Bio-intensive management of major soil borne diseases of tomato in Uttarakhand

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ABSTRACT: A glasshouse and field experiments were conducted by using Trichoderma harzianum (Th 43), Pseudomonas spp. (Pf 173) and Jas Mycorrhizal (AMF) for plant growth promotion and management of root rot and wilt disease of tomato. There were eight treatment combinations for glass house as well as field experiment. In glasshouse, maximum germination (91%), shoot and root length (40.83 cm, 9.79 cm), fresh and dry shoot weight (152.00 g, 28.38 g), fresh and dry root weight (9.33 g, 3.90 g), plant vigour index (4301.45) respectively was recorded in treatment combination of Th 43 + Pf 173 + AMF. In experimental field, maximum reduction of disease over control (72.16%) was found in treatment combination of T. harzianum (Th 43) + Pseudomonas spp. (Pf 173) + Jas Mycorrhiza (AMF). The maximum yield of tomato (486.70 q/ha) was also recorded in same treatment combination.

Key words: Growth promotion, Jas mycorrhizal, Pseudomonas spp., Trichoderma harzianum

INTRODUCTION

Tomato (Lycopersicon esculentum Mill.), is the most widely grown vegetable crop in the world (NHB database 2013). Because of its colour, taste, high nutritive value and diversified use, tomato is the most popular vegetable worldwide. Tomato is fairly adaptable, but grows well in warm conditions at an optimal temperature range of 15°C-25°C at an elevation ranging from 1000 to 2000 meter above sea level. High humidity and low temperature reduce fruit set, yield and quality. Very low temperature delays colour formation and ripening, and high temperature, i.e., 30°C, inhibits fruit set, lycopene development and flavour. Tomato crop thrives best in low to medium rainfall with supplementary irrigation during the off-season. Wet conditions increase disease attacks and affect fruit ripening. Well drained soil with good moisture retaining capacity, high organic matter and pH range of 5.0-7.50 are suitable for tomato cultivation (Robert, 2005; Waiganjo et al., 2006). In India, tomato is cultivated in 882 thousand ha area having production of 18,735.9 thousand metric tons with productivity of 21.24 mt/ha. Uttarakhand contributes an area of 9.08 thousand ha with the production of 113.65 thousand metric ton (Indian Horticulture Database, 2014). Diseases of tomato act as the major limiting factor in quality and productivity. Over 200 diseases have been reported to affect the tomato plants in the world (Watterson, 1986). Soil borne diseases like damping-off of seedlings, wilt and root rot are caused by several species of Fusarium, Pythium, Rhizoctonia and Verticillium etc. causing serious losses in tomato crop. These diseases are widely distributed throughout the world and can significantly reduce the yield and quality of tomato crops (Agrios, 2005). Generally chemicals have been used to manage these diseases over the years. In the beginning, use of chemical pesticides led to remarkable improvements in the productivity. However, the non target effect of these pesticides led to the resistance development in pests. residue in food chains leading to deleterious effect on human health and environment. Due to the excessive use of pesticides, cost of crop production has also increased. Pesticides are toxic in nature and are equally harmful to human beings if applied injudiciously (Abhilash and Singh, 2009). Of late misuse of chemicals has become the most serious environmental issue (Leoz et al., 2013). The challenge today is how to achieve not only food security but also food safety by employing effective as well as environmentally benign measure for management of plant pathogens. Biological control can be achieved either by introducing biocontrol agents directly into natural ecosystem or by adopting practices, which favour population build-up of biocontrol agents under natural conditions. Combination of both the approaches is probably ideal. Prominent among
biocontrol agents is *Trichoderma* which has been recognized as bio-pesticide since long to manage plant diseases as well as bio-fertilizer to increase plant growth and development. It strengthens the plant for its reproductive capacity, ability to survive under unfavorable conditions, increased utilization of nutrients, capacity to modify the rhizosphere and initiates strong aggressiveness against phytopathogenic fungi (Harman, 2000).

Fluorescent *Pseudomonads* are known to improve plant growth by a variety of mechanisms including production of siderophores, synthesis of antibiotics, production of plant growth hormones, enhancement of mineral uptake and synthesis of enzymes that regulate plant ethylene levels (Kloepper et al., 1986; Glick, 1995). Equipped with these abilities, fluorescent pseudomonads are also being exploited as potential crop protectants.

Arbuscular Mycorrhizal Fungi (AMF or AM fungi) are found in the roots of about 80-90 percent of plant species and mutually benefit in a typical symbiotic relationship (Wang and Qiu, 2006). They represent an interface between plants and soils, the mycelia of mycorrhiza grow both inside and outside the plant roots. AMF provide soil mineral nutrients (mainly phosphorus and nitrogen), water and pathogen protection to the plant (Bonfante and Genre, 2010). As a consequence of the above mentioned facts, ecological approaches are now being explored for sustainable plant disease management. The challenge today is to achieve food safety and its sustainability besides food security. Hence to achieve this goal this study was carried out to testing *Trichoderma harzianum* (Th 43) and *Pseudomonas* spp. (Pf 173) and Jas Mycorrhiza (Arbuscular Mycorrhizal fungus), alone and in combination for growth promotion and control of major soil born diseases under field condition.

**MATERIALS AND METHODS**

**Study site**

Glasshouse experiment was conducted in glasshouse of center of advance faculty training, Department of Plant Pathology, College of Agriculture, G. B. Pant University of Agriculture and Technology Pantnagar, U.S. Nagar-263145, Uttarakhand (India). The field experiment was conducted at Vegetable Research Centre (VRC), G.B. Pant University of Agriculture and Technology, Pantnagar. The centre is situated in the foothills of Himalayas at an altitude of 243.84 m above mean sea level at 29° North latitude and 79.3° East longitude. The climate is humid subtropical with maximum temperature ranging from 32°C to 43°C in summer and minimum ranging from 0°C to 19°C in winters. Monsoon occurs form 3rd week of June to middle of September. The frost is experienced from last week of December to the end of February.

**Experimental Material**

**Seeds:** Tomato seed of variety TO- 1458 (Syngenta India Ltd) was used in the investigation.

**Soil:** Soil collected from Crop Research Center, Pantnagar was used for glasshouse experiment after sterilization.

**Vermicompost:** Vermicompost obtained from Livestock Research Center, Pantnagar was used for colonization of bioagents and as carrier of microbes in field experiment.

**Microbes formulations:** Tale-based formulations of *Trichoderma harzianum* (Th 43) (NCBI Acc. MK044000.1 and *Pseudomonas* spp. (Pf 173) were obtained from Biocontrol Laboratory, Department of Plant Pathology, G. B. Pant University of Agriculture and Technology, Pantnagar. The Jas Mycorrhiza (Arbuscular Mycorrhizal fungus) manufactured by Shri Ram Solvent Extractions Pvt. Ltd, Jasipur, District Udam Singh Nagar, Uttarakhand, was used in the experiment.

**Evaluation of biocontrol agents for growth promotion under glasshouse condition**

A glasshouse experiment was conducted to test plant growth promotion effect of Th 43, Pf 173 and JM in a Completely Randomized Design (CRD) with three replications. Ten kg capacity plastic pots were filled with sterilized, well pulverized sandy-loam soil and treated as per given treatments. Untreated soil was kept as control. Fifteen seeds were sown in each pot. Observation on seed germination was recorded on 15 Days After Sowing (DAS). Thereafter, 5 plants per pot were maintained for 45 days to assess growth promotion effect. Watering of pots was done when required to maintain optimum level of moisture. In order to keep the plants free from insect pests, one spray of Metasystox (0.1 per cent) was given at 20 DAS.

**Treatments for glasshouse experiment**

1. *Trichoderma harzianum* (Th 43) @ 10 g/kg
2. *Pseudomonas* spp. (Pf 173) @ 10 g/kg
3. Jas Mycorrhiza (JM) @ 100 g/kg
4. Th 43 + Pf 173 @ each 5 g/kg
5. Th 43 + JM @ 10 g + 100 g/kg
6. Pf 173 + JM @ 10 g + 100 g/kg
7. Th 43 + Pf 173 + JM @ 5 g + 5 g + 100 g/kg
8. Control

**Observations**

Observation on seed germination was recorded at 15 DAS, while observations on shoot length (cm) and weight (g) and root length (cm) and weight (g) were recorded at 45 DAS.

**Seed germination (%)**

Seed germination (%) was recorded by using following formula
Seed germination (%) = \frac{\text{Number of seeds germinated}}{\text{Number of seeds sown}} \times 100

**Shoot and root length**

After 45 days of sowing, all the 5 plants were uprooted from each replication treatment. The plants were cut at crown level to separate the root and shoot portions. Shoot length (cm) was measured from highest apical bud to crown level and root length (cm) was measured from crown level to highest apical root apex.

**Fresh shoot and root weight**

After the measurement of shoot and root length, the fresh shoot and root were weighed (g) separately on electronic balance.

**Dry root and shoot weight**

After recording the fresh shoot and root weight, the same plants were kept in hot air oven at 80°C for 24 hrs for complete drying. After drying, root and shoot weight (g) were measured on electronic balance.

**Vigour index**

Vigour Index was calculated by using the seed germination per cent and shoot and root length of plant as below:

\[
\text{Vigour Index} = \frac{\text{Shoot length} + \text{Root length}}{\text{Germination per cent}}
\]

**Field evaluation**

The field trial was conducted during Kharif season of 2013-14 at Vegetable Research Center, GBPUAT Pantnagar. Bio-control agents, Th and Pf and Arbuscular Mycorrhizal Fungi (Jas Mycorrhiza), individually and in combinations were applied at the time of transplanting of seedlings. Experiment was set in a Randomized Block Design (RBD) maintaining three replications for each treatment.

**Field preparation**

Experimental field was prepared by one deep ploughing followed by three harrowing and leveling leading to fine and well pulverized soil. Before final leveling of the field, NPK was applied in the form of urea (40 kg), single super phosphate (80 kg), muriate of potash (60 kg) as basal application. Urea as nitrogenous fertilizer was applied @ 20 kg/ha each after 30 days of transplanting and 60 days of transplanting as top dressing.

**Seed root and shoot weight**

Tomato seeds of cultivar TO-1458 were sown in nursery bed in the month of August 2013 for raising seedlings. After sowing, seed bed was covered with mulch of dry straw to maintain soil moisture. Light irrigations were given at frequent intervals. After germination of seeds, mulch was removed from the seed bed. Standard agronomical practices were followed for raising the seedlings.

**Transplanting**

Tomato seedlings were uprooted from nursery beds 25 days after transplanting (DAT). Vermicompost colonized with bioagent was applied in the soil just before transplanting. The plot size was 2.5 x 2.5 m. A spacing of 50 cm between row to row and plant to plant was maintained. Six foliar sprays of mancozeb (INDOFIL) @ 3 g/liter of water were given first at 40 Days After Transplanting (DAT) rest five in fifteen days intervals after first spray to avoid foliar diseases. To keep the experimental field free from insect pests, four sprays of Metasystox (0.1%) were given at 25, 40, 60 and 80 (DAT). The untreated seedlings served as control. The experiment was laid out in a Randomized Block Design (RBD) with eight treatments, each with three replications.

**Treatments for field experiment**

1. *Trichoderma harzianum* (Th 43)
2. *Pseudomonas* spp. (Pf 173)
3. Jas Mycorrhiza (JM)
4. Th 43 + Pf 173
5. Th 43 + JM
6. Pf 173 + JM
7. Th 43 + Pf 173 + JM
8. Control

**Mode of application**

Bioagents Th and Pf were multiplied on vermicompost (@ 10 g/kg) separately as well in combinations (5 g+5 g/kg). The colonized vermicompost was applied (@ 50 g/plant) in each plant just before transplanting. The Jas Mycorrhiza (@ 100 g/kg) mixed in vermicompost, with or without colonized with bioagents was applied @ 50 g/plant in the soil just before transplanting.

**Observations**

Data on disease incidence was recorded 30, 45, 60 Days After Transplanting (DAT) for wilt and root rot diseases after each observation dead plants of tomato were uprooted and destroyed. The disease incidence was calculated using following formula:

\[
\text{Per cent Disease Incidence} = \frac{\text{Number of diseased plants}}{\text{Total number of plants observed}} \times 100
\]
Yield

Ripened fruits were harvested at regular intervals from each plot and total yield (q/ha) was calculated.

Statistical analysis

The data recorded under different experiments was subjected to Analysis of Variance (ANOVA) by using standard software STPR developed at Pantnagar University.

RESULTS AND DISCUSSION

Effect of bioagents under glasshouse conditions

Data (Table 1, Fig. 1) revealed that per cent germination in all the treatments was higher than that in control. Maximum germination (91%) was recorded in Th + Pf + JM and was at par with Th + Pf (88.3%) but significantly different from the other treatments and control (79.30%). Root and shoot length, fresh and dry weight of shoot and root were higher in all the treatments as compared to control. Maximum shoot and root length (40.83 cm, 9.79 cm), fresh and dry shoot weight (152.00 g, 28.38 g), fresh and dry root weight (9.33 g, 3.90 g), were recorded in treatment Th + Pf + JM followed by Th + Pf. Maximum plant vigour index (4301.45) was observed in Th + Pf + JM followed by Pf + JM, Th + JM, Th + Pf, and were at par with each other but were significantly higher than control (2931.97) (Fig. 2). The present findings on increase in growth parameters are supported by the findings of Elad et al. (2007). Their studies have shown that there was a 30 per cent increase in seedling emergence in plots inoculated with Trichoderma. Shoresh and Harman (2008) reported on overall increased in plant growth of maize when seeds were treated by Trichoderma. Mwangi et al. (2011) reported that treatment with T. harzianum and AMF significantly enhanced the plant heights and shoot and root dry weight of tomato. Azarmi et al. (2011) reported that shoot height, fresh and dry weight of shoot and root of tomato seedlings were significantly increased by the application of Trichoderma. Singh et al. (2013) observed greater plant growth promotion activity in tomato in the combination of Trichoderma harzianum and Pseudomonas. Tanwar et al. (2013) reported significantly increased chlorophyll a, plant height and root fresh weight, above ground dry weight, head fresh weight, and root nitrogen content in Broccoli in that consortium of AMF + Trichoderma + Pseudomonas.

Effect of bioagents under field conditions

All the treatments were effective in lowering the plant mortality (Table 2) as compared to control. However,

**Table 1: Effect of biocontrol agents and arbuscular mycorrhizal fungi on plant growth promotion in tomato under glasshouse conditions**

| S.No. | Treatment                      | Germination (%) | Shoot length (cm) | Root length (cm) | Fresh shoot weight (g) | Fresh root weight (g) | Dry shoot weight (g) | Dry root weight (g) | Plant Vigor Index |
|-------|--------------------------------|-----------------|-------------------|------------------|------------------------|-----------------------|---------------------|-------------------|------------------|
| 1     | Trichoderma harzianum (Th 43)  | 82.00 (65.18)   | 35.85             | 5.64             | 132.98                 | 7.48                  | 25.00               | 2.25              | 3292.57          |
| 2     | Pseudomonas spp. (Pf 173)     | 82.33 (65.67)   | 33.08             | 6.30             | 132.67                 | 6.89                  | 23.83               | 2.13              | 3319.05          |
| 3     | Jas Mycorhiza (JM)            | 81.00 (64.22)   | 35.11             | 6.52             | 123.17                 | 7.34                  | 25.33               | 2.05              | 3366.63          |
| 4     | Th + Pf                       | 88.33 (70.69)   | 33.06             | 5.98             | 126.07                 | 6.96                  | 24.50               | 1.82              | 3452.90          |
| 5     | Th + JM                       | 83.33 (65.91)   | 35.00             | 6.25             | 131.00                 | 6.78                  | 25.33               | 1.54              | 3416.07          |
| 6     | Pf + JM                       | 84.66 (66.42)   | 37.03             | 7.40             | 141.00                 | 8.21                  | 25.53               | 2.28              | 3603.18          |
| 7     | Th + Pf + JM                  | 91.00 (73.29)   | 40.83             | 9.79             | 152.00                 | 9.33                  | 28.38               | 3.90              | 4301.45          |
| 8     | Control                       | 79.30 (62.96)   | 32.17             | 5.21             | 115.00                 | 6.67                  | 22.66               | 1.95              | 2931.97          |
|       | CD (%)                        | 4.24 (4.47)     | 3.59              | 1.64             | 5.19                   | 0.60                  | 3.18                | 0.53              | 343.90           |
|       | CV (%)                        | 7.19 (4.31)     | 3.96              | 6.24             | 5.62                   | 1.47                  | 4.73                | 1.55              | 6.15             |

Microbes were directly added in the sterilized soil just before the sowing of seed in pots.

Data average of three replications. Data in parenthesis is angular transformed value.

Doses: Th @10g/kg, Pf @10g/kg, JM @100g/kg, Th + Pf @ each 5g /kg, Th + JM @10g + 100g /kg, Pf + JM @10g + 100 g /kg and Th + Pf + JM @5g + 5 g + 100g /kg.
combination treatment \( T.\, \text{harzianum (Th 43) + Pseudomonas spp. (Pf 173) + Jas Mycorrhiza (AMF)} \) was most effective in reducing plant mortality and enhancing the yield (q/ha). At 30 Days After Transplanting (DAT) 74.68%, 45 DAT 71.73% and 60 DAT 72.16% reduction in disease was found over control followed by treatment four combination of \( T.\, \text{harzianum (Th 43) + Pseudomonas spp. (Pf 173)} \) where as at 30 days after transplanting (DAT) 62.68%, 45 DAT 55.43% and 60 DAT 52.18% reduction in disease was found over control. 

Akuppru and Demir (2005) reported that reduction in 58 per cent plant mortality caused by \( Fusarium \) in tomato by the application of AMF and \( Pseudomonas\, \text{fluorescens} \). Yigit and Dikilitas (2007) reported 70.20 per cent disease reduction caused by \( Fusarium\, \text{oxysporum f. sp. lycopersici} \) in tomato by the use of combination of \( Pseudomonas\, \text{fluorescens} \) and \( \text{Trichoderma}\, \text{harzianum} \) - 22 under green house conditions. Srivastava et al. (2010) also reported that the combination of \( T.\, \text{harzianum, fluorescent Pseudomonas} \) and AMF gave significant disease reduction in incidence (70%), then control and increased in yield (20%). Mwangi et al. (2011) also reported that Th (P52) and AMF in combination significantly enhanced plant height, root dry weight and reduced wilt pathogen caused by \( F.\, \text{oxysporum f. sp. lycopersici} \) in tomato. Singh et al. (2013) has been reported disease reduction (53.23%) and significant increased in yield in tomato. They also observed that in the combination of \( \text{Trichoderma}\, \text{harzianum} \) and \( \text{Pseudomonas} \) consortium of these bioagents enhanced the plant growth.

In conclusion, the present study confirms that the soil

| Table 2: Effect of different treatments on the management of major soil born diseases (wilt and root rot) of tomato |
|---|---|---|---|---|---|
| S. No. | Treatment details | 30 DAT Plant Mortality | Percent decrease over control | 45 DAT Plant Mortality | Percent decrease over control | 60 DAT Plant Mortality | Percent decrease over control | Yield (q/ha) | Percent increase over control |
| 1 | \( T.\, \text{harzianum (Th 43)} \) | 12.66 (18.08) | 49.36 | 14.67 (21.68) | 52.17 | 20.67 (24.09) | 46.07 | 345.33 | 51.83 |
| 2 | \( \text{Pseudomonas spp. (Pf 173)} \) | 11.66 (19.98) | 53.36 | 16.67 (24.09) | 45.65 | 19.33 (26.07) | 49.56 | 335.00 | 50.35 |
| 3 | Jas Mycorrhiza (AMF) | 14.33 (22.21) | 42.68 | 20.00 (26.55) | 34.79 | 22.00 (27.96) | 42.60 | 327.33 | 49.19 |
| 4 | \( T.\, \text{harzianum (Th 43) + Pseudomonas spp. (Pf 173)} \) | 9.33 (17.77) | 62.68 | 13.67 (21.68) | 55.43 | 18.33 (25.34) | 52.18 | 374.33 | 55.57 |
| 5 | \( T.\, \text{harzianum (Th 43) + Jas Mycorrhiza (AMF)} \) | 10.00 (18.42) | 60.00 | 15.33 (23.05) | 50.02 | 21.33 (27.50) | 44.35 | 356.00 | 53.27 |
| 6 | \( \text{Pseudomonas spp. (Pf 173) + Jas Mycorrhiza (AMF)} \) | 11.33 (19.66) | 54.68 | 16.67 (24.09) | 45.56 | 20.67 (27.03) | 46.07 | 327.33 | 49.19 |
| 7 | \( T.\, \text{harzianum (Th 43) + Pseudomonas spp. (Pf 173) + Jas Mycorrhiza (AMF)} \) | 6.33 (14.51) | 74.68 | 8.67 (17.09) | 71.73 | 10.67 (19.04) | 72.16 | 486.70 | 65.82 |
| 8 | Control | 25.00 (29.99) | - | 30.67 (33.62) | - | 38.33 (38.25) | - | 166.33 | - |
| CD (5%) | 2.36 (2.06) | - | 2.22 (1.77) | - | 2.55 (1.81) | - | 4.27 | - |

Data in parenthesis are angular transformed value, Values are average of three replication

DAT= Date after transplanting, Plant Mortality= Due to wilt and root rot of tomato
application of the combination of *Trichoderma harzianum* (Th 43) + *Pseudomonas* spp. (Pf 173) + Jas Mycorrhizal (AMF) was not only very effective for the growth promotion of but also for the management of tomato root rot and wilt pathogens.

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**REFERENCES**

Agrios GN. 2005. *Plant Pathology*. USA: Academic press.

Abhilash PC, Singh N. 2009. Pesticides use and application: An Indian scenario. *J. Hazard Mater*. 165: 1-12. https://doi.org/10.1016/j.jhazmat.2008.10.061 PMid:19081675

Akkopru, Demir. 2005. Biological control of fusarium wilt in tomato caused by *Fusarium oxysporum* f. sp. *lycopersici* by AMF glomus intraradices and some Rhizobacteria. *J Phytopathol*. 153: 544–550. https://doi.org/10.1111/j.1439-0434.2005.01018.x

Azarmi R, Hajieghrari B, Giglou A. 2011. Effect of *Trichoderma* isolates on tomato seedling growth response and nutrient uptake. *Afr J Biotechnol*. 10: 5850-5855.

Bonfante P, Genre A. 2010. Mechanisms underlying beneficial plant- fungus interactions in mycorrhizal symbiosis. *Nat Commun*. 1: 48. https://doi.org/10.1038/ncomms1046 PMid:20975705

Elad Y, Zaqs ZY, Zuriel S, Chet I. 2007. Use of *Trichoderma harzianum* or alternation with fungicides to control cucumber grey mould (*Botrytis cinerea*) under commercial green house conditions. *Can J Bot*. 42(3): 324-332.

Glick BR. 1995. Enhancement of plant growth by free living bacteria. *Can J Microbiol*. 41: 109-117. https://doi.org/10.1139/m95-015

Harman GE. 2000. Myths and dogmas of biocontrol: Changes in perceptions derived from research on *Trichoderma harzianum* T- 22. *Plant Dis*. 84: 377-393. https://doi.org/10.1094/PDIS.2000.84.4.377

Kloeper JW, Scher FM, Laliberti M, Tipping B. 1986. Emergence promoting bacteria: Description and implication for agriculture. pp. 155-164. In: Swinburne TR (Ed.). *Iron Siderophore and Plant Disease*. Planum, New York. https://doi.org/10.1007/978-1-4615-9480-2_17

Leoz BM, Garibus C, Charcosset YJ, Perez, Jose MS, Antigueed I and Romera ER. 2013. Non target effect of these formulated pesticides on microbiobly mediated processes in a clay loom soil. *Sci Total Environ*. 449c: 345-354 https://doi.org/10.1016/j.scitotenv.2013.01.079 PMid:23454695

Mwangi MW, Monda EO, Sheila AO, Jefwa JM. 2011. Inoculation of tomato seedlings with *Trichoderma harzianum* and arbuscular mycorrhizal fungi and their effect on growth and control of wilt in tomato seedlings. *Braz J Microbiol*. 42(3): 324-332.

Srivastava R, Khalid A, Singh US, Sharma AK. 2010. Evaluation of arbuscular mycorrhizal fungus, fluorescent pseudomonas and *Trichoderma harzianum* formulation against *Fusarium oxysporum* f. sp. *lycopersici* for the management of tomato wilt. *Biol Control*. 53: 24–31. https://doi.org/10.1016/j.biocontrol.2009.11.012

Tanwar A, Kadian A, Gupta A. 2013. Arbuscular mycorrhizal inoculation and super phosphate application influence plant growth and yield of *Capsicum annum*. *J Soil Sci Plant Nutrition*. 13(1): 55-66. https://doi.org/10.4067/S0718-95162013005000006
Waiganjo MM, Wabule NM, Nyongesa D, Kibaki JM, Onyango I, Wepukhulu SB, Muthaka NM. 2006. Tomato production in Kirinyaga district Kenya, a baseline survey report. KARI/IPM CRSP, Nairobi, Kenya. pp. 1-43.

Wang B, Qiu YL. 2006. Phylogenetic distribution and evolution of mycorrhizas in land plants. *Mycorrhiza* 16: 299–363. https://doi.org/10.1007/s00572-005-0033-6 PMid:16845554

Watterson JC. 1986. *Diseases of the tomato crops*. Champan and Hall Ltd. Ny. pp. 461-462. PMCid:PMC1202784

Yigit F and Dikilitas M. 2007. Control of Fusarium wilt of tomato by combination of fluorescent pseudomonas, non-pathogen *Fusarium* and *Trichoderma harzianum* T-22 in greenhouse conditions. *Plant Pathol J.* 6(2): 159-163. https://doi.org/10.3923/ppj.2007.159.163