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Research Article

Effects of organic substrates and effective microorganisms (EM) on growth and yield of tomato (*Lycopersicon esculentum* Mill.) in greenhouse condition

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Abstract

Conventionally farmers are employing farmyard manure to increase the tomato yield. Leaf compost and poultry manure are microbial decomposed organic media that have rich source of nutrients, optimal water holding capacity and good circulation of air. However, farmers are still not satisfying with their results to increase the tomato production. This difficulty enforced to add and test additional supplements for increasing the performance of available organic substrates. To address these issues an experiment was carried out at Institute of Hydroponic Agriculture in Controlled Environment Greenhouse Conditions for testing of effective microorganisms (EM) with different mixtures of substrates. Four treatments of experiments were made with different mixtures of organic substrate and effective microorganism viz., T_1 poultry manure control (PM), T_2 poultry manure + effective microorganism (PM+EM), T_3 leaf compost control (LC) and T_4 leaf compost + effective microorganism (LC+EM). The quantity of EM was 80 ml for each plastic bag. The collected data were statistically analyzed by using complete randomized design (CRD) at 5% level of probability with statistix 8.1 software. The statistical analysis showed that Treatment T_2 poultry manure + effective microorganism (PM+EM) performed better results as compared to other treatments. Experimental results suggests to practice the effective microorganism with poultry manure.

Keywords: Effective microorganism; Leaf compost; Organic; Poultry manure; Tomato

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is the most widely cultivated fruit belongs to the family of Solanaceae [1]. It has highest per capita utilization of 24.9 kg per anum (Federal Institute for Agriculture and Food, FAO). It is used directly as salad or as a fruit or processed in goods or integral part of cooked foods. Its success is evident in the fact its rich in phosphorus, calcium and vitamin A and C [2]. Dietary quality of Tomato is portrayed by the fruits phytonutrients, prompting the helpful tomato role for consumption in heart infections [3]. Apparently, affirmative relationship among cancer inhibition and vegetables as well as fruits eating happens because of the existence of phytonutrients [4].

It is the need of the day that researcher innovate new techniques which enhance the productivity and fulfil the needs of the world. Agriculture system is converting from tradition to new and advance technique like moving from soil to soilless culture. Soilless culture systems are comparatively new technique which are using speedily since 40 years in greenhouse. This technique is increasingly followed by the people due to its high efficient productivity and yield of the crop [5]. The Soil less culture and hydroponics are usually used as synonyms of each other in literature. This system consists of water culture systems, supplied with nutrients and a porous growing media. This provides both air and water in optimum level for the plant growth and development [6]. In advanced countries it is the major technological component of the modern agriculture industry. This cultivation technology primarily adopted is to get rid of problems allied with soil like salinity and sodicity, soil fertility problems, soil borne pathogen and diseases etc [7]. Hydroponics has direct effect on the crop productivity and quality of fruits. It provides a controlled environmental system and a complete package of nutrients and water in optimum level to the plant. This suitable package of favourable environment allows the plant to grow vigorously and enhance the quality productivity in vegetable crops, such as tomato, melon and lettuce [8].

Organic substrates are widely used in hydroponically grown vegetables all around the world [9]. The density and compression of the organic media depend on the material or container used. The type of organic matter, amount of substrate in the container and irrigation system will primarily decide the growth of root and plant development [10]. There has been a developing medium to reduce uses of inorganic fertilizer applications to soils by using soil supplements even more adequately. Among different source of natural soilless media, vermicomposts have been perceived as having significant potential as soil alterations, and poultry manure contains considerable amounts of nutrients such as nitrogen (N), phosphorus (P), and other excreted substances such as hormones, antibiotics and pathogens [11]. Vermicomposts are results of natural tissue degradation through associations among worms and microorganisms. The process increase the rates of decay of the natural tissue, changes the physical and synthetic properties of the material, and brings down the C:N proportion, prompting a quick humification process in which the temperamental natural tissue is completely oxidized [12]. Effective microorganism (EM) is absolutely natural blended cultures of useful normally fermented microorganisms which may be used for expansion the fundamental microbial assorted variety in soil. The use of EM innovation in horticulture has acquired unrest the field of gardening, organic product science crop farming and land recovery. The phototropic or photosynthetic bacteria are an autonomous gathering, self-sufficient microorganisms. These microbes combine valuable substances which release from plant roots, hydrocarbon or harmful gases (hydrogen sulfide) with the utilization of sunlight and warmth of soil as an energy source. The helpful materials created by these organisms, incorporate sugars, nucleic acid, amino acids and bioactive substance that advance and improve plant development [13].

Soilless culture with the addition of effective microorganisms can enhance the quality and quantity of horticulture commodities up to significant level. This experiment was designed to study impact of organic waste and residues as a substrate with addition of effective microorganism on yield and quality of tomato hydroponics cultivation in greenhouse condition.

Materials and Methods

The experiment was conducted at Institute of Hydroponics Agriculture, PMAS Arid Agriculture University Rawalpindi during the year 2018-19. The experimental site is situated between Latitude: 33.62 and Longitude: 73.07. The polythene plastic bags were used for the testing of substrates. Two media were selected for making compost; green leaves and poultry manure. Leaves were collected from Institute of Hydroponic Agriculture, Arid Agriculture University Rawalpindi. A heap of these leaves were spread in the open field. In the last EM (Effective Microorganism) solution was sprayed for the decomposition of leaf litter. Then this process was repeated 5-6 times and covered with plastic sheet for two weeks. After two weeks the plastic sheet was removed and then mixed it. Poultry manure was procured from Poultry a reliable resource and sun dried fort nightly. For sowing seedling, mixed this compost with soil in ratio of 2:1. For testing of organic substrate and effective microorganism four treatments viz.; T_1 poultry manure control (PM), T_2 poultry manure + effective microorganism (PM+EM), T_3 leaf compost control (LC) and T_4 leaf compost + effective microorganism (LC+EM). The seedlings were transplanted to plastic bags after six weeks of seeds sowing. The experimental data against these treatments were recorded on different parameters viz., plant height, number of branches, number of leaves per plant, leaf area, leaf dry weight, flowering days, fruit per plant, fruit color, average fruit length, average fruit diameter, total soluble solids. The data of plant height, fruit length and fruit diameter were measured using a measuring tape. The fruit color was measured using spectrophotometer. The total soluble solids were measured by refractometer. The data were analyzed statistically using appropriate software Statistix 8.1 at 5% level of probability.

Results and Discussion

Plant height (ft)

Meanplant height presented in (Table 1) showed the effect of effective microorganisms with different media. Four treatments T_1 (PM), T_2 (PM+EM), T_3 (LC), T_4 (LC+EM) were selected for the experiment. The plant was selected from each treatment. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant ($P<0.05$). Mean value of the information demonstrated that plant attained maximum height (3.66 ft) in T_4, followed byT_3 (3.56 ft) and minimum height was recorded inT_1 (3.03 ft) was observed. This result is agreed with findings of [3] who observed the plant heightincreased as testing for the differences among the tomato planted on the poultry manure which have applied (100 ml). Effective microorganisms have the highest mean value of plant height 3.66 ft although the monitored plant has the least mean estimate of the plant of 3.03 ft. There was no critical contrast in between tomato mean plant height, planted on the rice husk and saw dust, however the mean plant structure of rice husk was noteworthy not quite the same as that of the substrate.

Table 1. Effect of EM on plant height of tomato plants in various growing media

Treatment	LC	PM	Mean
Control	3.03d	3.466c	3.25b
Control+80ml EM	3.56b	3.66a	3.61a
Mean	3.30b	3.56a	
CV	1.46		

Number of branches

Mean number of branches presented in (Table 2) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4 were selected for the experiment. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant ($P<0.05$). Mean value of the information demonstrated that plant attained maximum number of branches (14) at T_4, followed by T_3 and T_2 (9.66). While minimum number of branches in T_1 (7.33) was observed.

Scientist obtained statistically noteworthy information and measured the quantities of branches shaped overexpressing on one and a half months old plant of EM at 50 ml/pot, trailed by control. Except for the controlled, branch numbers are altogether expanded in the EM.in addition, EM overexpression lines additionally had more branches EM produced side-shoots much sooner than the wild kind on the main branches and shoots. Shoot including beginning inception of axillary meristems, bud advancement and outgrowth are controlled through a potent mix of plant hormones and conversion factors [14].

Table 2. Effect of different Level of EM on numbers of branches of tomato plants

Treatments	LC	PM	Mean
Control	8c	9.66bc	8.83b
Control+80ml EM	11.33b	16.66a	14a
Mean	9.66b	13.16a	
CV	11.77		

Number of leaves

Mean number of leaves presented in (Table 3) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant ($P<0.05$). Mean value of the information demonstrated that plant attained maximum number of leaves (16.66) at T_4, followed by T_3 (11.33). While minimum number of leaves in T_1 (8) was observed.

The same index is also found by [15] who reported that number of leaves are also affected by EM which are substantial ($P\leq 0.05$) treatment impacts on leaf number. Utilization of EM and leaf manure alone or their joined application didn't expand leaf number of tomato fundamentally over that of the control 8.5% reduction in leaf number with sole EM application is watched comparative with the control. The similar index is also observed by [16] reported that the increase unit of leaves /plant (102.11) is perceived with the application of 50 ml poultry manure.

Table 3. **Effect of different level of EM on number of leaves of tomato plants**

Treatments	LC	PM	Mean
Control	7.33c	9.66b	8.50b
Control+80ml EM	9.66b	14a	11.83a
Mean	8.50b	11.83a	
CV	7.33		

Leaf area (cm^2)

Mean leaf area presented in (Table 4) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant (P<0.05). Mean value of the information demonstrated that plant attained maximum leaves area (3.4) at T_4, followed by T_3 (2.8). While minimum leaves area in T_1 (2.33) was observed. The advantageous impacts of EM application on biometric factors is appeared in a prior examination led by [17]. This research, has two empirical models are developed and tested for non-destructive determination of leaf area with different level of EM of two important greenhouse crops, tomato and gerbera, as a function of leaf length included maximum length and width. The correlation coefficient between predicted and measured leaf area is highly significant with different EM level/bag. The model for tomato is validated in different cultivars [17].

Table 4. Effect of different level of EM on leaf area (cm^2) of tomato plants

Treatments	LC	PM	Mean
Control	2.33c	2.5c	2.41b
Control+80ml EM	2.8b	3.4a	3.1a
Mean	2.56b	2.95a	
CV	4.68		

Leaf dry weight

Mean leaf dry weight presented in (Table 5) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant (P<0.05). Mean value of the information demonstrated that plant attained maximum leaf dry weight (1.07) at T_4, followed by T_3 (0.73). While minimum leaf dry weight in T_1 (0.70) was observed.

The gainful impacts of EM application on biometric boundaries was appeared in a prior investigation led by [18] Plants cultivated in 50 ml effective microorganisms displayed a complex proportion of leaf dry weight equaled to other treatments, with the exception of the control plants. Cultured of plant with 100 ml effective manure had the final ratio of dry leaf weight is fundamentally higher from the plants which had gotten the week by week 50 ml EM contrasted with the control plants and those treated with higher 80 mL of effective manure.

Table 5. Effect of different level of EM on leaf dry weight of tomato

Treatments	LC	PM	Mean
Control	0.70c	0.82b	0.76b
Control+80ml EM	0.73bc	1.07a	0.90a
Mean	0.71b	0.95a	
CV	6.89		

Days to flowering

Mean days to flowering presented in (Table 6) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4 were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant ($P<0.05$). Mean valueof the information demonstrated that plant attained maximum days to flowering (73.66) at T_4, followed by T_3 (69.66). While minimum days to flowering in T_1 (65.33) was observed.

Scientist reported that days of flowering in tomato is decidedly identified with expanding every day mean light power and acquired the after effects of builds blossom of per plant bud number, high temperature cause high number of flowers droop. A few investigations have demonstrated that numbers of fruit each truss in tomatoes which belong to a similar family of plant as eggplant [19].

There is plentiful proof of progress to blooming of numerous yields are directly identified with day time temperature over an improper under in ideal or more an ideal stress, the opportunity to blossoming and fruit setting as needs be increments straightly [20]. They likewise exposed that the level of yield advancement is regularly touchy to temperature. The pace of crop advancement is expressed to govern crop span, which is vital in deciding crop profits [21]. Then again, studies on various crops have indicated that short light likewise significantly delays plants flowering time [22].

Table 6. Effect of different level of EM on days of flowering of tomato plants

Treatments	LC	PM	Mean
Control	65.33c	71b	68.16b
Control+80ml EM	69.66b	73.66a	74.66a
Mean	67.50b	75.33a	
CV	2.24		

Number of fruit per plant

Mean value of fruits per plant presented in (Table 7) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant ($P<0.05$). Mean value of the information demonstrated that plant attained maximum number of fruits per plant (24.66) at T_4, followed by T_3 (16.66). While minimum number fruit per plant in T_1 (13.66) was observed. The same result was also observed in [23] while he reported that the use of effective microorganism caused about a 26.9% expansion in fruit yield comparative with the power when applying compost brought about a 23.2% reduction in organic fruit yield. Similar results are also obtained by [24] where utilization of effective microorganisms expanded tomato crop yield fruit and plant growth. Obviously, the utilization of generally using of effective microorganism to the soil connected with an expansion in soil microbial biomass that expands cooperative organic obsession with nitrogen obsession by increments in Azotobacter bacteria.

Table 7. Effect of different level of EM on number of fruits per plant in tomato plants

Treatments	LC	PM	Mean
Control	13.66c	18b	15.83b
Control+80ml EM	16.66b	24.66a	20.66a
Mean	15.16b	21.33a	
CV	6.89		

Post-harvest parameters
Fruit color
Mean value of fruits colour presented in (Table 8) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4 were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant ($P<0.05$). Mean value of the information demonstrated that plant attained maximum fruits colour (29.66) at T_4, followed by T_3 (24.33). While minimum fruit colour in T_1 (17) was observed.

Similar result was also observed in **[25]** indicated that fruit of the various cultivars and sources had fundamentally different a/b color proportions at each testing date, for example on days 1, 7 and 14. That fruit from source 3 has picked at a highly mature stage than that from different sources. These outcomes suggested that at minimum two QTL exist on IL4-3, ic-4F through a bad impact in color enhancement ic-4H that develops color. The next QTL mapped chromosome 6 (ic-6A) shorter arm, where its results in the combined study were only highly important. The decrease in the inner color the beta gene found in IL6-3 raises β-carotene in the fruit to the detriment of lycopene **[26]**. Four covering lines characterized the ic-7B that decreased shading, while ic-7F was just powerful in the wet condition. Three QTL were characterized to chromosome 8: ic-8C planned to a little hereditary portion (2 cM) that must be kept up in a heterozygous state in IL8-1. A goal of the two connected QTL, ic-8E and ic-8F, depended on a comparative reason with respect to the connected loci on the long arm of chromosome 4. Ic-9G had its most strong impacts in the wet condition, and on chromosome 10 two major QTL were defined; ic-10B improving color and ic-10E is the QTL with the biggest decreasing impact on internal color in the population. Ic-11B was for the most part powerful below dry environments, while ic-12C **[27]** and ic-12H were recognized under the both environments. Marker and phenotypic investigations of separating populations including crosses of the developed tomato with its wild relatives revealed various QTL that adjust fruit color. The little red-fruited species L. pimpinellifolium is wealthy in lycopene, with values five-overlay higher than in the developed tomato. Eight QTL that adjust lycopene content in the fruit, including a significant QTL representing 12% of the all-out phenotypic variety, were recognized in an isolating populace including L. pimpinellifolium **[18]**. Progressed backcross investigation including an alternate promotion of L. pimpinellifolium distinguished five QTL that change natural product shading power **[28]**. Of the 13 QTL recognized in the red-fruited species crosses, 10 significantly affected improving shading. In a populace got from a cross with a L. esculentum var. cerasiforme **[29]**.

Table 8. Effect of different level of EM on fruit color of tomato plants

Treatments	LC	PM	Mean
Control	17d	19.33c	18.16b
Control+80ml EM	24.33b	29.66a	27a
Mean	20.66b	24.50a	
CV	3.04		

Average fruit length (cm)

Mean value of average fruit length presented in (Table 9) showed the effect of effective microorganisms with different media. Four treatments T1, T2, T3, and T4 were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant (P<0.05). Mean value of the information demonstrated that plant attained maximum average fruit length (6) at T4, followed by T3 (5.50). While minimum average fruit length in T1 (4.93) was observed.

Similarly, result was observed by [30] Usual fruit length was significantly (P≤ 0.05) influenced by a portion of the utilization of EM had a critical impact on Averagelength of fruit a positive pattern was seen with its application. So use of effective microorganism brought about an 11.6% expansion in fruit Length comparative with the control. At the point while effective microorganism was added to compost, a 9.9% expansion in normal comparative fruit was noted to manure handling. Scientist stated that there was no distinction in tomato development or yield between a set up natural framework and the similar conventional framework. When averaged across cultivars, organic yield was only about 63% of the conventional one [31]. Scientist showed that fertilizing with mature manure resulted with increased tomato average yield. The contrasts between regions were related with soil type and EM and exhibited the requirement for additional examinations to be completed under various conditions [32].

Table 9. Effect of different level of EM on average fruit length of tomato plants

Treatment	LC	PM	Mean
Control	4.93c	5.03c	4.98b
Control+80ml EM	5.50b	6a	5.75a
Mean	5.21b	5.51a	
CV	2.31		

Average fruit diameter

Mean value of average fruit diameter presented in (Table 10) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant (P<0.05). Mean value of the information demonstrated that plant attained maximum average fruit diameter (6.50) at T_4, followed by T_3 (6). While minimum average fruit diameter in T_1 (5.43) was observed.

The obtained outcomes in regards with the impact of EM application on yield and bunch weight and diameter are in accordance with the study of [33] on "Bartamuda" date palm. Scientist also declared that the all EM treatments advanced fruit development as reflected by quicker increment in diameter of fruit. The fruit actual size as far as diameter of fruit and weight of fruit at reap in treatments were all higher than in those taken in untreated. The impact of EM on reducing the effect of soil media on yield and bunch weight may be attributed to the increase of leaf total chlorophyll content which leads to more carbohydrates production through photosynthesis process and increasing vegetative growth (fruit size, fruit diameter and fruit weight, etc) and consequently improved fruit set percentage, retained fruit percentage and finally improved yield and weight [34].

Table 10. Effect of different level of EM on average fruit diameter of tomato plants

Treatments	LC	PM	Mean
Control	5.43c	5.53c	5.48b
Control+80ml EM	6b	6.50a	6.25a
Mean	5.71b	6.01a	
CV	2.11		

Total soluble solids (TSS)

Mean value of total soluble solid presented in (Table 11) showed the effect of effective microorganisms with different media. Four treatments T_1, T_2, T_3, and T_4 were selected for the experiment. Each treatment was replicated three times. The analysis indicated noteworthy difference among treatment (control vs treated plant), whereas the interaction among effective microorganism (EM) and organic substrate (leaf compost and poultry manure) were also significant ($P<0.05$). Mean value of the information demonstrated that plant attained maximum total soluble solid (4.56) at T_4, followed by T_3 (4.02). While minimum total soluble solid in T_1 (3.70) was observed.

Similar outcomes were accounted by [35] that total soluble solids substance of tomato is influenced through the association among EM, harvesting time and growing framework ($p<0.05$). First harvesting (30 days), customary tomato framework had more significant level of total soluble solids contrasted with their natural partners, yet these level are equivalent to the second harvesting (45 days), TSS increment as an outcome of the advancement of the postharvest maturing process. Production of fruit are highly acidic due to the large quantities of stored sugars and the in overall acidity normally occurring during maturation. Additional aspect deciding acidity fruit is the most common organic acid are malic lime, tartaric quinic, oxalic, fumaric, and succinic acid, every one of them having a novel taste that adds to the general flavour of fruits [36]. When overall values in both systems increased. This can be expected to slower pace of starch hydrolysis in the last category, indicating better quality support for tomato processing. The overall pattern saw the underlying increment of total soluble solids was followed by a reduction during storage [37]. Showed that starch is accumulated in green tomato that begin to fall with the start of ripening, followed by increasing soluble solids. It has been additionally revealed that absolute soluble solids increment with color and development [38]. The correspondence current outcome Increment in total soluble solid of tomato fruit might be because of over the top moisture loss which expands focus just as the hydrolysis of starches to soluble sugars [39]. Thus, it demonstrates the longevity and longer shelf life of the handling tomato over that are not processing.

Table 11. Effect of different level of EM on total soluble solid content of fruits (TSS) of tomato plants

Treatments	LC	PM	Mean
Control	3.70c	3.90b	3.80b
Control+80ml EM	4.02b	4.56a	4.29a
Mean	3.86b	4.23a	
CV	2.00		

Conclusion

It was concluded from current experiment that Treatment T_2 poultry manure + effective microorganism (PM+EM) showed better results in term of plant height, no. of fruit per plant, average fruit weight as compared to other tested substrates mixtures. Experimental results proposes to practice the effective microorganism with poultry manure as suitable combination for enhancing tomatoes production.

Authors' contributions

Conducted experiment and wrote first draft of manuscript: M Sajid, Supervised the experiment and helped in technical writing: SJ Butt, Technical guidance throughout my research: ZU Haq, Corrected this manuscript: I Naseem & A Iqbal, Formatted this manuscript and helped statistical analysis: QA Khan, Helped in data collection: H Ali.

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