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Positive effects of a formulated microbial consortium on the growth and well-being of okra and tomato crops

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ABSTRACT

The impact of microbial consortium (MC) comprising plant development-promoting organisms (PGPMs), for example, *Bacillus* sp., *Enterobacter* sp. (bacteria), *Aspergillus* sp., *Penicillium* sp. (fungus), and *streptomycin* sp. (actinomycetes) which are effective on two vegetable crops (okra and tomato). These strains were collected from five geologically isolated soil samples of agricultural fields around Bhubaneswar, Khurda, India (20.65946°N, 86.75409°E) and were biochemically characterized. The promising isolates were confirmed by 16s rRNA sequence. The MC was applied at five different concentrations, viz., 0.2%, 0.5%, 1.0%, 1.5%, and 2.0% (v/v using MS medium) along with a control were included. The combinations of above mentioned PGPMs strains significantly increased shoot height, plant height, leaf length, and leaf width at three-day intervals, and fresh weight, dry weight, and root length at the end of the study period. The results revealed that the protective effect of MC significantly increased all the parameters. The crop growth parameters were confirmed MC was effective when tested against control crops. The MC was more effective with the soil base than without a soil base. Among different concentrations of MC, 0.5% of MC was more effective for all the test crops as compared to other concentrations. So, 0.5% was optimal for microbial colonization to ensure the provision of soil nutrients, as no discernible change in growth parameters was observed to further increase in concentration. Also, a study on microbial and physicochemical parameters of all the treatments of all the crops was recorded. The lab study is a small-scale investigation to confirm the efficacy and the sustainability of MC in with soil and without soil of Odisha. Overall, the study illustrated a healthy biotic (consortium microbes and natural soil microbes) and abiotic (MS medium and soil supplement) interaction is advantageous for crop development and advancement.

KEYWORDS

Biotic and abiotic interaction; Microbial consortium; Phylogenetic tree; Phytological analysis; Plant growth promoting microbes

ARTICLE HISTORY

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Introduction

Agribusiness has been the biggest monetary source since the beginning of development. About 7.41 billion individuals possess the earth, involving 6.38 billion hectares of the earth's surface, of which 1.3 billion individuals are straightforwardly reliant on farming [1]. For sustainable agriculture maintenance, soil dynamic nature is of prime significance. Today, with a worldwide populace surpassing 7.7 billion, agribusiness inflexibly keeps on assuming a significant part in the endurance of humankind [2]. The interest in staples among the quickly developing worldwide human populace is climbing every day. To address this issue by expanding rural profitability, cultivating frameworks over the globe utilized synthetic composts [3,4]. Increased eco-concerns dissuade using chemicals in agriculture, and environmental technologists suggest organic manure practices instead. However, the use of organic manure practices may not be enough to meet the escalating food demand. Applying crop development animating viable microorganisms to the soil with or without organic manuring has been the focus of the scientific community recently [5,6]. These microbes would enhance the degradation process in soil, enhance the soil profile, and provide nutrients that would, in turn, stimulate agricultural crop growth and productivity [7,8].

Vegetable harvests are an essential wellspring of nourishment in our eating routine. It is grown everywhere in the world as a nutritive food. Intensive farming practices can lead to high yields and quality, but the extensive use of chemical fertilizers can have negative ecological impacts due to their cost and potential harm to the environment. Hence, as of late, there has been a recovery of enthusiasm for environmentally friendly, sustainable, and organic agricultural practices. They are a wellspring of proteins, vitamins, minerals, dietary fibers, micronutrients, antioxidants, and photochemicals. Apart from this, they also contain a wide range of potential photochemicals like anti-carcinogenic principles and antioxidants [9,10]. India is the second largest producer of vegetables, with the production of 19697 metric tons of vegetables in 2016-2017 on an area of 8.09 million hectares [11,12]. Still, the creation of vegetables is exceptionally low and needs improvement, with the goal that it can satisfy the dietary prerequisite of the developing populace. This nation is honored with different agroclimatic conditions with particular seasons, making it conceivable to grow a wide exhibit of vegetables. Among vegetables, okra and tomato have an incredible hugeness.

Since there is a lack of knowledge about chemical fertilizers, farmers have relied on them to boost crop yields for a long time. However, the continued use of chemical pesticides and fertilizer has made it difficult to maintain soil fertility and harmed the soil health profile. Therefore, numerous beneficial microorganisms were killed who lived inside the soil, and sometimes those products included chemical that was also harmful to human health. So, it becomes essential to decrease

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or reduce the use of chemical fertilizers from agricultural fields [13,14]. In their natural environment, crops are part of a rich ecosystem as well as numerous and diverse microbes which is present in the soil. It has been long accepted [15,16]. In this scenario, a major focus on plant growth-promoting microbes (PGPM) for restoring the agroecosystems to their original shape is gaining the attention of agronomists and environmentalists.

Various infinitesimal life forms such as bacteria, actinomycetes, and fungi assume a significant capacity in crop improvement and development as a PGPM. They establish beneficial relationships with target crops where the two players have an advantage [17]. PGPM increases agronomy profitability by decreasing the creation cost and environmental pollution as the usage of substance manure with productivity PGPM [18]. The rhizospheric plant-microorganism participation that supports plants by giving sustenance and biological protection is considered the ecological backbone. It might be altered to increase plant prosperity. Different microbial networks that advance development significantly through nitrogen obsession, phosphate and potassium solubilization, exopolysaccharides emission, biocontrol, natural matter disintegration, siderophores creation, and so on are utilized as biofertilizer inoculants [18-21]. Biological agricultural inputs, viz., biofertilizers, biopesticides, biodegrades, and microbial formulations comprising beneficial microbes, ensure healthy biogeochemical cycling in soil acting as miniature biofactory [22,23]. Commercially available microbial inoculants of either a single strain or a consortium are popular among farming communities [24].

Microbial inoculants are of growing interest for their potential role in improving soil fertility and enhancing an increase in crop yields and nutrient contents. Microbial inoculants are formulations composed of beneficial microbes that play a vital role in every ecosystem. When applied to seeds, soil, or seedlings, microbial inoculants improve directly or indirectly the nutrient availability to the host plant and promote plant growth [25,26]. They hold a great promise to improve crop yield [27]. In the present agricultural practices, there are a number of beneficiary soil microbes used as inoculants. They include *Pseudomonas* sp., *Azospirillum*, *Azotobacter* and, *Phosphobacterium*, etc. [28,29]. Microbial inoculants improve plant growth through a number of mechanisms, which include the production of plant hormones, the supply of nutrients, and the suppression of various phytopathogens etc. [30]. Moreover, they form an important component of organic farming practices. Therefore, the present study was endeavoring to evaluate the effect of microbial inoculants on the growth and yield of vegetable crops, viz., okra and tomato crops.

With a target to increase the impact of specific biotic and biotic networks on the prosperity and yield of agricultural crops on the okra and tomato crops specifically, soil samples were collected from agricultural fields in Kendrapara, Odisha, India. To screen for the potential viable microorganisms that could upgrade crop development, different microbial groups were isolated, pure cultured, and biochemically characterized. In view of the outcomes, a few selected microbial isolates, viz., *Bacillus* sp., *Enterobacter Hormaechei* (microscopic organisms), *Aspergillus* sp. furthermore, *Penicillium* sp. (parasites), and *Streptomyces* sp. (actinomycetes) were shortlisted as possible compelling microbes. The fundamental target of this investigation was to examine the impact of microbial inoculants on vegetable harvests, for example, okra and tomato with soil and without soil base, and evaluation of growth indicator parameters, viz., shoot height, plant height, root length, leaf width, leaf length, fresh weight, dry weight, for comparative empirical analyses.

Materials and methods

Crop materials

Crop material seeds of okra (*Abelmoschus esculentus*) and tomato (*Solanum lycopersicum*) cultivars were used in this investigation, and the experiment was conducted at the school of biotechnology, KIIT deemed to be University situated at 20.35879 latitude and 85.82214 longitude. Seeds of okra and tomato were used for the experiment based on economic and popular vegetable crops. Before starting an experiment, a handful of seeds were kept in a beaker with distilled water (250ml) for 15¬-20 minutes for the seed viability test. Settled seeds were collected and then wrapped in a smooth cloth overnight. As a result, the germinated seeds were used for the experiments, and only ten seeds were used for the experiment per plate; among them, five seeds were calculated for data analysis.

Collection of soil samples for experiment

Soil samples were collected randomly from the Katana, Kendrapada district of Odisha, for the experiment. The experimental site is situated at 86.75409 longitudes and 20.65946 latitude. The soil was red sandy loam with pH- 6.5. Using the random sampling method, soil samples were collected from each sampling unit at 0-15cm. The soil samples collected from each of the sampling sites were bulked and transported to the laboratory in well-labeled polyethylene bags. The core samples were then air-dried for 3 days for analysis. These were homogenized, sampled, and spread on trays to be properly cleaned of irrelevant materials such as pieces of root, leaf, small stem, etc., followed by drying and storing in plastic containers tightly sealed. For microbial analysis, the soil sample was kept at 4 °C to keep the field moist and to preserve biological properties.

Experimental design

The lab experiment was carried out in two various ways: one is soil base (SB), and the other one is blotting paper soil (BS) for 15 days was conducted at KSBT, KIIT at room temperature (25 °C). The microbial consortium was applied to the soil (SB) and without soil (BS) at five different concentrations, viz., 0.2%, 0.5%, 1.0%, 1.5%, and 2% (v/v using MS medium) and negative control (without any application whatsoever) were included in the study. All the treatments had triplicate plates.

Test set-up with soil base (SB)

Soil, as a natural resource, provides a hospitable place for crops to take root. It stores and supplies minerals and nutrients to the growing plants. The soil's organic matter content is a direct indicator of its fertility and also is an indicator of soil health. Considering this, to permit typical regular natural growth of the crop plant in a controlled laboratory condition, a treatment set with soil base was incorporated. Each soil base test set-up had 80.0g of soil (Figure 1).

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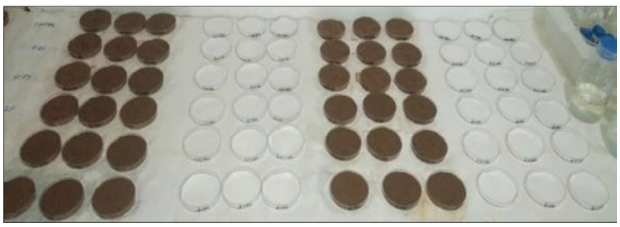

Figure 1. Experimental set-up with soil (brown Petri plates) and blotting paper (white Petri plates) bases.

Test set-up with blotting paper base (BB)

As a counterpart of the setup with a soil base, the soil base was replaced with a blotting paper base. Thus, herein, soil was denied as an essential supplement source. Here, a three-layer blotting paper was used as the base instead. Supplement-rich MS medium alongside the different MC arrangement focuses were put on each test setup as a mineral supplement optimizer. The control had the MS medium application, as it were. Each blotting paper base test setup had a three-layer blotching paper. Both the test setups are introduced in Figure 1.

Identification of isolates by 16S rRNA sequence analysis

The sequence data were assembled and analyzed using the basic local alignment search tool (BLAST) was performed by comparing the sequences obtained to other microbial sequences in the National Center for Biotechnology Information (NCBI) database (http://www.ncbi.nlm.nih.gov/BLAST/). For the construction of a phylogenetic tree, the 16S rRNA gene sequences of type strains and other strains closely related to our five isolates were obtained from the NCBI database. Multiple sequence alignments were performed by the MEGA X software.

Selected isolated for microbial consortium preparation

Local bacterial isolates were *Bacillus* sp. (Accession No. MN216320) and *Enterobacteria* sp. (Accession No. MN216322); *Aspergillus* sp. (Accession No.MN258895) and *Penicillium* sp. (Accession No. MH091068) were fungal isolated and *Streptomyces* sp. (Accession No. MN252568) isolates from actinomycetes was selected by confirming 16s rRNA sequencing. These selected isolates participated in a microbial consortium collected from rice fields in five different regions of Odisha. Nutrient agar (NA), actinomycetes isolation agar (AIA), and potato dextrose agar (PDA) media were used for bacteria, actinomycetes, and fungus isolates which were cultured for 24 and 72 hours, respectively. These isolates were used for the microbial consortium.

Microbiological parameters using for the study

To estimate the microbial population (CFUs/g), 1.0g of soil sample was serially diluted using sterile saline water; the diluted sample was spread plated and incubated at 37 °C (for bacteria) and 30 °C (for actinomycetes) for 24hr and 72hr respectively, on solidified nutrient agar (for bacteria) and actinomycetes isolation agar (for actinomycetes). 2.8g of the nutrient agar was added to 100ml of distilled water, heated till it dissolved, autoclaved, and cooled before plating. Likewise, solidified media for actinomycetes were prepared from 2.2g actinomycetes isolation agar respectively in distilled water. After completion of the incubation period, the colony-forming units were counted and converted to CFU/g by considering the dilution factor and weight of soil (1.0g).

Preparation of liquid Murashige and Skoog medium (MS medium)

Media preparation is one of the primary and essential steps for microbiological techniques. MS medium comprises necessary plant growth compounds like inorganic (salts of macro-nutrients, micro-nutrients, and iron) and organic (energy, vitamins, amino acids) sources, prepared in distilled water. Iron salt solution stock was kept in the amber color bottle to avoid photo-oxidation and was maintained at 4 °C. The working medium was prepared by adding the desired volume of the stock solution in the recommended volume of distilled water adjusting the pH to 5.8 prior to autoclaving. About 15-20ml of the medium was used in each test plate.

Determination of physicochemical properties of soil of study sites

The physical and chemical properties measured include pH using Kent pH meter model 7020, temperature (°C), and moisture content (%) by using the American Public Health Association (APHA) manual. Total organic carbon (TOC, %) was estimated using the Walky and Black method. Total phosphorous (P, %), nitrite (NO^{2-}, %), nitrate (NO^{3-}, %) and ammonium (NH^{4+}, %) were calculated by the spectophotometrical method.

Phytological parameters for the study

The experiment was conducted in lab conditions, with two stages, with soil (W/S) and without soil (W/oS) base, where many parameters were included. Growth parameters such as shoot height (SH, cm), plant height (PH, cm), root length (RL, cm), leaf length (LL, cm), width (LW, cm), and fresh weight (FW, g) and dry weight (DW, g).

Statistical analysis

All the analyses were performed in triplicates, and the results were collated to calculate the mean and standard deviation. The resulting data are presented in the form of graphs as mean along with standard deviation. The graphs are made using Microsoft Excel 2010 and Graph Pad Prism Software (Ver. 6.01), USA. These were used to evaluate the differences in the mean. T-test ($p<0.05$) was conducted using the LSD (least significant difference) to decipher the statistical significance.

Results

Microbial consortium (MC) effect on okra

At the end of the experiment, plant height (PH) of rice in SB was found to be 12.72cm and 7.65cm, whereas 12.39cm and 6.65cm in BB at 0.5% MC and control, respectively. The shoot height (SH) of SB was 10.88cm and 6.08cm, whereas 10.21cm and 6.24cm in BB at 0.5% MC and control, respectively (Table 1).

Similarly, the leaf length (LL) was 1.35cm and 0.95cm in SB, whereas 1.13cm and 1.13cm during the same duration in BB in 0.5% MC and control, respectively. The leaf width (LW) was 2.04cm and 1.59cm in SB and 2.24cm and 1.52cm in BB by the 15th day at 0.5% MC and control, respectively (Table 1).

The root length (RL) was 3.82cm and 2.20 in SB, 3.33cm and 1.12cm in BB, fresh weight (FW) was 4.82cm and 3.35cm in SB and 4.80cm and 3.09cm in BB, while the dry weight (DW) was 2.78cm and 1.14cm in SB and 2.70cm and 1.06cm in BB at by the 15th day at 0.5% MC and control respectively (Table 1).

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Table 1. The phytological report of the okra crop test at 0.2, 0.5, 1.0, 1.5 and 2.0% MC concentrations.

		Okra (SB)						Okra (BB)					
Parameters	Days	C	0.2% MC	0.5% MC	1.0% MC	1.5% MC	2.0% MC	C	0.20% MC	0.50% MC	1.0% MC	1.5% MC	2.0% MC
PH (cm)	3rd Day	1.80 ± 0.19	2.51 ± 0.04	2.62 ± 0.10	2.55 ± 0.18	2.50 ± 0.03	2.65 ± 0.06	1.56 ± 0.02	2.20 ± 0.06	2.38 ± 0.01	2.38 ± 0.04	2.4 ± 0.05	2.54 ± 0.03
	6th Day	2.37 ± 0.13	4.79 ± 0.07	4.71 ± 0.08	4.49 ± 0.23	5.03 ± 0.17	5.05 ± 0.14	2.17 ± 0.05	4.31 ± 0.02	4.69 ± 0.06	4.67 ± 0.10	4.7 ± 0.05	4.92 ± 0.01
	9th Day	4.51 ± 0.08	7.12 ± 0.09	7.46 ± 0.12	7.33 ± 0.05	7.85 ± 0.15	7.61 ± 0.30	3.55 ± 0.02	7.17 ± 0.01	7.54 ± 0.02	7.35 ± 0.20	7.3 ± 0.05	7.54 ± 0.03
	12th Day	5.72 ± 0.16	9.35 ± 0.03	9.91 ± 0.04	9.61 ± 0.28	10.51 ± 0.38	9.49 ± 0.04	5.54 ± 0.02	9.35 ± 0.04	9.55 ± 0.02	9.61 ± 0.28	9.9 ± 0.07	9.49 ± 0.04
	15th Day	7.65 ± 0.02	11.35 ± 0.02	12.72 ± 0.21	11.22 ± 0.46	11.59 ± 0.03	11.83 ± 0.38	6.65 ± 0.03	11.26 ± 0.03	12.39 ± 0.02	10.75 ± 0.17	10.59 ± 0.03	11.23 ± 0.03
SH (cm)	3rd Day	1.28 ± 0.03	2.35 ± 0.11	2.61 ± 0.37	2.30 ± 0.04	2.31 ± 0.08	2.30 ± 0.16	1.17 ± 0.04	2.07 ± 0.05	2.45 ± 0.03	2.33 ± 0.08	2.18 ± 0.14	2.26 ± 0.10
	6th Day	2.17 ± 0.12	3.12 ± 0.04	3.58 ± 0.01	3.24 ± 0.05	3.15 ± 0.06	3.21 ± 0.10	2.43 ± 0.05	3.32 ± 0.15	3.64 ± 0.04	3.57 ± 0.08	3.45 ± 0.18	3.45 ± 0.14
	9th Day	3.66 ± 0.09	6.42 ± 0.09	6.88 ± 0.04	6.62 ± 0.06	6.55 ± 0.09	6.47 ± 0.14	3.59 ± 0.20	5.57 ± 0.16	5.81 ± 0.02	5.76 ± 0.07	5.72 ± 0.15	5.73 ± 0.14
	12th Day	5.89 ± 0.04	7.78 ± 0.17	8.94 ± 0.03	8.89 ± 0.03	8.49 ± 0.03	8.66 ± 0.11	5.43 ± 0.38	7.52 ± 0.04	8.25 ± 0.05	7.94 ± 0.03	7.58 ± 0.39	7.67 ± 0.41
	15th Day	6.08 ± 0.04	9.85 ± 0.06	10.88 ± 0.29	10.05 ± 0.14	10.25 ± 0.25	10.16 ± 0.05	6.24 ± 0.09	9.29 ± 0.39	10.21 ± 0.03	9.63 ± 0.58	9.55 ± 0.49	9.28 ± 0.17
LL (cm)	6th Day	0.42 ± 0.01	0.62 ± 0.01	0.92 ± 0.01	0.67 ± 0.01	0.63 ± 0.01	0.66 ± 0.01	0.36 ± 0.01	0.42 ± 0.01	0.53 ± 0.01	0.46 ± 0.01	0.43 ± 0.01	0.46 ± 0.01
	9th Day	0.63 ± 0.01	0.66 ± 0.01	0.78 ± 0.01	0.78 ± 0.01	0.72 ± 0.01	0.71 ± 0.02	0.53 ± 0.01	0.68 ± 0.01	0.73 ± 0.01	0.78 ± 0.01	0.63 ± 0.01	0.71 ± 0.02
	12th Day	0.75 ± 0.01	0.86 ± 0.01	0.88 ± 0.01	0.94 ± 0.02	0.92 ± 1.11	0.92 ± 0.02	0.75 ± 0.01	0.87 ± 0.01	0.94 ± 0.01	0.94 ± 0.02	0.92 ± 0.01	0.92 ± 0.02
	15th Day	0.95 ± 0.01	1.03 ± 0.01	1.35 ± 0.02	1.16 ± 0.01	1.01 ± 0.01	1.17 ± 0.01	0.85 ± 0.01	1.02 ± 0.02	1.13 ± 0.01	1.16 ± 0.01	1.11 ± 0.01	1.16 ± 0.01
LW (cm)	6th Day	0.97 ± 0.01	1.01 ± 0.01	1.11 ± 0.01	1.05 ± 0.01	1.04 ± 0.02	1.07 ± 0.10	0.92 ± 0.01	1.01 ± 0.01	1.11 ± 0.01	1.05 ± 0.01	1.05 ± 0.02	1.05 ± 0.01
	9th Day	1.17 ± 0.01	1.43 ± 0.02	1.48 ± 0.01	1.31 ± 0.23	1.51 ± 0.01	1.53 ± 0.00	1.16 ± 0.01	1.43 ± 0.02	1.48 ± 0.01	1.44 ± 0.01	1.51 ± 0.01	1.47 ± 0.02
	12th Day	1.37 ± 0.01	1.77 ± 0.02	1.93 ± 0.01	1.61 ± 0.49	1.89 ± 0.02	1.88 ± 0.01	1.32 ± 0.01	1.88 ± 0.01	1.93 ± 0.01	1.90 ± 0.01	1.89 ± 0.02	1.86 ± 0.01
	15th Day	1.59 ± 0.02	2.04 ± 0.02	2.24 ± 0.01	1.70 ± 0.57	2.03 ± 0.15	2.03 ± 0.00	1.52 ± 0.01	2.09 ± 0.06	2.24 ± 0.01	2.31 ± 0.02	2.28 ± 0.01	2.32 ± 0.02
RL (cm)	15th Day	2.20 ± 0.09	3.17 ± 0.06	3.82 ± 0.03	3.86 ± 0.02	2.20 ± 0.09	3.48 ± 0.04	1.12 ± 0.08	2.12 ± 0.08	3.33 ± 0.07	2.84 ± 0.10	3.12 ± 0.08	2.69 ± 0.17
FW (gm)	15th Day	3.35 ± 0.03	4.54 ± 0.07	4.82 ± 0.17	4.92 ± 0.05	4.99 ± 0.22	4.71 ± 0.10	3.09 ± 0.09	4.39 ± 0.09	4.80 ± 0.02	4.77 ± 0.03	4.75 ± 0.04	4.46 ± 0.13
DW (gm)	15th Day	1.14 ± 0.03	2.41 ± 0.03	2.78 ± 0.03	2.69 ± 0.04	2.62 ± 0.09	2.53 ± 0.04	1.06 ± 0.04	2.37 ± 0.04	2.70 ± 0.01	2.69 ± 0.01	2.44 ± 0.11	2.47 ± 0.05

Value presented in table are average (n=3) and ± standard deviation.

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Microbial consortium (MC) effect on tomato

In the case of the tomato crop, plant height (PH) of SB was found to be 8.79cm and 4.81cm, whereas 7.96cm and 4.67cm in BB by the 15th day at 0.5% MC and control, respectively. The shoot height (SH) of SB was 7.87cm and 3.74cm, whereas 6.67cm and 3.24cm in BB by the 15th day at 0.5% MC and control, respectively (Table 2). Similarly, the leaf length (LL) was 0.07cm and 0.05cm in SB, whereas 0.06cm and 0.05cm during the same duration in BB in 0.5% MC and control, respectively. The leaf width (LW) was 1.28cm and 1.24cm in SB and 2.28cm and 1.23cm in BB by the 15th day at 0.5% MC and control, respectively (Table 2). The root length (RL) was 2.31cm and 1.04cm in SB, 1.19cm and 0.63cm in BB, fresh weight (FW) was 2.25cm and 0.42cm in SB and 2.15cm and 0.31cm in BB, while the dry weight (DW) was 1.47cm and 0.49cm in SB and 1.45cm and 0.11cm in BB at by the 15th day at 0.5% MC and control respectively (Table 2).

Considering the height of both okra (Figure 2) and tomato (Figure 3), the 0.5% MC was more effective compared to other MC concentrations. It was better in SB compared to BB, attributable to the presence of soil (as an additional source of nutrients). Among all the MC concentrations, the 0.5% MC was more effective in both the test crops than its other counterparts. Other parameters estimated and recorded in Tables 1 and 2 also showed similar trends. Overall, 0.5% MC is the suggested optimal concentration for effective microbial colonization and the provision of proper soil nutrient mobilization, as no discernible change in the growth parameters could be observed with a further increased MC concentration (Figures 2 and 3).

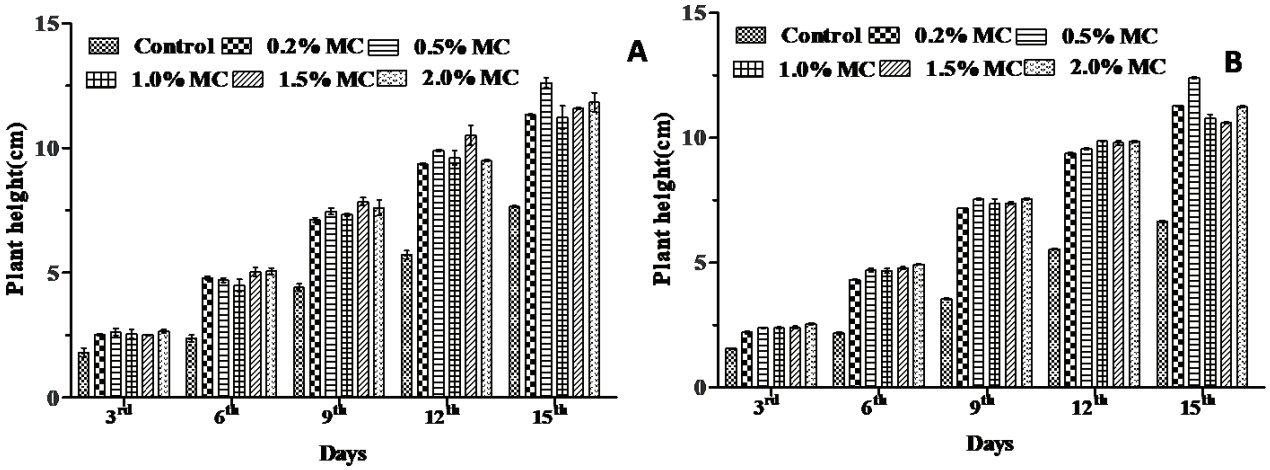

Figure 2. Effect of different concentration of microbial consortium (0.2, 0.5, 1.0, 1.5 and 2.0% MC) on plant height of okra crops both (A) SB and (B) BB test at different time intervals (3rd, 6th, 9th, 12th, and 15th days).

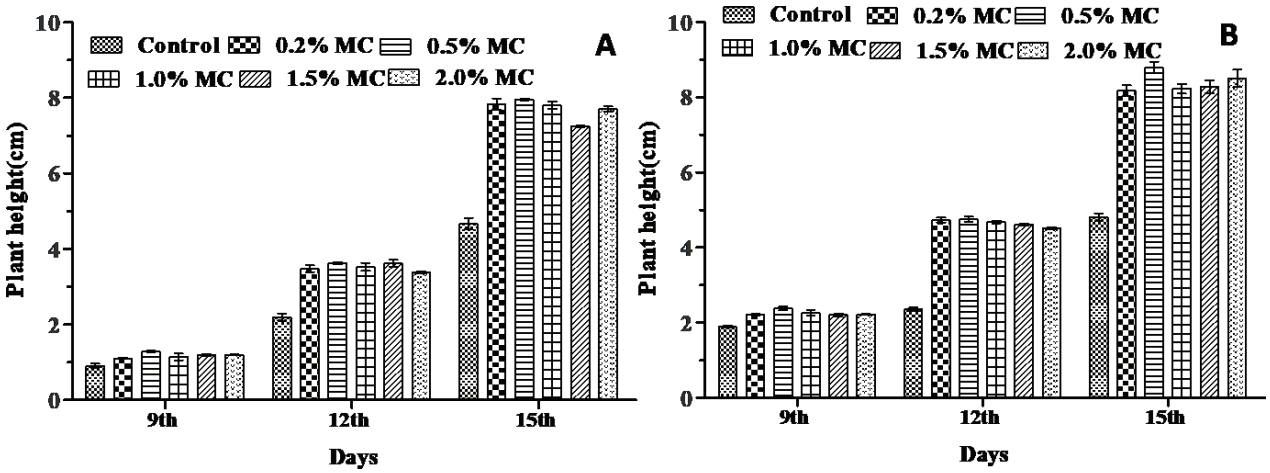

Figure 3. Effect of various MC concentrations on the tomato crop height both (A) SB and (B) BB test on 3rd, 6th, 9th, 12th, and 15thday.

The comparative impact of optimum MC concentrations (0.5%) on growth parameters

As discussed already, 0.5% MC with soil was found to be most effective for the enhancement of growth parameters for both of the crops (okra and tomato). A further attempt was made to evaluate which growth parameter was highly stimulated by MC. Seven growth parameters were considered for this experiment, among which four growth parameters viz., LL, LW, PH, and SH were monitored on the 6th (3rd monitor was not considered due to insignificant/no growth of growth parameters), 9th, 12th and 15th day at different time intervals. The ratio of 9th, 12th, and 15th to 6th was evaluated for all growth parameters and compared these values among growth parameters (Figure 4). However, the parameters viz., RL, FW, and DW growth parameters could not be included in the comparative study due

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Table 2. The phytological data of the tomato crop test at 0.2, 0.5, 1.0, 1.5 and 2.0% MC concentrations.

		Tomato (SB)						Tomato (BB)					
Parameters	Days	C	0.2% MC	0.5% MC	1.0% MC	1.5% MC	2.0% MC	C	0.2% MC	0.5% MC	1.0% MC	1.5% MC	2.0% MC
PH (cm)	9th Day	1.89 ± 0.02	2.21 ± 0.01	2.38 ± 0.04	2.26 ± 0.07	2.21 ± 0.04	2.22 ± 0.01	0.90 ± 0.05	1.10 ± 0.01	1.29 ± 0.25	1.14 ± 0.08	1.19 ± 0.02	1.20 ± 0.01
	12th Day	2.35 ± 0.04	4.73 ± 0.06	4.75 ± 0.06	4.68 ± 0.03	4.61 ± 0.03	4.50 ± 0.02	2.19 ± 0.10	3.48 ± 0.09	3.62 ± 0.02	3.52 ± 0.10	3.62 ± 0.09	3.38 ± 0.02
	15th Day	4.81 ± 0.10	8.18 ± 0.14	8.79 ± 0.15	8.23 ± 0.12	8.28 ± 0.17	8.54 ± 0.18	4.67 ± 0.15	7.83 ± 0.15	7.96 ± 0.02	7.80 ± 0.09	7.24 ± 0.02	7.70 ± 0.07
SH (cm)	9th Day	1.04 ± 0.03	1.13 ± 0.02	1.27 ± 0.04	1.16 ± 0.02	1.20 ± 0.01	1.19 ± 0.02	0.10 ± 0.01	0.22 ± 0.01	0.44 ± 0.10	0.22 ± 0.06	0.18 ± 0.05	0.20 ± 0.06
	12th Day	2.49 ± 0.11	3.41 ± 0.04	3.58 ± 0.09	3.55 ± 0.08	3.57 ± 0.06	3.50 ± 0.66	1.86 ± 0.12	2.33 ± 0.05	2.46 ± 0.09	2.48 ± 0.08	2.34 ± 0.02	2.31 ± 0.03
	15th Day	3.74 ± 0.17	7.77 ± 0.08	7.87 ± 0.09	7.48 ± 0.33	7.40 ± 0.15	7.55 ± 0.11	3.24 ± 0.14	6.60 ± 0.06	6.67 ± 0.11	6.57 ± 0.12	6.68 ± 0.08	5.66 ± 0.11
LL (cm)	9th Day	0.02 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01
	12th Day	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.05 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01
	15th Day	0.05 ± 0.01	0.06 ± 0.01	0.07 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01	0.06 ± 0.01
LW (cm)	9th Day	1.01 ± 0.01	1.04 ± 0.01	1.06 ± 0.01	1.01 ± 0.01	1.01 ± 0.01	1.01 ± 0.01	1.00 ± 0.01	1.02 ± 0.01	1.06 ± 0.01	1.01 ± 0.01	1.01 ± 0.01	1.01 ± 0.01
	12th Day	1.15 ± 0.01	1.14 ± 0.01	1.17 ± 0.01	1.12 ± 0.01	1.11 ± 0.01	1.12 ± 0.01	1.15 ± 0.01	1.14 ± 0.01	1.17 ± 0.01	1.12 ± 0.01	1.11 ± 0.01	1.12 ± 0.01
	15th Day	1.24 ± 0.01	1.24 ± 0.01	1.28 ± 0.01	1.17 ± 0.01	1.17 ± 0.01	1.20 ± 0.01	1.23 ± 0.01	1.24 ± 0.01	1.28 ± 0.01	1.17 ± 0.01	1.17 ± 0.01	1.16 ± 0.01
RL (cm)	15th Day	1.04 ± 0.05	2.06 ± 0.06	2.31 ± 0.04	2.22 ± 0.05	2.13 ± 0.08	2.20 ± 0.09	0.63 ± 0.05	1.06 ± 0.04	1.19 ± 0.01	1.01 ± 0.01	1.10 ± 0.01	1.05 ± 0.07
FW (gm)	15th Day	0.42 ± 0.03	2.23 ± 0.06	2.25 ± 0.05	2.15 ± 0.10	2.11 ± 0.03	2.20 ± 0.02	0.31 ± 0.04	2.14 ± 0.05	2.15 ± 0.04	2.09 ± 0.08	2.03 ± 0.02	2.09 ± 0.05
DW (gm)	15th Day	0.49 ± 0.61	1.42 ± 0.07	1.47 ± 0.14	1.28 ± 0.07	1.24 ± 0.06	1.19 ± 0.10	0.11 ± 0.02	1.27 ± 0.07	1.45 ± 0.07	1.23 ± 0.07	1.18 ± 0.02	1.08 ± 0.07

Value presented in table are average (n=3) and ± standard deviation

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to having only one result, which was monitored at the end of the experiment sacrificially.

As per Figure 4A, the 9th/6th values of PH, SH, LL, and LW of okra were found to be 1.58, 1.95, 1.12, and 1.33. The higher ratio of 9th/6th with SH suggested that SH showed higher times increment (0.95 times) compared to PH (0.58 times), LL (0.12 times), and LW (0.33 times), respectively with respect to 6th day. 12th/6th values of PH, SH, LL, and LW were found to be 2.10, 2.35, 1.17, and 1.73. The higher ratio of 9th/6th with SH suggested that SH showed higher times increment (1.35 times) compared to PH (1.10 times), LW (0.73 times), and LL (0.17 times), respectively, with respect to 6th day. Similarly, 15th/6th values of PH, SH, LL, and LW were found to be 2.63, 3.09, 1.69, and 2.01. The higher ratio of 9th/6th with SH suggested that SH showed higher times increment (2.09 times) compared to PH (1.63 times), LW (1.01 times), and LL (0.69 times), respectively, with respect to 6th day.

As per Figure 4B, 9th/6th values of PH, SH, LL, and LW of okra were found to be 2.18, 2.15, 1.25 and 1.17. The higher ratio of 9th/6th with PH suggested that PH showed higher times increment (1.15 times) compared to SH (1.18 times), LL (0.25 times) and LW (0.17 times), respectively with respect to 6th day. 12th/6th values of PH, SH, LL, and LW were found to be 4.78, 6.06, 1.75, and 1.28. The higher ratio of 9th/6th with SH suggested that SH showed higher times increment (5.06 times) compared to PH (3.78 times), LL (0.75 times), and LW (0.28 times), respectively, with respect to 6th day. Similarly, 15th/6th values of PH, SH, LL, and LW were found to be 8.06, 13.33, 2.25, and 1.57. The higher ratio of 9th/6th with SH suggested that SH showed higher times increment (12.33 times) compared to PH (7.06 times), LL (1.25 times), and LW (0.57 times), respectively, with respect to 6th day.

In terms of ratio analysis, the optimal MC concentration (0.5%) was found to be more effective on SH of both crops as compared to other parameter for both of the crops. The significant increases in growth parameters were in the following order: SH>PH>LW>LL for okra and SH>PH>LL>LW for tomato crops, respectively.

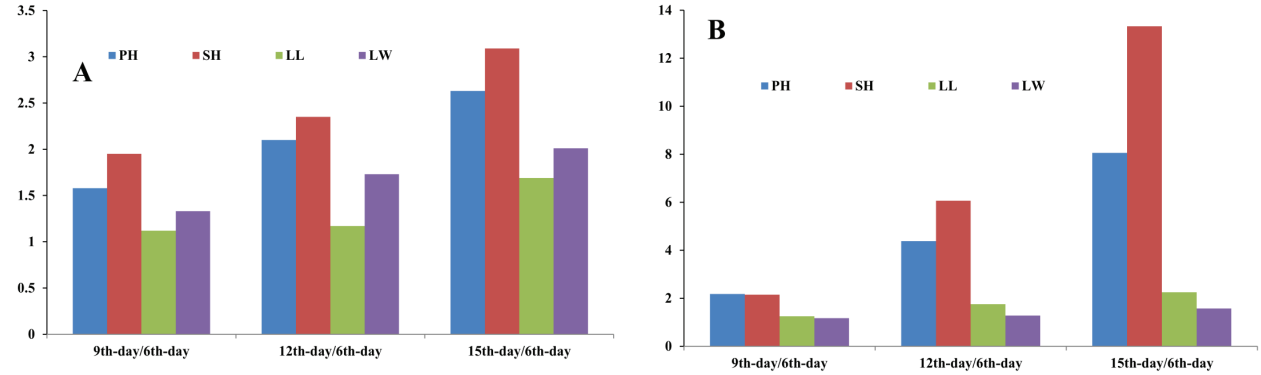

Figure 4. Variation of LL, LW PH and SH at different time intervals in rice crop (A) and okra crop (B) of 0.5% MC with soil during tomato crop growth.

Rhizosphere microbial population

Soil microbes are involved in various biochemical processes and are vital in maintaining soil fertility and yields. A microbial study of the soil confirmed the active bacterial, actinomycetes, and fungal populations that were an indicator of a healthier soil environment.

Microbial analyses (using the microbial counts formula: CFU/ml= No. of colonies × dilution factors/culture plate volume) confirmed that the soil microbial populations had more bacteria than actinomycetes and fungi (bacteria>actinomycetes>fungi).

The initial mean soil bacterial populations were 5.7 × 106, and 5.9 × 106 CFU/ml, the actinomycetes mean counts were 3.5 × 104 and 3.2 × 104 CFU/ml, and the fungal counts were 1.4 × 102 and 6.2 × 102 CFU/ml. After MC application, the microbial counts increased as observed by the 3rd, 9th and 15th day. Microbial analyses showed that bacterial, fungal, and actinomycetes population in SB soil was nearly the same among 0.2, 0.5, 1.0, 1.5, and 2.0% MC and control for a particular crop. The microbial population increased from the 3rd day to the 15th day (Table 3). The microbial population increased from the 3rd day to the 15th day (Table 3). For instance, the bacteria cell counts on the 3rd day were 6.3 × 106 for 5.7% MC, where it was 7.4 × 106 in control; by the 15th day, it was increased to 11.3 × 106 and 7.4 × 106 in 0.5% MC and control respectively in rice. Likewise, the actinomycetes and fungus counts also increased from the 3rd day to the 15th day in rice (Table 3). Likewise, the actinomycetes and fungus counts also increased from the 3rd day to the 15th day in okra (Table 3). In tomatoes, the bacterial counts by the 3rd day were 7.2 × 106 in 0.5% MC, whereas it was 5.3 × 106 in the control. By the 15th day, the count was increased to 12.8 × 106 and 7.3 × 106 CFU/ml in 0.5% and control, respectively. Similar was the trend in actinomycetes and fungi that increased from the 3rd day to the 15th day (Table 3).

Phylogenetic trees are widely used visual representations in the organic sciences and the main visual portrayals in evolutionary biology. As a result, phylogenetic trees have grown to be a crucial component of biology instruction [31]. Two approaches are frequently used for the identification of unidentified microorganisms that are used for the identification of microorganisms from all sources. Bergey manual is the manual that explains these biochemical tests in a purposeful manner that furthermore serves to identify the creatures [32]. The first is the biochemical qualities, where this approach drove various tests that incited information about obscure microorganisms. Atomic profiling is the second huge approach in which creatures' identification was done by 16s rRNA progression. As demonstrated by this gathering a couple of microbial identifications were done when diverged from

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Table 3. The soil microbial counts (CFUs/ml) at different time points during the study period.

			3rd Day			9th Day			15th Day		
Crop	0th Day	Treatments	Bacteria	Actinomycetes	Fungi	Bacteria	Actinomycetes	Fungi	Bacteria	Actinomycetes	Fungi
Okra	Bacteria- 5.7×10^6, and 5.9×10^6 CFU/g similarly Actinomycetes - 3.5×10^4 and 3.2×10^4 CFU/g, and fungal - 1.4×10^2 and 1.6×10^2 CFU/g.	Control	5.7×10^6	2.2×10^4	0.4×10^2	7.4×10^6	3.0×10^4	0.8×10^2	7.4×10^6	4.9×10^4	1.1×10^2
		0.2% MC	6.2×10^6	3.5×10^4	0.9×10^2	8.0×10^6	3.1×10^4	1.3×10^2	11.0×10^6	6.3×10^4	1.9×10^2
		0.5% MC	6.3×10^6	3.6×10^4	0.7×10^2	9.3×10^6	3.3×10^4	1.0×10^2	11.3×10^6	6.9×10^4	1.7×10^2
		1.0% MC	6.3×10^6	3.3×10^4	0.6×10^2	9.6×10^6	3.8×10^4	1.1×10^2	11.2×10^6	6.1×10^4	1.2×10^2
		1.5% MC	6.4×10^6	3.7×10^4	0.9×10^2	8.3×10^6	3.8×10^4	1.3×10^2	11.5×10^6	6.7×10^4	1.3×10^2
		2.0% MC	6.2×10^6	3.9×10^4	0.5×10^2	9.0×10^6	3.6×10^4	1.1×10^2	11.8×10^6	6.6×10^4	1.7×10^2
Tomato	Bacteria- 5.7×10^6, and 5.9×10^6 CFU/g similarly Actinomycetes - 3.5×10^4 and 3.2×10^4 CFU/g, and fungal - 1.4×10^2 and 1.6×10^2 CFU/g.	Control	5.3×10^6	2.5×10^4	0.5×10^2	7.9×10^6	3.2×10^4	0.6×10^2	7.3×10^6	4.2×10^4	1.2×10^2
		0.2% MC	6.9×10^6	3.0×10^4	0.7×10^2	8.8×10^6	4.3×10^4	1.2×10^2	12.2×10^6	6.5×10^4	1.2×10^2
		0.5% MC	7.2×10^6	3.3×10^4	0.9×10^2	9.0×10^6	4.0×10^4	1.1×10^2	12.8×10^6	6.8×10^4	1.5×10^2
		1.0% MC	6.7×10^6	3.6×10^4	0.7×10^2	9.1×10^6	4.2×10^4	1.0×10^2	12.4×10^6	6.2×10^4	1.5×10^2
		1.5% MC	6.6×10^6	3.7×10^4	0.5×10^2	9.6×10^6	3.9×10^4	1.4×10^2	11.3×10^6	6.4×10^4	1.3×10^2
		2.0% MC	6.5×10^6	3.1×10^4	0.8×10^2	9.4×10^6	3.5×10^4	1.7×10^2	12.7×10^6	6.7×10^4	1.7×10^2

various microorganisms [32,33]. Fundamentally, in this trial, microbial stains were disengaged from the gathered soil tests, and the strains were affirmed through 16s rRNA sequencing.

The 16s rRNA gene sequence obtained was compared against the DNA databank of JAPAN (DDBJ) and NCBI via BLAST analysis to retrieve similar sequences [34]. A Neighbor-joining (NJ) phylogenetic tree was constructed [35] using MEGA 7.0 [36]. A microbial consortium was built comprising bacterial, fungal, and actinomycetes strains. The 16s rDNA sequencing analysis of the isolate yielded base pairs, and NCBI BLAST search analysis showed that the sequence was 100% similar to the sequence of *Bacillus sp*. (Accession No. MN216320) and *Enterobacteria sp*. (Accession No. MN216322) along with fungal sp. *Aspergillus sp*. (Accession No.MN258895) and *Penicillum sp*. (Accession No. MH091068). A neighbor-joining tree based on 16S rDNA sequences showed that the isolate occupies a distinct phylogenetic position within the radiation, including representatives of the Streptomyces family, which was *Streptomyces sp*. (Accession No. MN252568). The 16S rDNA sequence was submitted to the GenBank, EMBL (Europe), and the DNA data bank (Japan) under the accession number.

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Physicochemical analyses

The pre and post-study soil chemical analyses for both crops are presented in Table 4. The mean initial pH, temperature, moisture content, Total organic carbon (TOC), nitrite, nitrate, ammonium, and phosphorous contents of both the crops in 0.2, 0.5, 1.0, 1.5, 2.0% MC and control were 6.05, 25 °C, 44%, 4.84%, 0.25 ppm, 0.13 ppm, 0.36 ppm, and 0.22 ppm were obtained across all the MC concentrations.

The corresponding values after the study in okra were 5.68, 24 °C, 48%, 5.12%, 0.45 ppm, 1.08 ppm, 1.47 ppm, and 0.47 ppm in control. Similarly, the corresponding values in the various MC concentrations were 5.70, 18.05 ℃, 54%, 5.14%, 0.49 ppm, 1.11 ppm, 1.69 ppm, and 0.63 ppm in 0.2% MC, 5.84, 16.70 ℃, 51%, 5.18%, 0.58 ppm,1.13 ppm,1.62 ppm, and 0.55 ppm in 0.5% MC, 6.70,17.87 ℃, 49%, 5.23%, 0.38 ppm, 1.06 ppm, 1.34 ppm and 0.69 ppm in1.0% MC, 6.87, 16.52°C, 48%, 5.18%, 0.64 ppm, 1.10ppm, 1.52ppm and 0.74 ppm in 1.5% MC, and 6.87, 16.66°C, 48%, 5.18%, 0.64 ppm, 1.10 ppm, 1.52 ppm and 0.74 ppm in 2.0% MC respectively (Table 4).

Similarly, in tomato, 5.70, 21.36 ℃, 55%, 5.10%,0.69 ppm, 1.10 ppm, 1.49 ppm, and 0.74 ppm were the pH, temperature, moisture content, TOC, Nitrite, nitrate, ammonium and phosphorous values in the control, 5.83,17.38 ℃, 51%, 5.15%,0.51 ppm,1.12 ppm,1.56 ppm and 0.93 ppm in 0.2%MC,5.88, 17.40 ℃, 53%, 5.11%,0.55 ppm,1.09 ppm,1.71 ppm and 0.70 ppm in 0.5%MC,5.70, 17.02 ℃, 49%, 5.13%, 0.65 ppm, 1.16 ppm, 1.65 ppm and 0.89 ppmin1.0%MC,6.84, 17.21 ℃, 51%, 5.14%, 0.32 ppm, 1.15 ppm, 1.88 ppm and 0.81 ppm in 1.5%MC, and 6.84, 16.00 ℃, 51%, 5.14%, 0.32 ppm, 1.15 ppm, 1.88 ppm and 0.81 ppm in 2.0% MC respectively for pH, temperature, moisture content, TOC, Nitrite, nitrate, ammonium and phosphorous respectively were found from soil experiment of tomato crop (Table 4).

Table 4. The soil physicochemical analyses at the time of sowing in okra and tomato crops.

Crop	0th day	Treatments	pH	Temp (℃)	Moisture content (%)	Total organic carbon (%)	Nitrite (ppm)	Nitrate (ppm)	Ammonium (ppm)	Phosphate (ppm)
Okra	pH-6.05, Moisture content- 44%, TOC- 4.84%, Nitrite- 0.25 ppm, Nitrate- 0.13%, Ammonium- 0.36% and Phosphate -0.22ppm	Control	5.68 ± 0.654	24.00 ± 0.5	48.00 ± 1.00	5.12 ± 0.321	0.45 ± 0.110	1.08 ± 0.232	1.47 ± 0.245	0.47 ± 0.244
		0.2%MC	5.70 ± 0.683	18.05 ± 1.0	48.00 ± 1.01	5.14 ± 0.323	0.49 ± 0.143	1.11 ± 0.223	1.69 ± 0.228	0.63 ± 0.173
		0.5%MC	5.84 ± 0.489	16.70 ± 0.9	48.00 ± 1.02	518 ± 0.343	0.58 ± 0.151	1.13 ± 0.211	1.62 ± 0249	0.55 ± 0.173
		1.0%MC	6.70 ± 0.863	17.87 ± 0.5	48.00 ± 1.03	5.23 ± 0.357	0.38 ± 0.100	1.06 ± 0.202	1.34 ± 0.236	0.69 ± 0.136
		1.5%MC	6.87 ± 0.887	16.52 ± 1.3	48.00 ± 1.04	5.18 ± 0.343	0.64 ± 0.194	1.10 ± 0.209	1.52 ± 0.278	0.74 ± 0.194
		2.0%MC	6.87 ± 0.887	16.66 ± 0.5	48.00 ± 1.05	5.18 ± 0.343	0.64 ± 0.194	1.10 ± 0.209	1.52 ± 0.278	0.74 ± 0.194
Tomato	pH-6.05, Moisture content- 44%, TOC- 4.84%, Nitrite- 0.25 ppm, Nitrate- 0.13%, Ammonium- 0.36% and Phosphate -0.22ppm	Control	5.70 ± 0.457	21.36 ± 1.58	55.00 ± 0.50	5.10 ± 0.318	0.69 ± 0197	1.10 ± 0.209	1.49 ± 0.267	0.74 ± 0.189
		0.2%MC	5.83 ± 0.373	17.38 ± 0.11	51.00 ± 1.00	5.15 ± 0.326	0.51 ± 0.141	1.12 ± 0.211	1.56 ± 0.223	0.93 ± 0.121
		0.5%MC	5.88 ± 0.381	17.40 ± 0.15	53.00 ± 0.50	5.11 ± 0.320	0.55 ± 0.143	1.09 ± 0.205	1.71 ± 0.289	0.70 ± 0.147
		1.5%MC	5.70 ± 0.736	17.02 ± 1.48	49.00 ± 1.00	5.13 ± 0.358	0.65 ± 0.156	1.16 ± 0.216	1.65 ± 0.278	0.89 ± 0.186
		2.0%MC	6.84 ± 0.784	17.21 ± 1.38	51.00 ± 0.50	5.14 ± 0.363	0.32 ± 0.134	1.15 ± 0.214	1.88 ± 0.256	0.81 ± 0.154
		2.0%MC	6.84 ± 0.784	16.00 ± 2.08	51.00 ± 1.00	5.14 ± 0.363	0.32 ± 0.134	1.15 ± 0.214	1.88 ± 0.256	0.81 ± 0.154

Value presented in table are average (n=3) and ± standard deviation

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Discussion

This study is based on the application of a mixed microbial culture (composed of strains of bacteria, actinomycetes, and fungi) SB and BB base for enhancing growth parameters of vegetable crops, viz., okra and tomato. Prior to the study, the seeds of crops were germinated, and these germinated seeds were considered for the study. Okra is grown extensively across India on an area of 0.36 million hectares, with a productivity of 9.83 t/ha and a production of 3.52 million tons. The crop is planted in Gujarat state on an area of 35,190 hectares, yielding 2,73,699 million tons with a productivity of 7.78 t/ha. Seed germination is the most significant and vulnerable phase of the crop cycle [37]. Seed germination and crop growth are significantly influenced by the nutrients available in the soil. Crops absorb all the essential nutrients (N, P, K, etc.) from the soil through root transporters, but the bioavailable forms of essential nutrients are limited in rhizospheres [38,39]. The rhizosphere acts as a microbial storehouse, which is the soil zone surrounding the crop's roots; the biological and chemical features of the soil are influenced by the roots. The concept of SB and BB base setup has been seen that soil is the best medium of essential supplements that help to crop stability, which is very important for crop growth toward the forward direction.

From Figure 2, all the MC concentrations were found to be more effective than the control in both SB and BB at initial to final days (0-d to 15-d) for plant height of okra. This result suggested that MC effectively metabolized the soil nutrients, thereby mobilizing the nutrients to water-soluble forms that help to stimulate the crop height [36,40], but in the case of control, the lower amount of plant accessible due to lack of microbial inoculants. In the comparison between SB and BS base, the PH (as a case study) was considered as a growth parameter with okra and tomato crops (Figures 2 and 3). The increased PH for microbial application SB than BB is due to the presence of soil for the former case (with soil case). It is evident that the soil contains various bound organic and inorganic materials along with microbes [41,42]. These naturally occurring microbes, along with the externally added microbial inoculants, could metabolize the soil materials and convert these bound forms of materials to water-soluble or crop-accessible forms. This phenomenon was completely absent in the case of BB-based applications. Additionally, the presence of soil with soil study stabilizes the crops by providing firmness and physical support to the crop, due to which shoot height grew vertically unhindered [43].

From Tables 1 and 2, it was confirmed that MC concentration was most effective for SB application. For this comparison between consortium effects with soil application, the RL was found to be 3.17, 3.82, 3.86, 2.20, and 3.48cm (SB) for okra and 2.06, 2.31, 2.22, 2.13, and 2.20cm for tomato, for 0.2, 0.5, 1.0, 1.5 and 2.0% microbial inoculants concentrations respectively after the 15-d study period. This result suggested that 0.5% was the optimal microbial inoculant concentration for soil biodegradation and providing soil nutrients to both crops, while further increase in concentration could not enhance the process; hence, no such improvement in RL was observed. So, the 0.5% microbial inoculant concentration was the most effective among all on RL. Likely, other parameters estimated and recorded in Tables 1 and 2 also showed similar trends. Overall, 0.5% MC is the suggested optimal concentration for effective microbial colonization and the provision of proper soil nutrient mobilization, as no discernible change in the growth parameters could be observed with a further increased MC concentration.

PGPM has been functioning as a co-evolution between plants and microbes, showing synergistic interactions and antagonistic with microbes and the soil [1]. The effectiveness of MC is supposed to be due to the mutual relationship between microbes present in microbial inoculants and vegetable crops [44,45]. This mutual relationship is an ecological interaction between biotic communities in which all the communities benefit. The microbial ability to enhance tolerance of plants in stressed soils and the impact of PGPM consortium on various crops [46]. In the present scenario, microbes might use secreted materials of the crop for growth and, in turn, produce crop growth-promoting hormones, metabolites, etc., that are used by the crop. Several studies have reported the effectiveness of microbial inoculants than control [47,48], e.g., a study used multiple species microbial inoculants for okra growth [45,49], and tomato [50-52] significantly higher growth was obtained with microbial application than control [49]. During ecological succession, both abiotic and biotic processes can modify plant-soil interactions. For example, over the relatively long time scales during which soils develop, soil biota can have strong but indirect influences on plant performance by decomposing organic material, mineralizing and immobilizing nutrients, weathering minerals, and ultimately regulating soil fertility [53] (Figures 5 and 6).

Normally, the bacterial counts of soil are higher than other microbes suggested that bacteria is the most abundant microbial group of soil followed by actinomycetes and fungi [54,55]. The similar result was also obtained in our study. The bacteria, actinomycetes and fungi count of soil prior to the study were found to be 5.7×10^6 CFU/g, 3.5×10^4 CFU/g and 1.4×10^2 CFU/g respectively. At the end of study the microbes were increased significantly for all the concentrations with both the crops (Table 3). According to Richardson, Hinsinger et al., Rashid et al. this substantial rise in microbial population indicated that the presence of a substantial quantity of nutrients in soil and the ideal experimental conditions facilitated the expansion of microbial population [56-58]. From microbial colony count study in soil was found to be higher after study than before study for all the crops at all MC concentrations, suggesting microbes showed the luxuriant growth resulting increased amount of available nutrients in soil for crop growth.

Further the physicochemical analysis of soil which showed that, phosphorus (phosphate form), available nitrogen (ammonium, nitrate and nitrite) and moisture content of soil were increased after the study than before study with all crops for all microbial inoculant concentrations (Table 4). This increase in these physicochemical parameters suggested that, the higher microbial counts in soil increased the biodegradation of soil, thereby increased the moisture content, phosphate and available nitrogen of soil which in turn stimulated the crop growth. The pH of the soil of was found to be 6.05. The optimal pH range for most plants is between 5.5 and 7.0; however, many plants have adapted to thrive at pH values outside this range. Because pH levels control many chemical processes that take place in the soil- specifically, plant nutrient availability. it is vital to maintain proper levels for crops to reach their full yield potential [59]. Soil temperature is

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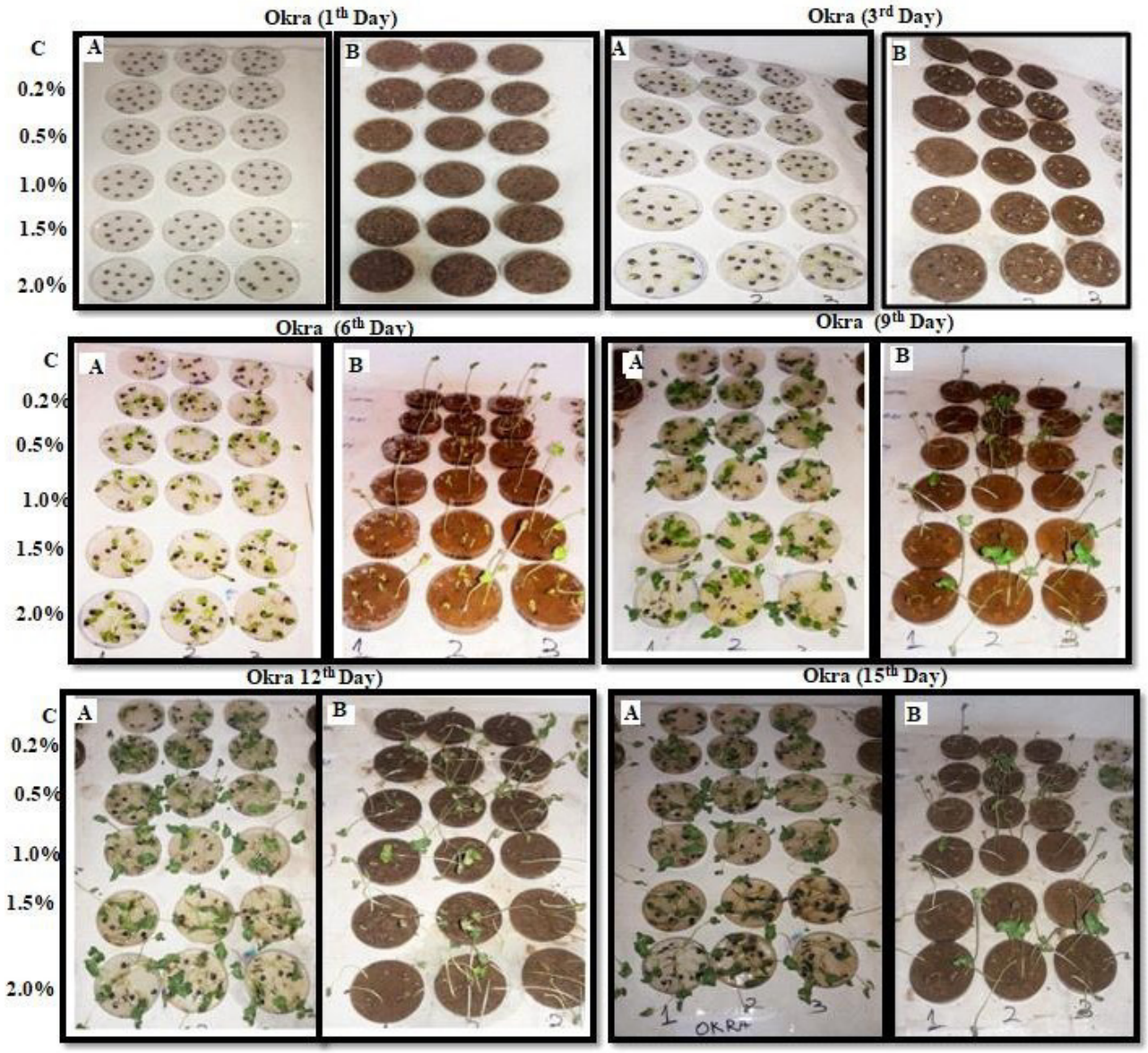
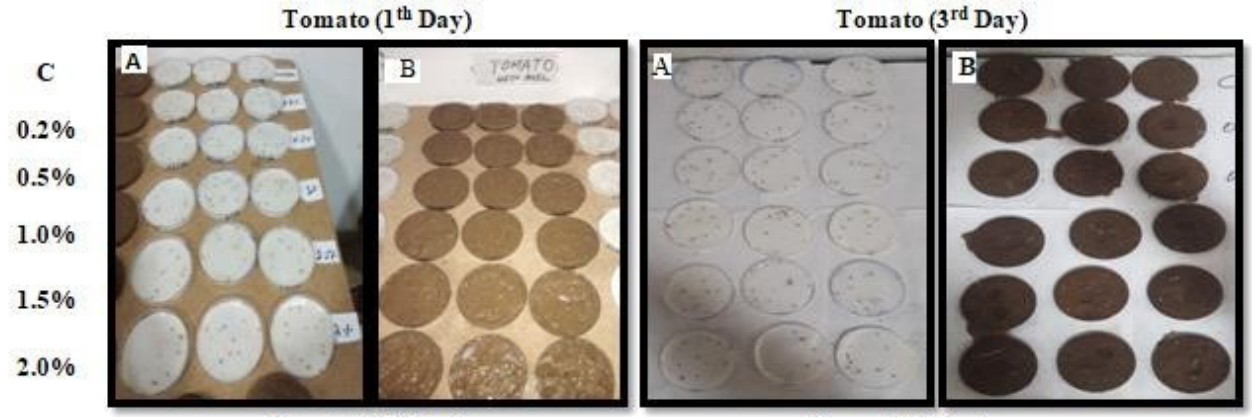


Figure 5. Effect of microbial consortia concentration (0.2, 1.0, 1.5, 2.0 %) both SB (A) and BB (B) base on okra crop.



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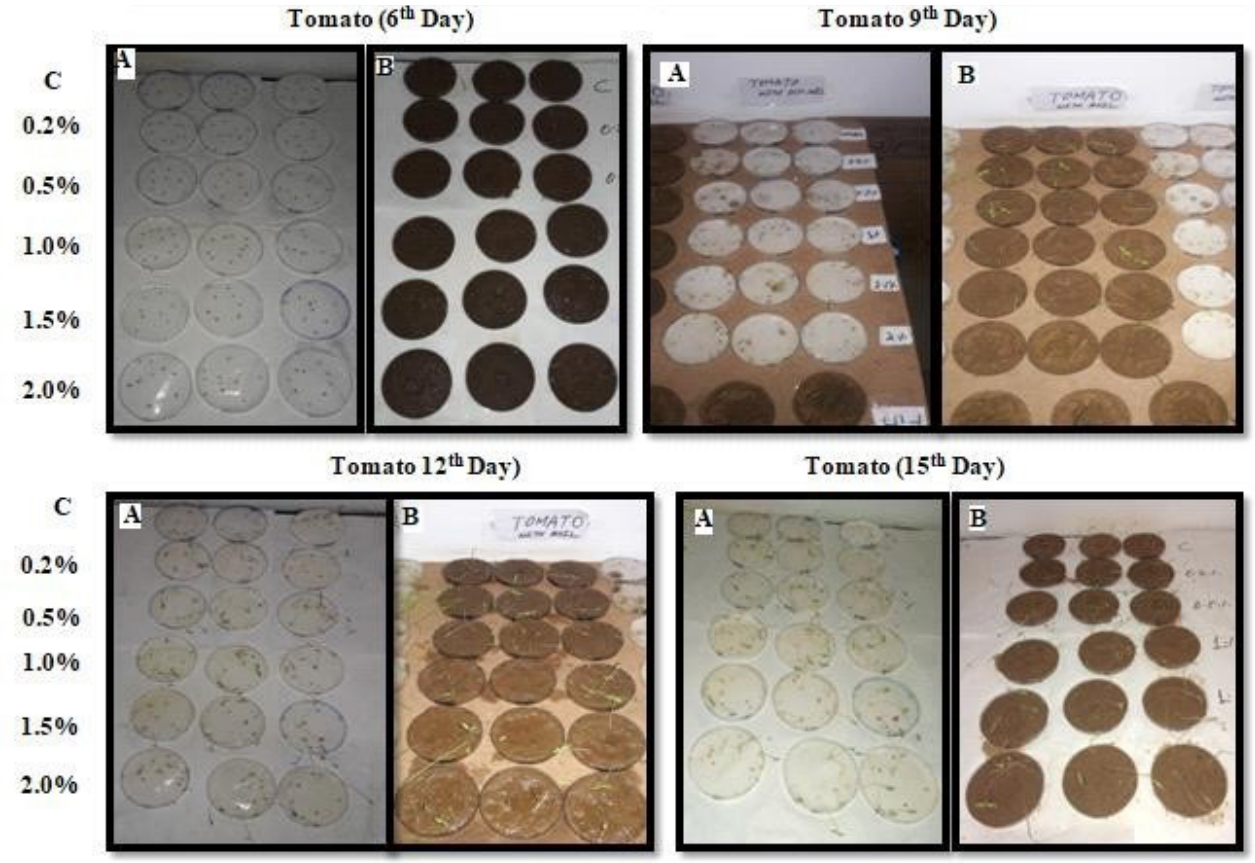

Figure 6. Effect of microbial consortia concentration (0.2, 1.0, 1.5, 2.0%) both SB (A) and BB (B) base on tomato crop.

another important parameter which range in between 15-24 °C. Water in the soil breaks down and dissolves minerals and critical elements in the soil. As the crop absorbs water through its roots in soil, it also transports nutrients into its cells [60,61]. Also, water affects soil formation, structure, stability and erosion, fertility that primary concern with respect to crop growth [62]. Additionally, all the physical parameters such as light, water, temperature etc. were same for all the experiments. Therefore, their impact was same for all the experiments and whatever the increase in growth parameters for all the crops SB than that of BS study is mainly due to nutrients present in soil and further the presence of externally added microbial consortium contributed to further enhancement of growth parameters by metabolizing the bound soil nutrients. The results attained from then present study, clearly showed microbial consortium to improve the growth of crops along with soil nutrition status. Consortium of microbes such as bacteria, fugus and actinomycetes (*Bacillus sp*., *Enterobacter sp*., *Aspergillus sp.*, *penicillium sp*. and *streptomycin sp*.) can help to increase plant growth in turn help in reducing the other chemical fertilizer application. This simple inoculation technology can be easily followed by the framing communities.

Conclusions

The application of MC on SB and BB base which effect on okra and tomato crops. The effect of MC concentrations was more effective than control when tested under laboratory conditions. Among SB and BB base, the MC was more effective SB than BB base for both the crops. PH, SH, LL, LW, RL, FW and DW growth parameters were increased significantly for all the concentrations of MC as compared to control. Further between MC applied with soil, 0.5% was highly effective than 0.2, 1.0, 1.5 and 2.0% for both okra and tomato crop. All the result suggested that 0.5% was the optimal MC concentration for soil biodegradation and providing soil nutrients to both the crops while further increase in concentration could not enhance the process, hence no such improvement in growth parameters were observed. Among the growth parameters such as, PH, SH, LL and LW, higher time influenced by microbial inoculants on SH of both the crops followed by PH, LL and LW. Microbes showed the luxuriant growth in soil was found to be higher after study than before study at all MC concentrations, also, increased amount of available nutrients in soil for crop growth such as, phosphorus (phosphate form), available nitrogen (ammonium, nitrate and nitrite) and moisture content. This increase in these physicochemical parameters suggested that, the higher microbial counts in soil increased the biodegradation of soil, thereby increased the moisture content, phosphate and available nitrogen of soil which in turn stimulated the crop growth. The results attained from then present study, clearly showed microbial consortium along with MS medium helps to improve growth of crops and soil nutrition status. Consortium of microbes such as bacteria, fugus and actinomycetes can help to crops growth in turn help in reducing the other chemical fertilizer application. This simple inoculation technology can be easily followed by the

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framing communities as microbial formulation along with suitable prebiotic materials.

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Disclosure statement

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