Increased Soil-Microbial-Eco-Physiological Interactions and Microbial Food Safety in Tomato Under Organic Strategies

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Abstract

Farmers' profit has been continuously squeezed as the costs have been rising faster than the realization, ushering the law of diminishing returns. The environmental and health impacts have been equally alarming as the toxic residues have entered the whole food chain which increases the incidence of chronic and dreaded diseases like cancer, arthritis, atherosclerosis, corroded membranes, weakened DNA walls, and damaged livers. The situation is really horrendous and calls for an immediate remedial answer, which is none else than reverting back to the organic farming system. Organic agriculture is an eco-friendly management system which upgrades agrological ecosystem health, biodiversity, and soil biological, physical, and chemical properties. Organic cultivation, quality of food, and human health complement the strong environmental arguments for going organic. Organic agriculture initiates self-sustenance, rural development, and nature conservation; the thread that weaves together this ambitious goal is the sustainable use of biodiversity.

9.1 Introduction

Tomato (*Lycopersicon esculentum*; family *Solanaceae*) is known for its popularity, due to the fact that it has been widely grown as an important vegetable throughout the world. It traces its origin from central and south parts of America (Vavilov 1951). It is credited as the second world's largest vegetable crop after potato, but maintains its top position in the list of processed vegetables. Tomato represents a major source of nutrients as a fresh commodity as well as processed product. Tomatoes' unique flavor

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accent as well as taste accounts for its popularity and wide usage. A large amount of tomatoes are being used to prepare products like ketchup, paste, puree, juice, powder, soup, etc. The high dry matter and soluble solids are desirable properties for the canned tomatoes industry since they improve the quality of tomato products (De Pascale et al. 2001). On the other hand, pH values are very important for tomatoes during processing since values which are higher than 4.4 result in mean sensitivity of the pulp to pathogens (thermophilic) (Paulson and Stevens 1974).

The total area under tomato cultivation in the world is 4.81Mha (production, 163.02 million tons; with productivity of 33.9 tons per ha) covering about 2 million producers and 170 countries with certified organic agriculture (Willer and Julia 2015). India holds about an area of 876,410 hectares (production, 17,848,160 MT), whereas the Himachal Pradesh accounts for cultivation area of 17,848 hectares (production, 400,000 MT) (Anonymous 2011) and about 3965.38 ha area under organic certification (Fig. 9.1). Solan district is known for the production of tomato covering 9555 ha area with a production of 3.4 lakh tonnes.

Tomato serves as an important commodity for upgrading the hill farmers in form of crop produced during off-season in Himachal Pradesh (mid-hill), fetching very attractive prices to the farmers. A constant nutrient and water supply is needed for the luxuriant growth of tomato. The rising global energy crises have led to a hike in the cost of chemical fertilizers and pesticides, which would reach beyond the reach of farmers at marginal side. Tomatoes are essential because of the high nutritional and medicinal values contributed to humans as most important role points toward reduction in cardiovascular diseases and certain types of lethal diseases like cancer (Canene et al. 2005). The benefits of tomatoes have been credited to the presence of lycopene which constitutes about 80–90% of the total carotenoid content. The vitamin C content in tomato fruits attributes toward the antioxidant properties of this fruit which cures and prevents diseases. Its value as a vegetable crop has been increased due to the presence of pigment anthocyanin. The adoption of organic strategies is necessary to upgrade the parameters of quality and nutrition. To boost up yields and reduce pest and insect incidence, the agricultural practices have been continuously relying on the use of mineral fertilizers. But the heavy uses of these fertilizers have led to an extensive damage, resulting in the deterioration of beneficial microbes, environmental hazards, and soil fertility.

The researches have shown that the increasing groundwater contamination and surface runoff (nitrate leaching) are the harmful outcomes of the excessive application of chemicals which have been continuously draining the water quality. The rising concerns about the harmful results of using chemical fertilizers have led to a strong urge in alternative strategies to ensure quality with competitive yields thus protecting the crops. Injudicious application of chemicals could cause diverse changes in the biological balances leading to an increase in cancer incidence through the residues (toxic) present in the edible produce. The organic tomatoes are more preferred in comparison to the conventional ones because of better quality, taste, flavor, aroma, texture, storage, and shelf life.

To achieve these properties, usually the farmers often apply large amounts of chemical fertilizers, which exert ill effects on soil and environment and ultimately reduce quality of

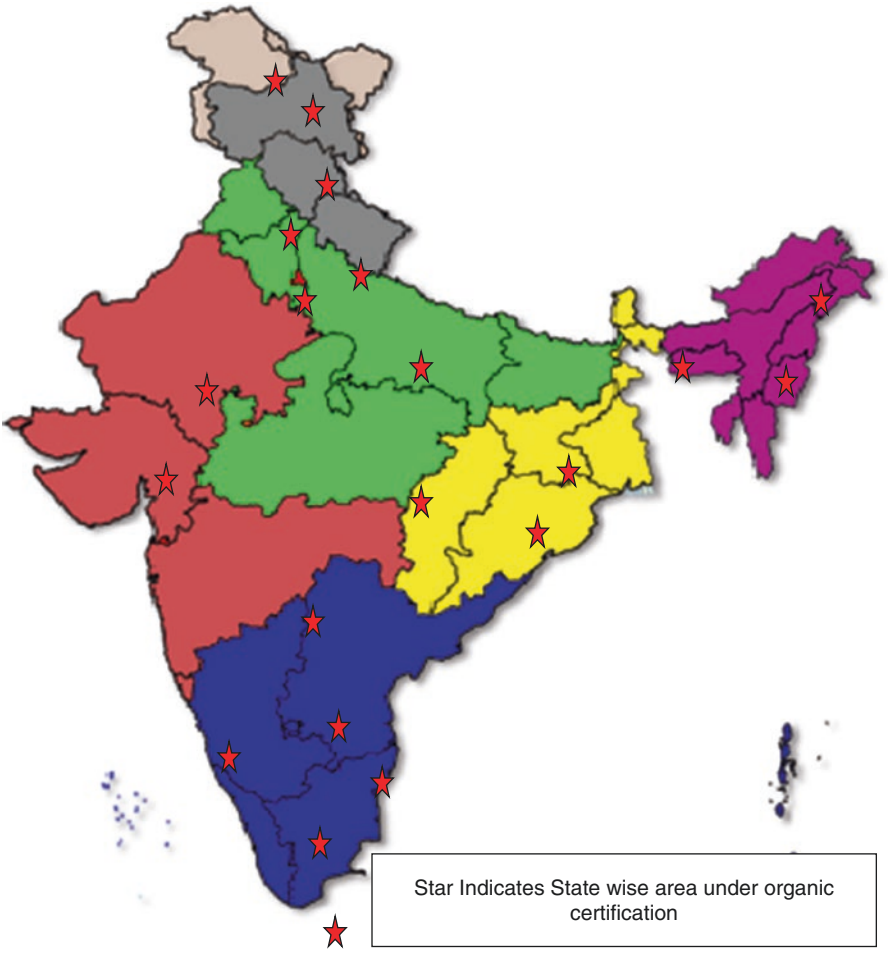

Fig. 9.1 Map indicating the state-wise area under organic certification (Source: Data from APEDA Accredited Certified Agencies in Tracenet)

crop, though increasing the yields. The new approaches in farming system have introduced modern and eco-friendly practices with long-term sustainability. The pattern of organic agricultural land has been increased tremendously from an era of 1999 to the present (Fig. 9.2). The judicial employment of beneficial microbial inoculants (biofertilizers) along with organic manures is considered as an alternative requirement of the crop. The new farming strategies implementing the use of organic supplements have been proven effective in improving soil structure, soil fertility, and crop yields.

Organic matter is an important source of nutrients which is easily supplied to the plants, and their incorporation to the soil would maintain and increase the microbial populations and their activities, which in turn would increase biomass content, respiration rates, and biomass carbon/total carbon ratio. Thus, crop yields have been increased

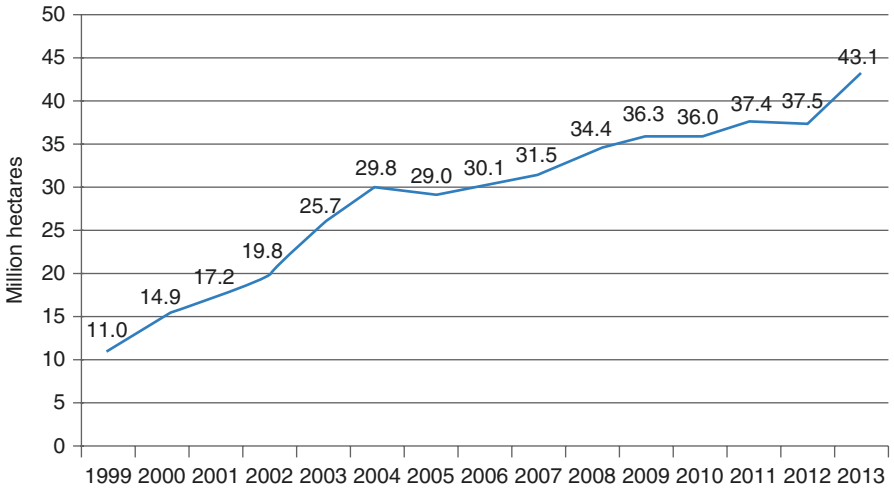

Fig. 9.2 Growth of organic agricultural land (1999–2013): Source-ICCOA (International Competence Center for Organic Agriculture)

with the improvements in soil quality and nutritional profile through the additions of organic supplements (Tonfack et al. 2009). The domestication or scaling up process of a species is the major step in the seedling process where every step needs to be properly executed. The full monitoring phase should start from the handling and managing process of the nursery, finally rating the performance of their survival percentage. The way a seedling is brought up results in assurance of healthy future. Improving quality of a seedling directly affects the survival, growth, and productivity rates of the future product. A good and healthy stock of nursery is essential to raise a good planting material.

The major reasons of seedling mortality on-farm include:

1. The poor health of the seedlings at the time of planting.
2. Unhealthy and poor seedlings are likely to have growth at slower range, thus are less able to compete with weeds or adverse conditions and become more susceptible to insects and pests.
3. Further, in a poor nursery, the wastage of money and time is seen as fewer seedlings will be brought up from a given quantity of seed.
4. Thus sound nursery practice is the foundation of any successful planting program scheme.
5. Soilless culture is a technique for crop production without soil. Crops are grown in the essential nutrient solution or on a proper medium; therefore, soilless culture involves no work such as tools or machines.

Increased disease incidence, lack of healthy soils, and the desire for standardizing optimal conditions for plant growth are leading to the worldwide focus of growing plant in soilless media instead of soil (Winsor and Schwarz 1990).

In addition, treating seeds with beneficial microorganisms provides long-lasting conservation against yield-reducing fungal/bacterial diseases by creating a cover of

protection around the seed root system, which helps in the development of healthier and firm root system, thereby enhancing crop productivity with better yields. The species of *Trichoderma* (*Trichoderma harzianum* and *Trichoderma viride*) are the most important species and have been formulated for about 87 different crops against the soilborne (70) and foliar pathogens (17), respectively (Sharma et al. 2014).

The initiation of agriculture with organic supplements has led to enhance ecosystem health (biodiversity) and biological activity of the soil. The urge to go organic is coupled with the correct combination of organic practices in combination with quality of food and health of human beings. It emphasizes the use of practices generated on farm in preference to use of off-farm inputs, taking into account the specific microclimatic situation which is generally adapted locally.

This is mainly done by implementing a triad of practices including agronomic, biological, and mechanical methods in contrast to synthetic materials (FAO/WHO 1997). The main scenario focuses on maintaining soil fertility for generations, to produce poison-free food for consumers, to secure productivity, and to meet competition from likely cheaper imports, high water percolation, recharging groundwater, development of nitrogen and phosphate-fixing bacteria and microorganisms involved in transferring atmospheric moisture, soil enrichment by transfer of biomass of agro-waste, emergence of mixed farming system, new marketing channels, premium prices, and higher product demand going worldwide (Figs. 9.3 and 9.4). Global markets for organic products are increasing on a wide globe, hence satisfying criteria of food safety (less incidence of diseases like mad cow disease, cancer, etc.), health aspects (over 20% more vitamins and minerals), price premiums (market-led growth, USA), environmental concerns, and sustainability.

Safety and Quality of Food Stands as the Primary Issue to Each Individual The quality can be defined as a complex feature of food that determines perception and acceptability of a consumer. The increasing awareness of a consumer about food, health, and environment has led to an increased interest to go organic.

The data shows that the fruits/vegetables produced organically possess pesticide residues and nitrate levels at much lower stage (below the minimal residual limits) than the conventional fruits and vegetables.

In some reports it has been seen that the organic foods possess higher levels of plant (secondary) metabolites which are beneficial as they link to essential antioxidants such as polyphenolic compounds but also consist and underline some potential concern of health, when one talks about the naturally occurring toxins. As the synthetic chemicals are not preferred (prohibited) in organic cultivation, more biochemical energy can be restored and used effectively for synthesizing the secondary plant metabolites (Jadhav et al. 1981).

Tomato is one of the essential vegetable crops of Solan (HP) grown for both economic and biological reason with million tons of annual production. The present situation figured out presents a clear data of the conventional tomato production in both open-field and greenhouse conditions in Solan (HP) (Fig. 9.5). Due to the suitable climate, there is a great scope for the upgradation and promotion of organic farming.

To support the organic farmers, the various statutory bodies and government have formulated supportive policies in 2010, covering about 30,110 farmers with

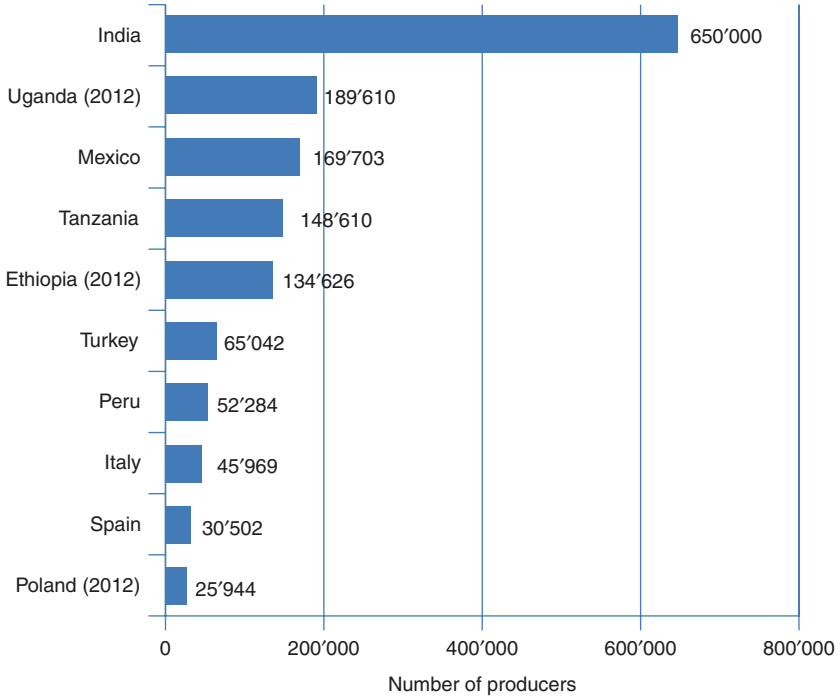

Fig. 9.3 Ten countries with the largest number of organic producers (2013) (Source: ICCOA)

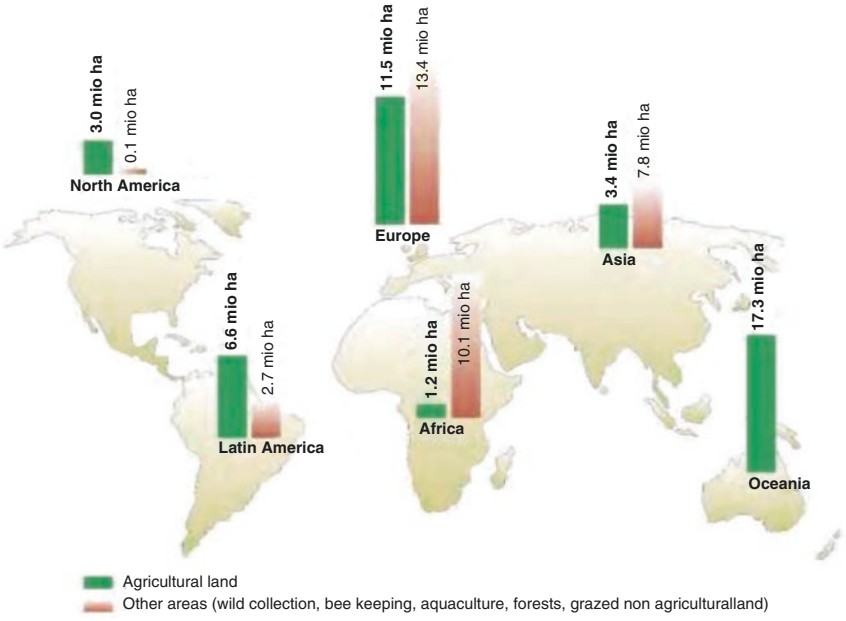

Fig. 9.4 Organic agriculture worldwide: statistics (Source: ICCOA)

the near vision of converting villages (200) to complete bio-villages and 50% assistance to set up individual vermicompost units (20,000). However, government has already started the organic cultivation (registration and certification) process to implement organic fertilizers in tomato production, but the farmers still lack awareness about the incorporation of organic formulation.

Keeping in view the above facts, the present studies were carried out with an open-pollinated and indeterminate tomato variety (cv. Solan Lalima), which has been recently released by University of Horticulture and Forestry (UHF-Nauni) for commercial cultivation of tomato. It shows superiority over the present tomato hybrids available in the markets in terms of fruit quality and productivity. Being open-pollinated variety, it's a suitable option for organic cultivation.

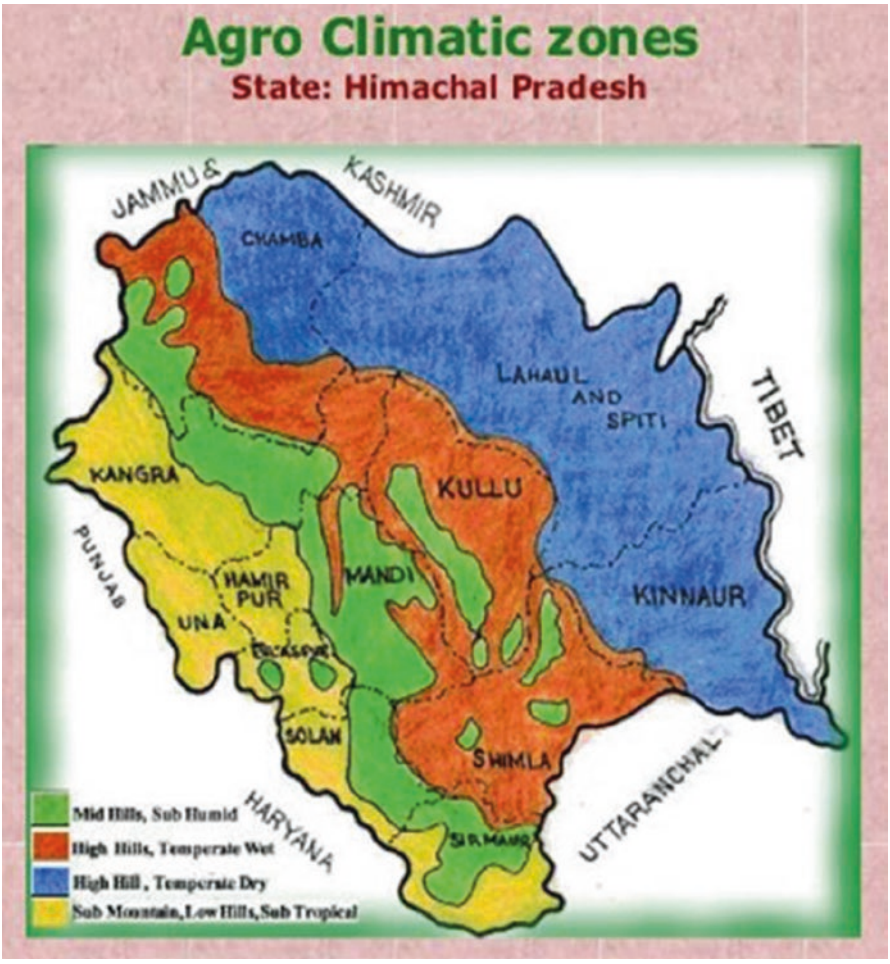

Fig. 9.5 Agroecological zonation of Himachal Pradesh (Source: Centre for Geo-informatics Research and Training, CSK Himachal Pradesh Agricultural University, Palampur, Himachal Pradesh, India)

Therefore, the farmer can produce the seeds at their own farm. The studies were, hence, conducted to see the influence of different organic and inorganic nutrient sources on the soil fertility status, beneficial microbial population, crop quality, yield, economics, and food safety in tomato.

9.2 Materials and Methodology

The present study entitled *The effect of manures and bio-fertilizers on the interaction of microbes with soil and effect on food safety in tomato* was carried out during a tenure of 2 years (2013–2014). The details of the methodology used have been described as under:

9.2.1 Location of the Experimental Field

The experimental field was set up at village Basal (farmer's field), under block Solan, Himachal Pradesh at an (elevation of 1270 m) above mean sea level (30–52′ north and latitude 77–11′ east).

9.2.2 Weather of the Experimental Site

The weather for mid-hill conditions is marked by sub-temperate and subhumid agroclimatic zone (Himachal Pradesh). The rainfall on an average ranges from100 to 300 cm, in the month of August and June.

9.2.3 Experimental Layout

The experiment trial consisted of a primary nursery stage and a secondary field trial. The treatments and procedures followed are separately discussed.

9.2.4 Organic Amendments and Inputs

9.2.4.1 Organic Manures and Fertilizers Used

Organic Manures Used

- FYM (farmyard manure)
- VC (vermicompost)
- Procured from the farmer's field having on-farm inputs

Organic Fertilizers and Agents Used in Biocontrol

- AZO (*Azotobacter*)
- PSB (phosphate solubilizing bacteria)
- Neem cakes, *Trichoderma viride*
- *Pseudomonas fluorescens*
- Asafetida (Poabs Green Pvt. Limited, Kerala)

9.2.5 Organic Package of Practices Adopted for Growing Healthy Tomato Nursery

The tomato seeds (cv. Solan Lalima) were sowed in plastic trays with dimensions measuring 13 × 9 = 117 seeds. The nursery was set up with six organic treatments replicated thrice. The control was laid according to farmer's practice in the field in a seed bed (1 m × 3 m). The different combinations of media were used which contained both soilless and soil growth media mixed with various organic manures and biofertilizers. The detailed description of various treatments is given in Table 9.1.

9.2.6 Seed Source, Seed Variety, and Seed Rate Used

9.2.6.1 Seed Source: From Department of Vegetable Crops – Dr. Y.S. Parmar, UHF, Nauni, Solan)

Table 9.1 The detailed description of various treatments followed during tomato nursery raising

S.no.	Treatments	Combinations of various growth media combined with organic practices
1	**T_1**	FYM + Soil (1:1)
2	**T_2**	FYM+ VC+ Soil(1:1:1)
3	**T_3**	FYM + coco peat + VC + Vermiculite + *Azotobacter* (1:1:1:1:1)
4	**T_4**	FYM + coco peat + Vermiculite + *Azotobacter* (1:1:1:1)
5	**T_5**	FYM + soil + *Azotobacter* (1:1:1)
6	**T_6**	FYM + *Azotobacter* (1:1)
7	**T_7 Control (farmer's practice)**	FYM + soil + no seed treatment + Drenching with Dithane and bevisteen (2.5 g/L and 0.5 g/ L of H_2O)

FYM Farmyard manure, *VC* vermicompost

9.2.6.2 Seed Rate: 400 g/ha (40 gm/biga)

9.2.6.3 Seed Treatment

The seeds were treated with Beejamrut (6 g/40 g seed) and *Trichoderma viride* (0.32 g). The seeds were dried in the shade and again treated the seeds with a mixture of *Azotobacter* and PSB (0.8 g each). Finally dry the seeds in shade and sow within 8 hrs of treatment.

9.2.6.4 Tomato Variety Used

Solan Lalima (open-pollinated and indeterminate variety) variety of tomato shows a superior quality and productivity over the tomato hybrids in the markets which are commonly used by the farmers. Solan Lalima offers an advantage in terms of quality as well as yield increments for the farmers.

9.2.6.5 Treatment of Trays Used for Raising Nursery

The trays were treated with 1:7 formalin.

9.2.6.6 Seedling Treatment

- Neem spray (7 g/L) was given once for 15-day-old seedlings, to protect seedlings from sucking pests like whitefly and thrips.
- The process of drenching (*Pseudomonas fluorescens*, 10 g/L) is done before transplanting to prevent foliar diseases.
- Dipping of root portion of seedling in asafetida suspension (100 g in 5 L of water for 20 min) was done to prevent soilborne pathogens causing wilt diseases, before transplanting. Twenty-day-old tomato seedlings were transplanted to the main experimental field.

9.2.7 Observation and Calculation

Observation was recorded for the following aspects:

- Seedling germination
- Length of root (cm)
- Length of shoot (cm)
- Number of roots
- Seedling vigor
- Incidence of emergence (pre and post) damping-off was calculated.

9.2.8 Field Parameters

9.2.8.1 Experimental Setup of the Field

RBD (randomized block design) was adopted as a field design with eight treatments (replicated five times), consisting of 40 plots measuring 1 m × 3 m where the seedlings were planted at a distance of 90 cm × 30 cm consisting 24 plants per plot. The

T_1–T_6 (six treatments) organic treatments were grown in different blocks, which were laid separately at a 7 m distance from the farmer's (T_7) and chemical treatment (T_8). The doses have been calculated by analyzing the soil and applied manures and biofertilizers and the dozes recommended in organic package of tomato crop.

T_1 312q/ha of farmyard manure + 4 kg/ha *Trichoderma viride*

T_2 78q/ha of vermicompost +*Trichoderma viride* at 4 kg/ha

T_3 312q/ha of VC + *Azotobacter* + phosphate solublizing bacteria + *Trichoderma viride* (4 kg/ha each)

T_4 Farmyard manure at 78q/ha + *Azotobacter* + PSB + *Trichoderma viride* (4 kg/ha)

T_5 *Trichoderma viride* (4 kg/ha) + PSB (4 kg/ha)

T_6 *Trichoderma viride* (4 kg/ha) +*Azotobacter* (4 kg/ha)

T_7 Chemical fertilizers (farmer's practice)+ *Azotobacter*

T_8 **Chemical treatment** (fertilizers + pesticides + weedicides) (Directorate of extension education Dr. YS Parmar, UHF Solan)

9.2.9 Soil Analysis

Before commencement of the experiment, the soil of the experimental area and manures used were analyzed for physiochemical properties. To combat with low and high percentage of NPK and organic carbon, 25% high and low application of manures and biofertilizers were used in accordance with the recommended package.

9.2.9.1 Field Operation Protocol Followed

9.2.9.2 Random Selection from the Field Experiment

A random selection of five plants was considered from each bed. On a whole 200 plants were considered under field parameter analysis.

9.3 Results and Discussion

The studies focused on the use of organic manures and biofertilizers for the two successive years (2013–2014) at village Basal, 5 km away from Solan town, Himachal Pradesh**.** The highlights of the present studies are being discussed under the following headings.

9.3.1 Raising of Healthy Nursery

The focus on choosing a seed which is healthy as well as free from disease is the most essential requirement to have the satisfied product performance. The main stress should be laid on lowering the biotic and abiotic strains which offer limited yield constrains and reduction in incidence of insect pest disease (IPD) which

hinders the economic security of a farmer. The yields have been seen to reduce specially in hills due to the reemergence of pre and post insect pest-like {damping-off (*Pythium aphanidermatum*), bacterial wilt (*Ralstonia solanacearum*), and fusarial wilt (*Fusarium oxysporum*)} and diseases at regular intervals, right from the raising of a nursery to the period of harvesting, where the incidence of most destructive disease, etc. can be witnessed which ruin the crop diversity and quality to the most worst level.

The problem becomes more severe when the crop is attacked by the cascade of diseases one after the other. The use of conventional chemical pesticides is considered the most preferred practices to manage the outbreaks of these diseases, but the indiscriminate chemical approach to deal with these hazards has contributed to adverse effects like soil acidity, impairing soil physical conditions, reducing beneficial microbial population, and continuously degrading organic matter, increasing plant susceptibility to insect pest diseases, and decreasing soil lives. Thus, these eco-friendly agents are highly effective with excellent shelf life, and delivery method is also suitable (Bhagat et al. 2013).

It was observed from the results that all the organic treatments were found effective in increasing the parameters like seedling emergence and vigor index of tomato under both nursery and field conditions, but the maximum increase in vegetative parameters under nursery trials was recorded in treatment T_3 consisting of FYM + VC+ vermiculite+ coco peat+ *Azotobacter* over the control (T_7). The results were excellent for the organic fertilizers incorporated with coco peat, vermiculite, and *Azotobacter* which marked superiority over untreated control, where no seed bio-priming was done and the seedlings were raised in an open-field condition, which was recorded with lower germination percentage and decreased growth parameters in contrast to an organically cultivated nursery with soilless culture.

9.3.1.1 Effect of Seed Treatments on Nursery Growth Parameters

The present results revealed that the application of various combinations of organic treatments for raising tomato seedlings (cv. Solan Lalima) produced significant differences in nursery growth attributes over the conventional treatment (control). The studies revealed the superiority of organic seed treatments (bio-priming with antifungal and antibacterial agents) over the untreated check (control).

The bio-priming and seed treatment carried out in the present studies increased the vegetative attributes related to nursery seedling. The significant effect of seed treatment and bio-priming was in conscience with the studies conducted by Garg et al. (2007), where seed treatment with *T. viride* had a number of effects on aonla seed germination and seedling growth. This in turn made the root system strong and deep which provided with number of benefits like enhanced nitrogen fertilizer use efficiency, increased tolerance to drought, and probably also other abiotic stresses.

This fungus has been reported to keep the conductive tissues healthy by the secretion of some growth hormones since this fungus multiplies on its own; it is different from other seed dressing fungicides. This increase in seedling germination and growth may be attributed to the efficiency of *T. viride* at colonizing seedling roots and enhancing root growth in terms of root length, root hair development, and

depth. Similar studies conducted by Harman et al. (2004) reported another form of *Trichoderma* isolate viz. *T. harzianum* for seed bio-priming in maize, which resulted in increased levels of proteins and exo- and endochitinase in both root and shoot. The increased capability of *Trichoderma* isolated in increasing seedling growth parameters is due to the increased solubilization of some insoluble and soluble minerals under in vitro conditions by the mechanisms, namely, medium acidification, chelating metabolite activity production.

The present observations were strongly supported with similar findings reported on testing organic amendments and agents action toward controlling disease, seedling vigor, and percent emergence in cauliflower (Sharma and Sain 2005), in capsicum (Kabdal et al. 2010), and in tomato (Pietr et al. 2002). The results were at par with Bhagat et al. (2013) where the incorporation of isolates isolated from *Trichoderma* strain and bacterial antagonists used for seed bio-priming of tomato revealed better improvement in emergence of seedlings (%), vigor (%), and biomass. The mechanism related to the hormone secretion and nutrient uptake from the organic matter present in the soil has been highlighted as an important process indulged in promotion of plant growth (Windham et al. 1986; Kleifeld and Chet 1992).

9.3.1.2 Reduction in Damping-Off

The plant diseases (nearly 10–20%) have affected the world food production. However, the heavy use of the chemicals during the past years has given birth to the number of problems related to the environmental concerns, thereby limiting the yield; thus, an eco-friendly approach is gaining popularity which solves the problems related to environmental hazards.

It has been seen that the biological agents seem to have more potential in controlling the postemergence rots where the incidence of disease was reduced to a higher level (59%) as compared to preemergence rot (45.6%). The results of the studies agree with the research conducted by Hooda et al. (2010), where disease reduction in postemergence rot incidence was recorded maximum compared to pre-rot incidence. This was due to the time required for the bioagent inoculum multiplication in rhizosphere and collar region of seedling. Similarly the control of damping-off has been seen through the *Trichoderma viride* and *Pseudomonas fluorescens* application.

The study resulted in enhanced control strategies for damping-off as likewise observed by Kabdal et al. (2010). The present results are at par with the similar findings (Bhagat et al. 2013) where the application of antagonist fungus (*Trichoderma*), as treatment agent for both soil and seed, had a remarkable effect on lowering the incidence of disease and increasing percent yield over control. This can be supported by the studies that stress on the simultaneous application of *Trichoderma* as seed priming and soil incorporation agent as it results in providing a protective cover in the seed coat by the rapid multiplication of bioagents and upgrading a greater strength to compete the pathogens.

The reduction reported in the incidence of damping-off in the present study may be attributed to the mechanisms involved by the biocontrol agents which include a

cascade of antagonistic reaction (antibiosis, volatile toxic metabolite secretion, mycolytic enzymes, parasitism, and competition for space and nutrients), which are considered effective against a series of plant pathogens present in the soil (Khandelwal et al. 2012; Babu and Pallavi 2013).

The present results get strong evidences from the studies conducted on colonization of pea seed by *T. viride* resulting in efficient production of antibiotic production (viridian) in the seed controlling *Pythium* spp. This hydrolytic enzyme combination with the antibiotics may have resulted in an effective level of antagonism (Howell and Stipanovic 1995). The mechanisms of biocontrol process is also supported by the studies conducted by who observed that soil inoculation with *Trichoderma* spores helps in controlling a serious disease called damping-off related to citrus seedling.

Various studies also highlighted that the biosynthesis of siderophores in *P. fluorescens* plays a role in the suppression of pathogens (Costa and Loper 1994) indicating the biocontrol potential against pytopathogenic fungi in both the in vivo and in vitro conditions, respectively (Saraf et al. 2008).

9.3.1.3 Effect of Growing Medium on Nursery Growth Parameters

In recent years, nursery production has transitioned from the use of mineral soil-based potting media to soilless culture. Soilless culture includes hydroponic systems and solid media systems called soilless media: they are made of simple or complex mixtures of materials (Johnson 1985). The combination of these materials is what makes them attractive for use in greenhouse settings, where the environment can be manipulated. Most commonly, soilless media are composite mixes composed of shredded *Sphagnum* peat, shredded coir, composted bark, or sawdust-based materials with the addition of sand, vermiculite, and/or perlite (Ingram et al. 1991). Ideally, these manufactured soilless mixes provide a pathogen-free physical support system necessary for plant growth and thus avoid some of the major problems that are associated with mineral soils. The available nutrients, percent organic matter, pH, and water holding capacities (pore size) of soilless media vary greatly from each other and from mineral or composite soils.

Growing of crops on soil is the conventional practice in crop production; the search for an alternative means of media for cropping came as a result of increasing knowledge in plant nutrition as well as other serious difficulties observed in the use of soil in crop production. Soil possesses numerous limitations for plant growth due to the presence of disease-causing organisms (flora and fauna), poor drainage, and aeration resulting from soil compaction and degradation due to soil erosion and leaching (Mbata and Orji 2008; Ekwu and Mbah 2001). The soilless culture is the new cultivation system of plants that use nutrient solution for raising the plants. The most intensive culture system emphasizes on yield maximizing of crops and the most intense form of agricultural enterprises for commercial production of greenhouse vegetables (Dorais et al., 2001; Grillas et al., 2001; Jensen 1997). The soilless culture in the greenhouse stands as an alternative strategy to the field production carried out for quality vegetable (Pardossi et al. 2002). Therefore, quality of the horticultural crops grown through soilless culture is comparatively superior to the soil cultures conventionally preferred (Massantini et al. 1998).

The present study revealed a superiority of T_3 treatment in terms of soilless media composition, increasing seedling germination percentage, root and shoot length, and vigor percentage over the control. The present findings are in line with the work reported, where the similar effect was observed significant with the combinatorial use of growing media consisting of peat, composted tree bark combined with composted tea wastes, and rice husks. The similar findings gained a strong support through the studies reported by Sahin et al. (2005) who observed the nursery practices followed by the farmers in Nigeria which did not ensure sustainability criteria as the field soils were found generally unsatisfactory for the nursery production as compared to soilless nursery raising media, indicating the seedlings raised in the media with soil were poorer in most vegetative parameters measured in contrast to the soilless medium.

These results are further in agreement with those reported that the composted organic compounds in growing media increased the parameters shoot and root biomass production, in comparison to the field soils which are unsatisfactory for the production of plants (Sahin et al. 2005). The use of FYM as a basal application results in providing additional nutrient to the plant as well as improving soil properties (Reddy and Swamy 2000) and results in proper decomposition and mineralization with solubilizing effect on soil nutrients. Vermicompost is considered the best medium which provides increased levels of oxygen and water to the roots; storage of water and nutrients for the plant; physical, chemical, and biological balance; and requirement for good plant growth (Atefe et al. 2012). Vermicompost as a nursery mixture stands as an excellent growth rejuvenator, as it supplies efficient nutrients to the plant. On the other hand, coco peat improves retention of moisture and thus increases the available nutrient content, porosity, and hydraulic conductivity of the soil (Savithri and Khan 1993). *Azotobacter*, in addition, enhances the process of nitrogen fixation in plants and maintains a direct link for the continuous supply of biological active compounds. The addition of *Azotobacter* may have resulted in the process of nitrogen fixation and production of phytohormones and growth stimulants which aid in controlling many insects and pathogens (Kloepper and Schroth 1980).

9.3.2 Field Trials

The production and consumption areas have been seen to pass through a spectacular breakthrough in India from the past four decades. The farmers have been continuously facing the burning energy cost and inflammations related to high prices due to the use of fertilizers and pesticides. Also, the continuous use of chemical fertilizers is leading to yield reduction and adverse effects on the soil as well as human health. The essential nutrients are required for essential functions and must be provided to the plant at the right time and quantity (Shukla and Naik 1993). With the increase in the process of intensification in cropping, the effect of heavy doses of chemical fertilizers has been analyzed, and the importance of organic materials is being felt for supporting the soil health and productivity.

The growing awareness and interest of both the producer as well as the consumer toward the organic varieties have led to the use of organic cultivation techniques for future use. In addition, higher price of food produced organically than conventionally produced (Oberholtzer et al. 2005) is encouraging producers to go fully organic. The consumer demand has also been seen to divert toward organically produced food which is considered safer and more nutritious to eat (Lester 2006).

9.3.2.1 Vegetative and Quality Attributes

The maximum increase in all the vegetative and crop quality attributes was observed in organic treatment T_3, followed by T_4. The maximum increase was prominent by combined application of manures with biofertilizers and biocontrol agents, followed by the single incorporation of organic manures (T_2 and T_1) and biofertilizers (T_5 and T_6) with biocontrol agents as compared to the control and chemical treatment. Increase in vegetative growth and quality attributes in the present studies may be attributed to T_3 (vermicompost+ PSB+ *Azotobacter* + *T. viride*) with the additional supplementation of vermicompost by *Azotobacter*, phosphate solubilizing bacteria (PSB), and *T. viride*, followed by T_4 (farmyard manure + PSB + *Azotobacter* + *T. viride*).

9.4 Summary and Conclusion

The studies carried out from 2013 to 2014 highlights the importance of soil health and implementing techniques for soil management in agricultural practices. The major work includes protecting soil fertility through improved system of drainage which ultimately sorts the problems related to environmental hazards. The organic methods of cultivation are adopted for disease management by on-farm generated inputs and conservation tillage.

Organic farming depends on an effective biological activity in the soil and contributes to the diversity and increment of beneficial soil microorganisms. The important benefits of this includes: increased mineral uptake, the nutrient supply enhancement, crop vigor improvement, nutrient leaching reduction, soil structure improvement, and resistance to pest and diseases.

It can be concluded that the organic cultivation provides security and safety ensuring the environmental protection and attractive returns to the farmers.

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