. *Frontier of Plant Science* 2016; 7, 170.
11. Worku M, Sahe, S. Review on Disease Management Practice of Tomato Wilt Caused *Fusarium oxysporum* in Case of Ethiopia. *Journal of Plant Pathology and Microbiology* 2018; 9: 460. doi: 10.4172/2157-7471.1000460.
12. Agrios, G. N. Plant pathology, 5th ed. Academic Press, Inc.: New York. 2005.
13. Nirmaladevi, D., Venkataramana, M., Srivastava, R. K., Uppalapati, S. R., Gupta, V. K., and Yli-Mattila, T. Molecular phylogeny, pathogenicity and toxigenicity of *Fusarium oxysporum* f.sp. *lycopersici*. *Scientific Report* 2016; 6:21367. doi:10.1038/srep21367.
14. Hibar, K.; M. Daami-Remadi; W. Hamadi and M. El-Mahjoub (2006). Bio-fungicides as an alternative for tomato *Fusarium* crown and root rot control. *Tunisian Journal of Plant Protection* 2006; 1: 19 – 29.
15. Adebayo, O.S. and E.J.A. Ekpo. Efficacy of fungal and bacterial biocontrol organisms for the control of *Fusarium* wilt of tomato. *Proceedings of 22nd annual conference of the Horticultural Society of Nigeria (HORTSON) held at Ibadan, Olarewaju, J.D.; Alegbejo, M.D. and Showemimo, F.A. (eds.) pp2004; 112 – 116.*
16. Pritesh, P. and Subramanian, R. B. PCR based method for testing *Fusarium* wilt resistance of tomato. *African Journal of Basic and Applied Sciences*, 2011; 3(5): 222- 230
17. Srinon, W. K.; K. Chuncheon; K. Jirathiwatkal; K. Soyong and S. Kanokredhakal. Efficacy of antagonistic fungus against *Fusarium* wilt disease of cucumber and tomato and the assay of its enzyme activity. *Journal of Agricultural Technology* 2006; 2(2): 191 – 201.
18. Horinouchi, H.; N. Katouyama; Y. Taguchi and M. Kyakane (2008). Control of *Fusarium* crown and root rot of tomato in a soil system by combination of a plant growth promoting fungus, *Fusarium equiseti*, and biodegradable parts. *Crop Protection* 2008; 27: 859 – 864.

Formatted: Font: Not Italic

19. Katsube, K. And Akasaka, Y. Control of Fusarium wilt of spinach by transplanting seedlings pretreated with non-pathogenic *Fusarium oxysporum*. *Japanese Journal of Phytopathology*, 1997; 63:389 – 394
20. Momol, M. T. and Pernezny, K. Florida plant disease management Guide: Tomato. University of Florida, 2003; 3: 53 - 63
21. Muslim, A. Horinouchi, H. and Hyakumachi, M. Biological control of Fusarium wilt of tomato with hypovirulent binucleate *Rhizoctonia* in greenhouse conditions. *Mycoscience*, 2003; 44 (2): 77 – 84.
22. Larkin, R. P., Hopkins, D. L. and Martin, F. N. Suppression of Fusarium wilt of water melon by non-pathogenic *Fusarium oxysporum* and other organisms recovered from a disease-suppressive soil. *Phytopathology*, 1996; 86: 812 – 819.
23. Monda, E. O. Biological Control of Fusarium wilt of tomato. Botany Department, Kenyatta University, Kenya. *Journal of Tropical Microbiology*, 2002; 1: 74-78.
24. Hamed, E.R., Abdel-sayed, M. H. F. and Shehata, S. Suppression of Fusarium wilt of water melon by biological and chemical control. *Journal of Applied Sciences Research*, 2009; 5 (10): 1816 – 1825.
25. Tsuda, K., Kosaka, Y., Tsuge, S., Kubo, Y. and Horino, O. Evaluation of the endophyte *Enterobacter cloacae* SM10 isolate from spinach roots for biological control against Fusarium wilt of spinach. *Journal of General Plant Pathology*, 2001; 67: 78 – 84.
26. Ojha, S. and Chatterjee, N. C. Integrated management of fusarium wilt of tomato with implementation of soil solarization, *Archives of Phytopathology and Plant Health*, 2012; 45 (18): 2143 – 2154
27. Barea, J. M.; R. Azcom and C. Azcom-Aguilar. Mycorrhizal fungi and plant growth promoting rhizobacteria *In: Plant Surface Microbiology*. Varma, A.; L. Abbott; D. Werner and R. Hanapp (eds.). Springer-Verlag Herdley Germany, pp: 2004; 351 – 371.
28. Hartman, G. E.; B. Latorre; E. Agosin; Martin; R. S.; d. g. Riegel; P. A. Nielsen; A. Tronsmo and R.S. Pearson. Biological control and integrated control of Botrytis Bunch Rot of grape vine using *Trichoderma* spp. *Biological Control*, 1996; 7; 259 – 266.
29. Di-pietro, A.; M. P. Madrid; Z. Caracuel; J. Delgado-Jarana and M.I.G. Ronceno. *Fusarium oxysporum*: Exploring the molecular arsenal of a vascular fungus. *Molecular Plant Pathology*, 1993; 4: 315 – 325.
30. Singh, D. P.; Y. C. Shin; C. S. Park and Y. R. Chung. Biological control of Fusarium wilt of cucumber by chitinolytic bacteria. *Phytopathology*, 1999; 89: 92 – 99.
31. Shishido, M.; C. Miwa; T. Usami; Y. Amemisya; and K. B. Johnson. Biological and efficiency of Fusarium wilt of tomato by non-pathogenic *Fusarium oxysporum* FO-2 in different environments. *Phytopathology* 2005; 95: 1072 – 1080.
32. Jayaraman, S., Naorem, A.K., Lal, R., Dalal, R. C., Sinha, N.K., Patra, A.K and Chaudhari, S.K. Disease-suppressive soils—beyond Food Production: a Critical Review. *Journal of Soil Science and Plant Nutrition*, 2021; 2-30. <https://doi.org/10.1007/s42729-021-00451-x>
33. Podile, A. R.; G. S. Prasad and H. C. Dube. *Bacillus subtilis* as antagonist to vascular wilt pathogens. *Current Sciences*, 1985; 54: 864 – 865.
34. Ramamoothy, V.T. Raguchander, and R. Samiyappan. Induction of systemic resistance by plant growth promoting rhizobacteria in crop plants against pests and diseases. *Crop Protection* 2001; 20:1 – 11.
35. Silva, J. C. and W. Bettiol . Potential of non-pathogenic *Fusarium oxysporum* isolates for control of Fusarium wilt of tomato. *Fitopatologia Brasileira* 2005; 30: 409 – 412.
36. Rose, S.; M. Parker and Z. K. Punja. Efficacy of biological and chemical techniques for the control of Fusarium root and stem rot on greenhouse cucumber. *Plant Disease* 2003; 87: 1462 – 1470.

Formatted: Font: Not Italic

Formatted: Font: Not Italic

37. Kapor, I. J. and B. Kar (1988). Antagonistic effects of Soil Microbes *Fusarium oxysporum* f. sp. *lycopersici* *International Journal of Tropical Plant Disease* 6: 257 – 262.
38. Srinivasan, K.; Garibaldi, G.; A. Garibaldi and M. L. Gullino. Bacterial antagonists from used rock wool soilless substrates suppress Fusarium wilt of tomato. *Journal of Plant Pathology* 2009; 91 (1): 147 – 154.
39. Bananomi, G., Antignani, V., Pane, C. and Scala, F. Suppression of soil borne fungal diseases with organic amendments. *Journal of Plant Pathology*. 2007; 89: 311–324.
40. Abbasi, P.A.; J. Al-Dahmari; F. Sahin, H.A.J. Hoitink and S.A. Miller . Effect of compost amendments on disease severity and yield of tomato in organic and conventional production systems. *Plant Disease* 2002;86: 156 – 161.
41. Boyd-Wilson, K. S. H. and Walter, M. Suppression of Fusarium wilt and seedlings blight by composted and uncomposted radiate pine bark. *Australian Plant Pathology* 2002; 31: 57 – 61.
42. Cheuk, W.; K. V. Lo ;R. Coperman,; P. Joliffe and B. S. Fraser. Disease suppression on glasshouse tomatoes using plant waste compost. *Journal of Environmental Science and Health*, 2005; 40(30): 449 – 461.
43. Termorshuizen, A.J., van Rijn, E., van der Gaag, D.J., Alabouvette, C., Chen, Y., Lagerlöf, J., Malandrakis, A.A., Paplomatas, E.J., Rämert, B., Ryckeboer, J., Steinberg, C. and Zmora-Nahum, S. Suppressiveness of 18 composts against 7 pathosystems: variability in pathogen response. *Soil Biology and Biochemistry*, 2007; 38: 2461–2477.
44. Pane, C., Vilecco, D., Campanile, F., Zaccardelli, M. Novel strains of *Bacillus*, isolated from compost and compost-amended soils, as biological control agents against soil-borne phytopathogenic fungi. *Biocontrol in Science and Technology*, 2012; 22: 1373–1388.
45. Avilés, M., Borrero, C. and Trillas, M.I., Review on compost as an inducer of disease suppression in plant grown in soilless culture. *Dynamic Soil Dynamic Plant* 2011; 5: 1–11.
46. Zhang, J., C., Howell, R. and Starr, J. L. Suppression of Fusarium colonization of cotton roots and Fusarium wilt by seed treatments with *Gliocladium virens* and *Bacillus subtilis*. *Biocontrol Science and Technology* 1996; 6:175-188.
47. Loffredo, E. and Senesi, N. In vitro and in vivo assessment of the potential of compost and its humic acid fraction to protect ornamental plants from soilborne pathogenic fungi. *Science and Horticulture* 2009; 122: 432 – 439.
48. Lutz S, Thuering B, Oberhaensli T, Mayerhofer J, Fuchs JG, Widmer F, Freimoser FM and Ahrens CH. Harnessing the Microbiomes of Suppressive Composts for Plant Protection: From Metagenomes to Beneficial Microorganisms and Reliable Diagnostics. *Frontiers in Microbiology*, 2020; 11:1810 -1825. doi: 10.3389/fmicb.2020.01810
49. Mehta, C. M.; Palni, U.; Frane-Whittle, I. H.; Sharma, A. Compost: Its role, mechanism and impact on reducing soil-borne plant diseases *Waste Management*, 34(3):607 - 622
50. Haruna, S. G. Effect of vermicomposts on vegetative growth and yield characters of tomato infected with Fusarium wilt. *ADAN Journal of Agriculture* 2021; 2 (1): 90 – 103.
51. Haruna, S. G. Integrated Management of tomato wilt incited by *Fusarium oxysporum* f. sp. *lycopersici* using host resistance and bio-enriched vermicompost. *Nigerian Journal of Mycology* 2021; 13: 176 – 192.
52. Albanell, E., Plaixats, J. and Cabrero, T. Chemical changes during vermicomposting (*Eisenia fetida*) of sheep manure mixed with cotton industrial wastes. *Biology, Fertilizer and Soils* 1988, 6: 266 – 269.

53. Edwards, C.A. and Burrows, I. (1988). The potential of earthworm composts as plant growth media. *In: Edwards, C.A., Neuhauser, E.F. (Eds.), Earthworms in Environmental and Waste Management.* SPB Academic Publishers. B. V. The Netherlands, pp. 211–220.
54. Recycled Organics Unit. Aqueous compost extract (compost tea). *Information Sheet No. 7 – 7 – 1*, 2007.
55. Recycled Organics Unit. Recycled Organics Industry Dictionary & Thesaurus. Standard terminology for the recycled organic industry, 2002. <http://www.rolibrary.com/>
56. Ghorbani, R. A.; M. Koocheki; M. Jahan and G. A. Asadi. Effects of organic fertilizers and composts extracts on organic tomato production. *Aspects of Applied Biology*, 2006; 79: 113 – 116
57. Divers, S. Compost Teas for Plant Disease Control. National Centre for Appropriate Technology, U.S. Department of Agriculture. AATRA Publication, Fayetteville, Arkansas, 1998.
58. Trankner, A. Use of agricultural and municipal wastes to develop suppressiveness to plant pathogens. Pages 38 – 42 *In: Biological Control of Plant Diseases: Progress and Challenges for the Future*, E.G. Tjanos, G.C. Papaviros and R.J. Cook (eds.) Platinum Press, New York, 1992.
59. Yohalem, D. S.; E. Y. Nordhorn and T. H. Andrews. The effect of water extracts of spent mushroom compost on apple scab in the field. *Phytopathology* 1994; 86: 914 – 922.
60. Scheuerell, S. J. and W. F. Mahaffee. Compost tea: principles and properties for plant disease control. *Compost Science and Utilization* 2002; 10(4): 313 – 338.
61. Scheuerell, S. J. and W. F. Mahaffee (2004). Compost tea as a container medium disease for suppressing seedling damping-off caused by *Pythium ultimum*. *Phytopathology* 94: 1156 – 1163.
62. Al-Dahmani, J.H.; P.A. Abbasi; S.A. Miller and H.A.J. Hointink. Suppression of bacterial spot of tomato with Foliar sprays of compost extracts under screenhouse and field conditions. *Plant Disease* 2003; 87: 913 – 919.
63. Hointink, H. A. J.; Y.; Stone, A. G. and D. Y. Hans. Suppression of plant diseases by composts. *HortScience* 1997; 32: 184 – 187.
64. Kai, H.; T. Vedia and M. Masaguchi. Anti-microbial activity of bark compost extracts. *Soil and Biochemistry* 1990; 22(7): 983 – 983.
65. Nakasone, A. K., Bettioli, W., de Souza, R. M. The effect of water extracts of organic matter on plant pathogens, *Summa Phytopathology*, 1999; 25: 330 – 335
66. Gurama, A. U., Adebitan, S. A., Haruna, S. G., Tijani, A. and Dawakiji, A. Y. Effect of compost extracts applied at different times of transplanting tomato seedlings on Fusarium wilt of Tomato. *International Journal of Bioscience*, 2013; 3(12) 1-8.
67. Basak, A. B., Lee, M. W. and Lee, T.S.. Inhibitive activity of cow urine and cow dung against *Sclero-tiniasclerotiorum* of cucumber. *Microbiology*, 2002; 30 (3): 175-179
68. Ashlesha, J. and Sugha, S. K. Cow dung preparations in the management of *Rhizoctonia solani*, *Plant Disease Research*, 2009; 24: 30- 33
69. Sinha, R. K., Agarwal, S., Chauhan, K. and Valani, D. The wonders of earthworms and its vermicompost in farm production: Charce Darwin's friend of farmers' with potential to replace destructive chemical fertilizers from agriculture, *Agricultural Science* 2010; 1: 76 – 94
70. Sang, M. K., Kim, J. G. and Kim, K. D. Biocontrol activity and induction of systemic resistance in pepper by compost water extracts against *Phytophthora capsici*. *Phytopathology* 2010; 100 (8): 774-783
71. Sugha, S. K. Antifungal potential of panchagavya. *Plant Disease Research Ludhiana*, 2005; 20: 156 – 158.

72. Dogra, S. Antifungal potential of panchagavya against some soil borne pathogensM Sc. Thesis, p 76. Department of Plant Pathology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India, 2006.
73. Angus, J. F., Gardner, P. A., Kirkegaard, J. A. and Desmarchelier, J. M.. Bio-fumigation isothiocyanates released from brassica roots inhibit growth of the take-all fungus. *Plant and Soil*. 1994; 162: 107-112.
74. Matthiessen, J. N., and Kirkegaard, J. A. Bio-fumigation and enhanced biodegradation: opportunity and challenges in soilborne pest and disease management. *Critical Review in Plant Sciences*, 2006; 25: 235 – 265.
75. Trindade, H. and Aries, A. Biofumigation: the effect of intercropping green manure or compost in the soil on the control of agricultural pests and diseases. *Agrotechnology*2011; 1:36– 37.
76. Arnault, I., du Fretay, G., Vey, F. Tissier, A., Fleurance, C. and Auger, J. Soil fumigation with Allium sulphur volatiles and Allium by-products. Proceedings, Second biofumigation conference, Moscow 26 – 29 June 2006.
77. Smolinska, U. and Kowalczyk, W. The impact of the brassicaceae plant materials added to the soil on the population of *Fusarium solani* (Mart.) Sacc and *Fusarium oxysporum*. *Journal of Horticultural Research* 2014; 22(1): 1 – 12
78. Gimsing, A. L., and Kirkgaard, J. A. Glucosinolates and biofumigation: Fate of glucosinolates and their hydrolysis products in soil. *Phytochemistry Review* 2009; 8: 299 – 310.
79. Brown, P. D. and Morra, M. J. Control of soil-borne plant pests using glucosinolate-containing plants. *Advance Agronomy*, 1997; 61: 167 – 231.
80. Gouws, R. Biofumigation: What is it, and what benefits can it add to existing farming systems? An international overview, 2004. CHIPS pp 43 – 44.
81. Van Dam, N., Tytgat, T. G. and Kirkegaard, J. Root and shoot glucosinates: a comparison of their diversity, functions and interactions in natural and managed ecosystems. *Phytochemistry Review* 2009; 8: 171 – 186.
82. Arnault, I., Fleurance, C., Vey, F., Du Fretay, G and Augur, J. Use of Alliaceae residues to control soil-borne pathogens, *Industrial Crops and Products*, 49: 265 – 272.
83. Karavina, C and R. Mandumbu. Biofumigation for crop protection: potential for adoption in Zimbabwe. *Journal of Animal & Plant Sciences*, 2012; 14 (3): 1996 – 2005 <http://www.m.elewa.org/JAPS>
84. Balesh, T., Zapata, F., and Aune, J. B. (2005). Evaluation of mustard meal as organic fertilizer on tef (*Eragrostis tef* (Zucc) Trotter under field and greenhouse conditions. *Nutrient Cycling in Agroecosystems* 73: 49 – 57.
85. Szczyglowska, M., Piekarska, A., Konieczka, P. and Namiesnik, J. Use of Brassica plants in the phytoremediation and biofumigation processes. *International Journal of Molecular Sciences* 2011; 12: 7760 – 7771.
86. Fahey, J.W., Zalcmann, A. T. and P. Talalay. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. *Phytochemistry*, 2001; 56: 5 – 51
87. Arnault, I., Vey, F., Fleurance, C. Nabil, H. and Auger, J. (2008). Soil fumigation with *allium* sulfur volatiles and *allium* by-products. 16th IFOAM Organic World Congress, Modena, Italy, June 16 – 20.
88. McGuire, A. M. Mustard green manure crops replace fumigant and improve infiltration in potato cropping system. *Agroindustria* 2004; 3: 331 – 333.
89. Kumar, P. Biofumigation, Concept Notes and Compilation of Session Guide on Biofumigation. Inter-country Programme for Vegetable IPM in South and South-East Asia Phase II (FNPP/GLO/002/NET & GPC/RAS/191/AUL. Food and Agricultural Organisation of the United Nation Nations, 2005; 34 pp.

90. Cohen, M.F., Yamasaki, H. and Mazzola, M. Modification of microbial community structure, nitric oxide production and incidence of *Rhizoctonia* root rot in response to *Brassica napus* seed meal soil amendment. *Soil Biology and Biochemistry*, 2005; 37: 1215 – 1227.
91. Haruna, S. G. Effect of soil amendments with bio-fumigant crops and animal manure on growth and yield of tomatoes infected with *Fusarium* wilt, *Ife Journal of Agriculture* 2023; 35 (2)119 – 131.
92. Katan, J., Greenberger, A., Alon, H. and Grinstein, A. Solar heating by polyethylene mulching for the control of diseases caused by soilborne pathogens, *Phytopathology*, 1976 ;66:683–688.
93. Gruenzweig, J. M., Rabinowitch, H. D. and Katan, J. Physiological and developmental aspects of increased plant growth in solarized soils. *Annual Applied Biology*, 1993; 122: 579 - 591.
94. Stapleton, J.J. Soil solarization in various agricultural production systems. *Crop Protection* 2000; 19: 837–841.
95. Raaijmakers, J. M., Paulitz, T. C., Steingberg, C., Alabouvette, C. and Moenne-Loccoz, Y. The rhizosphere: a playground and battle field for soilborne pathogens and beneficial microbes. *Plant Soil*, 2009; 321: 341 – 361.
96. Siddiqi, S. A., Bajwa, R., Khan, S. M. and Jamil, F. F. Effect of Single or Double Soil solarisation on Density of *Fusarium oxysporum* sp. *ciceri* in Field. *Pakistani Journal of Phytopathology* 2011; 23(1): 78-85
97. Barakat, R. M. and AL-Masri, M. I. (: Enhanced soil solarization against *Fusarium oxysporum* sp. *lycopersici* in the Uplands. *International Journal of Agronomy*. 2012; 1: 1 - 7.
98. Pokharel, R. and Hammon, R. Increased efficacy of biofumigation by soil solarization and integrating with Brassica meal cake and poultry manure to manage soil-borne problem in onion. Report Submitted to EPA, PESP program 2010; 23pp.
99. Stapleton, J. J. and DeVay, J. E. Soil solarization: a non-chemical approach for management of plant pathogens and pests. *Crop Protection*, 1986; 5: 190 – 198.
100. Gelsomino, L., Badalucco, L. and Cacco, G. Soil carbon, nitrogen and phosphorus dynamics as affected by solarization alone or combined with organic amendment, *Plant and Soil*, 2006; 279: (1 – 2): 307 – 325.
101. Gallo-Liobet, L and Siverio, F. Influence of soil solarization on *Phytophthora cinnamomi* in avocado (*Persea americana* MILL.). Proceedings of The World Avocado Congress III, 1995 pp. 400 – 403
102. Berbegal, M., García-Jiménez, J. and Armengol, J. Effect of cauliflower residue amendments and soil solarization on *Verticillium* wilt control in artichoke. *Plant Disease* 2008;92: 595 – 600
103. Chen, Y., J. Katan, A. Gamliel, T. Aviad, and M. Schnitzer. Involvement of soluble organic matter in increased plant growth in solarized soils. *Biology and Fertility of Soils* 2000, 1: 28 – 34.
104. Fuentes, P., Aballay, E. and Montealegro, J. R. Soil solarisation and fumigation for control of nematodes in a monocultivated soil with tomatoes. *Fitopatologia*, 1997; 32 (1): 71-80
105. Mauromicale, G., Antonino, L. M., Angela, M. G. and Alessia, R. Soil solarization, a non-chemical method to control branched bromrape (*Orabanche ramosa*) and improve the yield of greenhouse tomato. *Weed Science*, 2005; 53(6): 877 – 883.
106. Eshel, D., Gamliel, A., Grinstein, A. Di-Primo, P. and Katan, J. Combined soil treatments and sequence of application in improving the control of soilborne pathogens. *Phytopathology*, 2000; 90: 751 – 757.
107. Lodha, S. and Israel, S. Combining solar heat on farm wastes and summer irrigation for improved control of *Fusarium oxysporum* f. sp. *cumini*. In: Proceedings

- the VIth IS on chemical and non-chemical soil and substrate disinfection. A Vacchter, (ed.) ACTA Horticulture, 2005; 698, ISHS SD.
108. Hussein, A. S. Comparative efficacy of unsolarised and solarised soil interacted with neem with neem cake and Carbendazim amendments effect on *Fusarium oxysporum* f. sp. *lycopersicif* tomato, *European Academic Research* 2015; 2 (11): 14917 – 14926
 109. Klein, E., Katan, J. and Gamliel, A. Soil suppressiveness to *Fusarium* disease Following organic amendments and solarisation. *Plant Disease* 2011; 95: 1116 – 1123.
 110. Ploeg, A. T. and Stapleton, J. J. Glasshouses studies on the effects of time, temperature and amendment of soil with broccoli residues on the infestation of Melon plants by *Meloidogyne incognita* and *Meloidogyne javanica*. *Nematology* 2001; 3(8): 855 – 861.
 111. Haruna, S. G., Tijjani, A., Edun, B. T. and Sheriff, H. H. Preliminary evaluation of the use of soil solarisation and organic amendments for managing Fusarium wilt of tomato, *Savannah Journal of Agriculture* 2018; 13(1): 31 – 38.
 112. Blok, W. J., Lamers, J. G., Termorshuizen, A. J., and Bollen, G. J. Control of soilborne plant pathogens by incorporating fresh organic amendments Followed by tarping. *Phytopathology* 2000; 90; 253–259. doi: 10.1094/PHYTO.2000.90.3.253
 113. Momma, N., Yamamoto, K., Simandi, P., and Shishido, M. Role of organic acids in the mechanisms of biological soil disinfection (BSD). *Journal of General Plant Pathology* 2006; 72, 247–252. doi: 10.1007/s10327-006-0274-z
 114. Swilling K.J., Shrestha. U. Ownley,. B.H., Gwinn, K.D. and Butler D.M. Mechanisms of Anaerobic Soil Disinfection: Volatile Fatty Acids Reduce Viability of *Athelia* (*Sclerotium*) *rolfsii* *Sclerotia* in Acidic Soil Conditions and Have Limited Effects on Endemic *Trichoderma* spp. *Frontier in Sustainable Food Systems*, 2021; 5:747176.doi: 10.3389/fsufs..747176
 115. Mahadevan A. Biochemical aspects of plant disease resistance. *In- Part I: Performed inhibitory substances: Today and Tomorrows* Printers and Pub. New Delhi, India, 1982; pp. 425-431.
 116. Conventry, E. and Allan, E. J. (2001). Microbiological and chemical analysis of *Neem* (*Azadirachta indica*) Extracts: New data of antimicrobial activity. *Journal of Phytoparasitica*, 29 (5): 441-450
 117. Kimaru, S. K., Waudo, S. W., Monda , E., Seif, A. A. and Birgen, J. K. Effect of neem kernel cake powder (NKCP) on *Fusarium* wilt of tomato when used as a soil amendment, *Journal of Agriculture and Rural Development in tropics and subtropics* 2004;105(1): 63 – 69.
 118. Ghewande, M. P. Management of Foliar diseases of groundnut (*Arachis hypogaea*) using plant extracts. *Indian Journal of Agricultural Sciences*, 1989;59: 133-134
 119. Qasem, J. R. and Abu-Balan, H. A. Fungicidal activity of some common weed extracts against different plant pathogenic fungi, *Journal of Phytopathology*, 1996; 144:157 – 161
 120. Shivpuri, A, Sharma, O. P. and Thamarai, S. Fungitoxic properties of plant extracts against pathogenic fungi. *Journal of Mycology and Plant Pathology*, 1997; 27(1): 29 – 31
 121. Sheu, Z. M. and Wang, T. C. First Report of Race 2 of *Fusarium oxysporum* f. sp. *lycopersici*, the Causal Agent of Fusarium Wilt on Tomato in Taiwan. *The American Phytopathological Society* 2006; 90 (1): 111
 122. Mwangi, M. W., Monda, E. O. Okoth, S. A. and Jefwa, J. M. (2011). Inoculation of tomato seedlings with *Trichoderma harzianum* and arbuscular

- mycorrhizal fungi and their effect on growth and control of wilt in tomato. *Brazilian Journal of Microbiology* 42: 508 – 513.
123. Cerkauskas, R. Tomato Diseases: Fusarium wilt AVRDC Fact Sheet Publication, 2005; 05627.
 124. Conventry, E. and Allan, E. J. Microbiological and chemical analysis of Neem (*Azadirachta indica*) Extracts: New data of antimicrobial activity. *Journal of Phytoparasitica*, 2001; 29 (5): 441-450
 125. Akkopru, A. and Demir, S. Biological control of Fusarium wilt in tomato caused by *Fusarium oxysporum* f. sp. *lycopersici* by AMF *Glomus intraradices* and some Rhizobacteria. *Journal of Phytopathology*, 2005; 153: 544 – 550. doi: 10.1111/j.1439-0434.2005.01018.x
 126. Amini, J. (2009). Physiological races of *Fusarium oxysporum* f. sp. *lycopersici* in Kurdistan province of Iran and reaction of some tomato cultivars to race 1 of the pathogen. *Plant Pathology Journal* 8: 68 – 73.
 127. Agrios, G. N. Plant pathology, Third edition. Academic Press Inc. New York 1988
 128. Kimaru, S. K. Efficacy of neem kernel cake powder against *Fusarium* wilt of tomato, MSc. Thesis, Kenyatta University, Kenya, 1998.
 129. Sally, A. M., Randal, C. R. and Richard, M. R. Fusarium and Verticillium wilts of Tomato, Potato, Pepper and Eggplant. The Ohio State University Extension, 2006.
 130. Owino, P. O., Waudu, S. W. and Kuria, M. Control of Fusarium wilt of tomatoes using soil amendments. *East African Agricultural Journal*, 1995; 60 (4): 235-245.
 131. Jeff, G. The importance of Organic Matter in Soil Fertility and Crop Health. Organic Broadcaster. *The Bi-monthly periodical of the Midwest Organic Sustainable Education Service*, 2009; 715: 778-5775
 132. Waiganjo, M. M., Wabule, N. M., Nyongesa, D., Kibaki, J. M., Onyango, I., Webukhulu, S. B. and Muthoka, N. M. Tomato production in Kirinyaga District, Kenya. A baseline survey report, 2006; KARI/IPM-CRSP Collaborative project.
 133. Recycled Organics Unit. *Compost use for pest and disease suppression in NSW*. ROU Recycled Organics Unit, 2006. Internet publication www.recycledorganics.com. Date accessed 23rd August, 2023
 134. Singh F, Hooda J and Sindhan G.S. Biological control of tomato wilt caused by *Fusarium oxysporum* f. sp. *lycopersici*. *Journal of Mycology and Plant Pathology* 2004; 34(2): 568-570

Comment [U10]: Correct all references