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# Management tactics for fusarium wilt of tomato caused by *Fusarium oxysporum* f. sp. *lycopersici* (Sacc.): A review

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**Abstract**
Tomato is a high-esteem dietary component, adding to nourishment both country and urban populace the world over. There are many factors involved in low yield of tomato including the infestations by fungi, bacteria, nematodes or viruses and the competing weeds are predominant. Among them *Fusarium* wilt disease of tomato caused by *Fusarium oxysporum* f. sp. *lycopersici* is one of the most important and widespread disease of the cultivated tomato. It is a soil borne pathogen in the class Hyphomycetes that causes wilt of tomato as the only host of pathogen. The earliest symptoms on young plants are clearing of vein-lets and drooping of the petioles. The first symptom of *Fusarium* wilt is yellowing of the older lower leaves. Lower leaves show yellowing and die. This review archived different strategies utilized in the tactic of the malady, which is profoundly dangerous in both nursery and field developed tomatoes. The most cost-effective and ecologically well-disposed technique being the Integrated Disease Management (IDM) which are been pushed for so that won't be unsafe to the environment, valuable organisms, plants, creatures and human lives. However, efforts should be on examining and developing their efficacy, efficiency and durability on the fields and not just in the greenhouse.

**Keywords:** tomato, *fusarium* wilt, management, environment, symptom

## Introduction

Tomato (*Lycopersicon esculentum* Mill.) has a place with the family Solanaceae and it is viewed as one of the world's most mainstream vegetables (Pritesh *et al*., 2011) [65]. It is the most important tropical vegetable crop widely used throughout the world (Hadian *et al*., 2011). It is a high-value horticultural crop for the local market and an important dietary component, contributing to improved nutrition and livelihood for both rural and urban population (Waiganjo *et al*., 2006) [82]. The organic products are utilized crisp in plates of mixed greens or cooked as a vegetable, in handled structure as tomato glue (puree), tomato sauce, ketchup, squeeze and can likewise be dried. They are wealthy in nutrients mostly A and C and are picking up significance since it contains lycopene, a sustenance part known to lessen the frequency of prostate malignant growth, heart and age related maladies (AVRDC, 2003) [14].

Tomato is genuinely versatile, yet develops well in warm conditions with ideal temperatures of 15 $^0$C - 25 $^0$C. High humidity and temperatures lessen natural product set and yields. Exceptionally low temperatures defer shading arrangement and aging while temperatures over 30 $^0$C repress natural product set, lycopene advancement and flavor. Tomato flourishes best in low to medium precipitation with valuable water system amid the off season. Wet conditions increment disease assaults and influence fruit ripening Tomatoes grow well in a wide range of soil types which are high in organic matter, well drained and a pH range of 5-7.5(Waiganjo *et al*., 2006; Hanson *et al*., 2001) [82]. Tomato plants prefer soil that is well drained and heavily amended with organic matter. The soil should have good moisture retaining capacity. Elevation of between 1000 m to 2000 m above sea level is suitable for tomato growth (Robert, 2005).

India ranks second in the area as well as in production of Tomato. The major tomato growing countries are China (30.7%), India (11.5%), USA (8.1%), Turkey (7.0%) and Egypt (5.3%). In India, it is being grown in about 7.67 lakh hectares with an annual production of 163.85lakh metric tons (Horticultural Statistics at a Glance 2017). Yield loss due to this disease is 25.14-47.94% in Uttar Pradesh (Enespa and Dwivedi, 2014) [26] has been recorded.

However, many constraints affect productivity and quality of tomato among which diseases play a salient role (Pritesh *et al*., 2011) [65]. The most common diseases of tomato include early blight, anthracnose, bacterial wilt, bacterial canker, tomato spotted wilt, *Verticillium* wilt and *Fusarium* wilt (Winand *et al*., 1999) [84]. The wilt diseases are caused by bacteria (*Ralstonia solnacearum*) and fungi *Verticillium* and *Fusarium* spp. (Mardi *et al*., 2002) [50]. Tomato *Fusarium* wilt is considered as one of the most important diseases of tomato both in field and greenhouse-grown tomatoes worldwide (Abdel-Monaim, 2012; Amini *et al*., 2010) [1, 9].

## Pathogen

*Fusarium oxysporum* f. sp. *lycopersici* (Sacc.) (W.C. Snyder and H.N. Hans), a soil borne plant pathogen in the class Hyphomycetes, causes *Fusarium* wilt specifically on tomato. There are more than 100 *Fusarium* vascular wilt diseases worldwide. Apart from causing diseases, they colonize outer cells of roots as harmless endophytes after the pathogen has killed the root tissues and others live as saprophytes in soil (Burgess *et al*., 2008) [18-19]. The pathogen has three physiological races (1, 2, and 3, hereafter r1, r2 and r3) and are distinguished by their specific pathogenicity on tester plants carrying dominant race-specific resistance genes (Cai *et al*., 2003).

This disease was first described by G. E. Massee in England in 1895. It have worldwide importance where at least 32 countries had reported the disease, which is particularly severe in countries with warm climate (Mui-Yun, 2003) [55]. The *Fusarium* fungus is a known pathogen of tomato plant (Suarez *et al*., 2007) which is present in all important tomato growing regions of the world (Mohammed, 1990) [52] and produces three types of asexual spores; microconidia, macroconidia and chlamydospores (Arios, 1988). Some strains of *Fusarium oxysporum* are not pathogenic and may even antagonize the growth of pathogenic strains and can be used as biological agents (Fravel *et al*., 2003) [28].

## Symptoms of *Fusarium* Wilt Disease on Tomato

The fungus directly penetrates roots and colonizes the vascular tissue (Inoue *et al.,* 2002) [36]. The symptoms of *Fusarium wilt* range from stunted growth, yellowing and wilting of the leaves, reddish discolorations of the xylem vessels (visible inside the stem as lines or dots in cross section) and white, pink or orange fungal growth on the outside of affected stems (particularly in wet conditions), to root or stem decay.

Symptoms of attack first appear as slight vein clearing on the outer portion of the young leaves followed by epinasty of the older leaves (Sally *et al*., 2006) [72]. This symptom often occurs on one side of the plant or on one shoot. Successive leaves yellow wilt and die, often before the plant reaches maturity. As the disease progresses, growth is typically stunted, and little or no fruit develops. If the main stem is cut, dark brown streaks may be seen running lengthwise through the stem. The browning of the vascular system is characteristic of the disease and generally can be used for its identification (Mui-Yun, 2003) [55]. On the outside of affected stems, white, pink or orange fungal growth can be seen especially in wet conditions (Ajigbola and Babalola, 2013) [6].

Walker (1971) [83] and Jones *et al*. (1991) showed that the symptoms often occur on mature plants after flowering and at the beginning of fruit 21 setting. Initial symptoms can appear as slight wilting on part of the plant. Chlorotic symptoms being to appear on one side of leaf, then leaf lets become yellow on one half of the leaf. As symptoms progress, wilting is often associated with one side of the plant.

## Etiology of fungus

The detail description of *Fusarium oxysporum* f. sp. *lycopersici* was given by several workers (Gerlach and Nirenberg, 1982; Upadhyay and Rai, 1987) [33, 81] which are as follows:

- **Macro-conidia: -** Fusiform, hyaline, mostly two to three septets and measure 2.5- 3.3 x 3.5-5.5µ in size.
- **Micro-conidia: -** Microconidia are one celled, hyaline and ovoid to ellipsoidal and measure 2.5- 4 x 6-15µ in size.
- **Chlamydospore: -** Formed in older mycelium

## Ecology and Dissemination of the Pathogen

The causal agent of *Fusarium* wilt is soil borne pathogen which can persist many years in the soil without a host. Most infections originate from the population associated with infected tomato debris. Healthy plants can become infected by *F. oxysporum* if the soil in which they are growing is infested with the pathogen (Farr *et al*., 1989) [28] *Fusarium oxysporum* occurs, survives and grows in soils of all types, but sandy soil provides conditions that are most favorable for growth and development (Lowell, 2001). The pathogen is soil borne and stays in invaded soil for as long as ten years. Soil and air temperatures of 28 0C are ideal for illness. If soil temperatures are optimum but air temperatures below optimum, the pathogen will extend into the lower parts of the stem, but the plants will not exhibit external symptoms (Mui-Yun, 2003) [55].

The pathogen is primarily spread over short distances by irrigation water and contaminated farm equipment (Stephen *et al*., 2003) [76] but can also be spread over long distances either in infected transplant or soil (Agrios, 1988) [5]. The disease can likewise be transmitted through infected plant material and through contaminated soil. Different method for spreading the disease is through human movement around the infected field, or the use of irrigation water and implements previously used on an infected crop (Ajilogba *et al*., 2013).

## Disease Epidemiology

The pathogen enters the plant through root tips (Sally *et al*., 2006) [72] and can remain viable in the soil for up to 30 years (Thanga velu *et al*., 2003) [79]. The mycelium grows in the xylem vessels where they cut off water supply resulting to wilting (Stephen *et al*., 2003) [76]. There is often an association of *Fusarium* wilt and nematode colonization where the nematodes provide entry route for the fungus. Enzymes may also facilitate *Fusarium* penetration into plant host (Babalola, 2010). Infection and disease development in *Fusarium* wilt is favored by warm soil temperature and low soil moisture (Lewis, 2003) [48]. The disease tends to be most severe in sandy soils and generally less of a problem in heavier clay soils (Larkin *et al*., 2002) [42].

## Management of Fusarium Wilt Disease

*Fusarium* wilts are generally presumed to be monocyclic - that is, the disease does not exhibit plant-to-plant spread during the season (Egel and Martyn, 2007) [24]. This is primarily because there are no propagules capable of dissemination to other plants to cause secondary infections that form above ground until very late in the season. However, the time of appearance of symptoms and the rate of disease progression in plants may vary considerably within a field, giving the appearance of secondary spread. There is some evidence that suggests some *Fusarium* wilts, for example, *Fusarium* wilt of tomato, may be a polycyclic disease capable of significant secondary spread during the season (Egel and Martyn, 2007) [24].

There is some evidence that suggests some *Fusarium* wilts, for example, *Fusarium* wilt of tomato, may be a polycyclic disease capable of significant secondary spread during the season (Egel and Martyn, 2007) [24]. Tillage practices, flooding or heavy rain, contaminated farm equipment, and other cultural or environmental factors may be involved. Field-to-field spread can occur when equipment and infected plants are moved from one field to another. It is possible that macro conidia formed on the decaying vines on the soil surface could be blown short distances and aid in the spread. Apart from total crop loss, other losses result from loss in marketable yield i.e., fruit that is formed but cannot be sold because they are too small, misshapen, low in nutrients, or may be cracked or sunburned. The control of *Fusarium* wilt of tomato is critical in keeping up plant vigor and natural product quality and amount. Though *Fusarium* wilt is a difficult disease to control according to (Elmer, 2006) [25] and (L. Haridon *et al*., 2011) [44], numerous strategies have been proposed to control this fungal pathogen (Biondi *et al*., 2004; Ahmed, 2011). However, attempts to control the disease have experienced limited success due mainly to emergence of new pathogenic races (Juliano *et al*., 2005). Recorded strategies that are utilized in the control of the, disease include cultural, biological, use of resistance, chemical and use of natural products, (Pottorf, 2006) [64] and utilization of characteristic items (Kimaru *et al.*, 2004).

**Cultural Control**

Cultural control includes practices and cultivating procedures that will build the quality and amount of the yield and furthermore decrease the impact of pests and maladies. It includes manipulation of the environment in non- mechanical ways to control plants pests and diseases.

It includes altering farming practices to make the environment unfavorable for the growth of disease pathogens and pests (Islam, 2001) [37]. It is also the purposeful manipulation of a garden or farm in the growing, planting and cultivation of plants to reduce plant disease, pest damage and numbers of pests. It has been shown that the correct implementation of cultural methods to control soil borne pathogens yields improved soil structure and consequently decreases incidence (Neshev, 2008) [58, 59]. Crop rotation helps to reduce the amount of pathogens in the soil. For it to effectively control a soil borne pathogen, the pathogen must be completely eliminated along with the plant residues from the farm land (Neshev, 2008) [58, 59]. These methods are mainly preventive and a good knowledge of the nature, behavior and environmental conditions of the growth of the disease agent is very important to controlling the disease development. However, management of seed borne and soil borne diseases such as wilt caused by *Fusarium* species has always been problematic (Rao and Balachadran, 2002) [67]. Crop rotation with non-solanaceous crops for four to six years is usually recommended to avoid pest problems common to this group of vegetables by reducing the populations of these fungi. The crop should be rotated with grasses and cereals whenever possible (Sally *et al*., 2006) [72].

Mulching, which is the addition of a thick layer of mulch on the soil surface help control weed, optimize soil moisture and keep the soil cool. This helps create unfavorable conditions for soil borne pathogens thereby controlling diseases (Raid, 2011). Mulching also avoid splashing of soil borne diseases on tomato leaves during watering (Francis, 2012).

Intercropping of tomato and maize should be encouraged as the tomato gets shade from the maize and is produced out of season, thereby increasing the farmer's yield and income. In Cuba this method increased annual yield by 5-6 tonnes/ha (Wol fswinkel, 2010).

Weed control by destroying susceptible diseased weeds helps to reduce the incidence of transfer of pathogens like *Fusarium* spp. to plants. Excessive handling of plants, which includes tying, thinning and pruning, result to wounds and increase their susceptibility to *Fusarium* wilt pathogen (Ajigbola and Babalola, 2013) [6].

**Biological Control**

Biological control increasingly capturing the attention of plant pathologist all over the world as a possible means of controlling soilborne pathogen. Among the bacterial antagonists species of Arthobacter, Bacillus and Pseudonomas (Kapoor and Kar, 1988) [41]. Lemanceae and Alabouvett (1991) [47], Fuchs *et al.* (1997) [31] mentioned that several 30 biological control agents including bacteria and non- pathogenic strains of *Fusarium oxysporum* have shown promise for the control of *Fusarium* wilt of tomato. In general, biological control agents have been more effective at reducing Fusarium wilt in tomato under controlled greenhouse conditions than under field conditions. Panteleev (1972) [62] reported that coating seed with culture of *Trichoderma viridae* lowered incidence of *Fusarium oxysporum* f.sp. *lycopersici* on tomato from 29.5 to 6–15%

To provide an environmentally friendly *Fusarium* disease control system, the use of antagonistic microorganisms represents an alternative disease management strategy (Lugten berg and Kamilova, 2009) [49]. The mechanisms adopted by biological control agents could be direct, indirect or mixed (Pal and Gardener, 2006) [61]. The use of bio agents was reported quite effective to control *Fusarium* wilt disease on tomato (Freeman *et al*., 2002) [30]. According to (Momol *et al*., 2003) [53] various studies have reported the suppression of plant pathogens by thermophilic organic compost including *Rhizoctonia, Phytopthora, Plasmidiophora brassicae*, *Gaeumannomyces graminis* and *Fusarium* (Pitt *et al*. 1998, Kannangowa *et al.* 2000, Cotxarrera *et al.* 2002) [63, 40, 22]. Traditionally produced thermophilic organic composts support the growth of selected microbes while vermin composts harbor vast microbial diversity and activity. Presence of a wide range of antagonistic bacteria in vermin compost ensures the effective biocontrol of soil borne phyto pathogenic fungi (Scheuerell *et al*. 2005, Singh *et al*. 2008). Several isolate of non-pathogenic *Fusarium* spp. (*F. oxysporum* and *F. solani*) that effectively controlled *Fusarium* wilt in greenhouse test have been identified. The isolates include CS-20, CS-1, CS-24 and Fo 47 of which was consistently effective when applied at high rate. (Attitala *et al*. 2001) [13] showed that after spraying with zoospores of *Phytophthora cryptogea* followed by *Fusarium oxysporum* f. sp. *lycopersici* inoculation, tomato plants show no wilt disease.

Also, in another studies conducted by (Akkopru and Demir 2005) [7], arbuscular mycorrhizal fungi (AMF) *G. intraradices* and some Gram-negative and fluorescent rhizobacteria (RB), *P. fluorescens, P. putida* and *Entero bactercloaceae*, isolated from the rhizoplane of solanaceous plants were effective against *Fusarium oxysporum* f. sp. *lycopersici*. (Monda, 2002) [54] reported that bacterial bio control agents with promising bio control activities against *Fusarium oxysporum* f. sp. *lycopersici* include *Peudomonas flourescens, P. putida, P. chlororaphis*, *Bacillus subtilis, Streptomyces pulcher, S. corchorusii*and *S. mutabilis.* Rhizobacteria which may act directly as bio fertilizer, and bio stimulants through production of plant growth hormones such as indole acetic acid, gibberelin, cytokinin, ethylene, dissolved minerals, and also indirectly prevents the development of pathogenic microorganisms through siderophore, and antibiotic production (Mc Milan, 2007; Sarma *et al.*, 2009) [73, 59].

(Widnyana *et al*., 2013) reported that three isolates of rhizobacteria isolated from the rhizosphere plants of the families Solanaceae and Leguminoseae namely KtS1, TrN2 and TmA1 and identified as *Pseudomonas alcaligenes* exhibited antagonistic activity against *Fusarium oxysporum* f. sp. *lycopersici* by effectively reducing the incidence of wilt disease on tomato under greenhouse experiment.

Biological agents are reported to induce the growth of various crops. These responses may be due to (i) suppression of deleterious root micro-flora including those not causing obvious disease, (ii) production of growth stimulating factors (iii) increased nutrient uptake through solubilization and sequestration of nutrients and/or enhanced root growth. The genus *Trichoderma* is among the most prominent and commonly used organisms for plant growth promotion and biological control of plant pathogens (Tronsmo and Hjeljord, 1998).

**Use of Resistance Cultivar**

The most cost-effective and environmentally safe method of control is the use of resistant cultivars where they are available. The use of resistant varieties is the best strategy for the disease control (Sheu *et al*., 2006) [74] and also one of the most effective alternative approaches to controlling wilt disease (Singh, 2005). But, due to breakdown of resistance in the face of high pathogenic variability in the pathogen population, the usefulness of many resistant cultivars is restricted to only a few years (Kutama *et al*., 2011).

Cultivars resistant to or tolerant to Fusarium wilt are available for some plants, e.g. peas and China aster. However a cultivar that is resistant to a particular forma specialis may not be resistant to the other races of the same forma specialis (Burgess *et al*., 2008) [18-19]

According to (Pritesh *et al*., 2011) [65] identification and utilization of tomato plant varieties resistant to the disease represents a valid alternative to the use of chemicals. However, breeding for resistance can be very difficult when no dominant gene is known. In addition, new races of pathogens overcoming host resistance can develop (Allopru *et al*., 2005; Momol *et al*., 2003) [53]. The advantages of this method include saving the cost of chemical for control of the disease and enhancing cultivation of previously infested field.

**Chemical Control**

Agricultural chemicals are commonly used for management of pests and diseases. Seed treatment with synthetic fungicides considerably reduce wilt incidence in tomato. However, their use is costly as well as environmentally undesirable (Song and Goodman, 2001) [75].

Fungicides are main management tool of plant diseases but bio agents specially *Trichoderma* species also success to control pathogenic activities of plant pathogenic fungi (Taran, 2000) [78]. To adopt a suitable management strategy for managing *Fusarium* wilt of tomato is therefore of paramount importance Some of these chemicals include prochloraz, propiconazole, thiabendazole, carbendazim, benomyl, thiophante, fuberidazole and all of the benzimidazoles. (Nel *et al*. 2007) [56] reported that benomyl was partly effective against *F. oxysporum* f. sp *cubense* using the root dip treatment method. This method was applied to using carbendazimal on tomato seedlings infected with *Fusarium* wilt and it led to about 24% increase in yield (Khan and Khan, 2002) [42].

The high frequency of chemical use, non-target effects, development of resistance to many chemicals, pathogens which remain viable for many years and risks to human health and the surrounding environment have stimulated development of alternative methods for disease management. Moreover, pesticides generally are more effective against aerial plant pathogens than their soil-borne counterparts (Recycled Organics Unit, 2006) [68]. It is also technically difficult to treat large amount of soil, and the range of approved chemicals is declining as active compounds are withdrawn for toxicological and environmental reasons, for example, methyl bromide has been phased out due to its extremely high ozone depleting potential.

The current trend to near zero-market tolerance for pesticide residues in fresh leafy vegetables provides an additional motivation to search for non-chemical means to control pests and diseases (Reuveni *et al*., 2002) [69]. *Fusarium* wilt is controlled by disinfecting the soil with methyl bromide, chloropicrin or metham sodium. Systemic fungicides such as benomyl, thiabendazole and thiophanate have been used to control *Fusarium* wilt.

However, sustainable use of fungicides in *Fusarium* wilt management is difficult due to development of resistant isolates and damaging effects on the natural environment, the agro ecosystem and human beings (Pritesh *et al*., 2011; Dewaard *et al*., 1993) [65]. The excessive misuse of a wide range of fungicides has resulted this to be harmful to the environment and increased the resistant pathogen populations (Ogzonen *et al*., 2001) [60].

Prochloraz has shown to be very effective against Fusarium wilt of tomato and banana (Song *et al.*, 2004; Nel *et al*., 2007. In addition to other potential health, safety and environmental risks, methyl bromide was classified as an ozone-depleting compound and has been banned from use. Larkin and Fravel, 1998, Biological control of *Fusarium* wilt can offer a potential alternative to chemical fungicides. Alwathnani *et al*., 2012 [8].

Chemical control measures create imbalances in the microbial community, which may be unfavorable to the activities of the beneficial organisms and may also lead to the development of resistant strains of pathogens. Pollution of the soil by overuse of chemicals has also led to harmful effects on humans (Asaka and Shoda, 1996) [11]

**Use of botanical extracts**

Though many research efforts have been carried out to find alternative and environmentally safe methods to control plant diseases (Agbenin *et al*., 2004) [3], the use of plant products for the control of *Fusarium* wilt in crops is limited (Agbenin and Marley, 2006) [2].

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. The demand of plant based therapeutics is increasing in developing countries as they are natural products easily available and having no harmful effects. The present study was undertaken to evaluate some plant extracts against *Fusarium oxysporum f. sp. lycopersici* causing wilt disease of tomato.

Tests done by Kimaru *et al*. 2004 revealed that neem cake powder contains ingredients that have fungistatic effects against *Fusarium* wilt of tomatoes. Similar findings were also reported by (Coventry *et al.*, 2001) as the neem extracts were found to possess antimicrobial activity with notable effects on some fungal pathogens. (Hanaa *et al*., 2011) [35] investigated the effect of *Azadirachta indica* (Neem) and *Salix babylonica* (Willow) 10% aqueous extracts on *Fusarium* wilt disease in tomato and revealed that the

percentage of disease incidence was reduced to the level of 25.5% and 27.8% after 6 weeks of infection respectively.
(Agbenin and Marley 2006) [2] reported that crude extracts of neem (*Azadirachta indica*) and garlic (*Allium sativum*) at concentrations ranging from 5% to 30% of thematerial in 100 ml of potato Dextrose Agar inhibited mycelial growth of *Fusarium oxysporum* f. sp. *lycopersici* at various levels. Dry neem seed extract gave 100% inhibition. Fresh neem leaf extract reduced mycelial growth with increasing concentration while in garlic; there is no difference in growth inhibition among the various concentrations used. (Umar *et al.*, 2013) [80] studied the influence of different quantities (0.0, 25, 50, 75 and 100 g/ha) of farm yard manure (FYM) on the growth and disease incidence of *Fusarium* wilt on tomato and reported that there was consistently significant reduction in the incidences and severities of tomato wilt due to *Fusarium*, which suggest that it could be beneficial to farmers in the reduction of wilt caused by *Fusarium* for higher yield tomato production in northern Nigeria.

**Physical method**
**Soil Solarization**
This is done by spreading a clear plastic sheet over the soil for several weeks. This helps to trap solar energy which in turn inhibits soil borne diseases, nematodes, insects and many weed seeds. This is usually done during the summer when the air temperature is high and there is intense radiation (Ploeg and Stapleton, 2001). Combination of soil solarization and two layers of mulching decrease the rate of fungal infection in plants (Garibaldi and Gullino, 1991).
Hot water can be used according to Tetaya (2001) and can keep the soil sterilized for up to three years. Steam can also be used especially in greenhouse conditions. (Gullino, 2001). Soil disinfection helps to keep the soil sterile and free from disease causing pathogens.
Combination of soil solarization and two layers of mulching decrease the rate of fungal infection in plants. (Garibaldi and Gullino, 1991)

**Integrated Disease Management**
Integrated Disease Management (IDM) is recognized as an effective approach for increasing agricultural productivity and combating environmental degradation in developing countries (Waiganjo *et al.,* 2006) [82]. 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 (Recycled Organics Unit, 2006) [68].
The inclusion of green manures and cover crops in a rotation is an excellent way to sponsor fertility, suppress weeds and provide a break in pest cycles (Jeff, 2009) [38]. Incorporating several different species of crops in a rotation, along with manures and/or compost, ensures a diversity of organic matter sources. This diversity leads to a more minerally balanced soil and a pool of nutrients which become available slowly over time, reducing leaching, waste and toxicity that can result from immediately-available inorganic fertilizer additions (Jeff, 2009; Recycled Organics Unit, 2006) [38, 68].
Crop rotation with non-similar crops such as cabbage and cauliflower for at least 4-5 years, use of disease resistant cultivars, use of natural antagonistic organisms especially bacillus based biological control agents (BCAs), farm hygiene and the use of chemicals such as prochloraz and methyl bromide are some of the integrated control strategies for the control of *fusarium* wilt of tomato (Ajilogba *et al*., 2013). Ultimately, managing for good soil fertility is extremely important because the soil environment and the surrounding air environment are in reality virtually inseparable, and the establishment of a functional and stable system in one environment can have far-reaching impacts in the other (Dishon, 2012) [23].

**Conclusion**
In conclusion aside from looking at the fact that these methods are working in different ways, efforts should be on examining and developing their efficacy, effectiveness and durability on the fields and not just in the greenhouse. The distinct formulations of microbial products that will give the most proficient result should also be considered very important in biological control. Area of interest should therefore be on educating farmers on the appropriate use of cultural practices and their integration into other strategies for a better and a safer result.

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