Efficacy of Indigenous Liquid Compatible Microbial Consortia on Seed Germination and Seedling Vigour in Tomato (Solanum lycopersicum L.)

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A B S T R A C T

In vitro study conducted to check out the efficacy of indigenous liquid compatible microbial consortia (CMC-1; P. fluorescens Pf-2 + P. fluorescens Pf-3 + T. asperellum T-11 + T. asperellum T-14 and CMC-2; P. fluorescens Pf-2 + P. fluorescens Pf-3 + T. asperellum T-11) on plant growth promoting activities like seed germination, seedling vigour index, shoot length, root length, dry and fresh weight of shoot, dry and fresh weight of root was carried out by standard filter paper method. In vitro result shows that, CMC-1 significantly increased vigour index of tomato seedlings (124.30 %), including germination per cent (22.99 %), shoot length (83.44 %) and root length (81.37 %) over control at 10 DAS. In vivo study also conducted during 2017-18 and 2018-19. In vivo experimental results also revealed that, CMC-1 significantly increased seedling vigour index (116.87 % at 20 DAS and 81.14 % at 30 DAS), germination per cent (20.75 % at 10 DAS), shoot length (67.12 % at 20 DAS and 33.74 % at 30 DAS) and root length (103.16 % at 20 DAS and 147.62 % at 30 DAS) over control. Among the tested microbial consortia, outstanding results were obtained in CMC-1 indicating better plant growth promoting potential and thus exhibiting tremendous potential for their commercial exploitation.

Keywords
Indigenous compatible microbial consortia, Tomato, Plant growth promoting activities

Introduction

Tomato is an indispensable vegetable crop which is the major source of nutrients and medicinal values, hence known as ‘Neutreatecal vegetable’ (Afroz et al., 2009; Saleem et al., 2009; Noureen et al., 2010). Tomato is a highly adaptive to warm season and can be grown successfully in plains as well as in hills. Cultivation of tomato in monsoon season is assuming a great importance in the north-eastern region of India.
in general and Nagaland in particular owing to its high prices of produce obtained from other parts of the country during this period (Babu, 2006).

Plant growth-promoting rhizobacteria (PGPR) and microorganisms (PGPM) either live together with non PGPR strains in the rhizosphere in different combinations (Vacheron et al., 2013). Considering this community-based living style of PGPR strains, the current trend is to mix BCAs of diverse microbial species having plant growth-promoting activities to achieve desired agricultural outcomes. Application of microbial consortium consisting of efficient strains for biological control may be a superior technique compared to application of alone microbes for managing plant diseases.

Moreover, application of microbes in a consortium may improve efficacy, consistency and reliability of the microbes under diverse environmental and soil conditions soil (Stockwell et al., 2011). Compatible microbes are applied together as a consortium, the crop plants are expected to get a combined benefit of high N and P availabilities for uptake leading to better plant health and yield.

Combining an antagonist bioagent may further facilitate disease free growth of the plants. Therefore, applying microbes as a consortium has great potentiality particularly in modern agriculture where minimization of chemical fertilizers and pesticides is one of the priorities.

However, in most of these studies conducted earlier, the fate of the microbes in soil when inoculated as consortia in the rhizosphere was not assessed and a greater emphasis should therefore be given to this aspect for better utilization of microbial consortia in enhancing their efficacies (Jain et al., 2012; Singh et al., 2013).

**Materials and Methods**

**Preparation of liquid compatible microbial consortia (CMC)**

A 250 ml suspension of each selected native isolates of *T. asperellum* (T-11 and T-14) was prepared from 9 days old cultured PDA medium plates. The plates were rinsed with sterile distilled water and the mycelia were carefully scraped off the agar with a bent glass rod. This suspension was filtered through filter paper (Whatman No. 1) to separate the spores from the mycelia. The concentration was adjusted to $3.7 \times 10^8$ spores/ml (Dubos, 1987) with the help of haemocytometer.

A 250 ml of each selected native isolates of *P. fluorescens* (Pf-2 and Pf-3) cell suspension was prepared by inoculating the strain into King’s B broth followed by shaking for 48 hrs (150 rpm) at room temperature. The bacterial suspension was roughly adjusted optically at $1 \times 10^9$ cfu/ml (O.D. 600= 1) (Mulya et al., 1996). Liquid consortia were prepared by mixing equal volume of each selected isolate just before use (Srinivasan and Mathivanan, 2009).

**In vitro efficacy of liquid CMC on tomato seedlings**

The healthy seeds of tomato cv. Pusa Ruby were selected for experimental purpose. The seeds were obtained from local market. Tomato seeds were surface sterilized with 1.0 % sodium hypochlorite for 2 min for all treatments followed by three rinsed with sterile distilled water. The *in vitro* experiment was conducted in a complete randomised design (CRD) and six replications were maintained for each treatment. The total four numbers of treatments viz., T1- CMC-1 (*P. fluorescens* Pf-2 + *P. fluorescens* Pf-3 + *T. asperellum* T-11 + *T. asperellum* T-14), T2-CMC-2 (*P. fluorescens* Pf-2 + *P. fluorescens* Pf-3 + *T. asperellum* T-11 + *T. asperellum* T-14), T3-CMC-3 (*P. fluorescens* Pf-2 + *P. fluorescens* Pf-3)

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Pf-3 + *T. asperellum* T-11), T3- chemical control and T4- control were used. This experiment was carried out by standard filter paper method (three layered moistened filter papers in Petri plates, 10 seeds/plate and 20 seeds/replication) (ISTA, 1993).

**Wet seed treatment**

The surface sterilized seeds were soaked with liquid formulations of consortia [@1.0 % or 10 µl/ 1 g seeds; 10 µl formulation of CMC added in 990 µl of sterile distilled water/1 g seed (400 tomato seeds)] and shade dried in laminar air flow for 5 hrs (Srinivasan and Mathivanan, 2009).

**For chemical control treatment**

The surface sterilized seeds were treated with captan 50 % WP (seed dressing @ 0.3 % or 3 mg/1 g seed) (Srinivasan and Mathivanan, 2009).

**For control treatment**

The surface sterilized seeds were soaked in sterile distilled water (@1 ml/ 1 g seed) and shade dried in laminar air flow for 5 hrs (Srinivasan and Mathivanan, 2009).

**In vivo efficacy of liquid CMC on tomato seedlings**

Tomato cv. Pusa Ruby seeds were surface sterilized with 1.0 % sodium hypochlorite for 2 min for all treatments followed by three rinsed with sterile distilled water. The *in vivo* experiment was conducted during 2017-18 and 2018-19 in a complete randomised design (CRD) and six replications were maintained for each treatment.

Tomato treated seeds (400 seeds/treatment) were sown in pre sterilized nursery beds with 2 per cent formalin.

**Observations and recording procedures**

**Per cent germination at 10 DAS**

Per cent germination was calculated using the following formula –

\[
\text{Per cent germination} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100
\]

**Seedlings shoot length and root length (cm)**

The root length and shoot length of individual seedlings (10 seedlings/replication) were measured. The shoot length was measured from collar region to the tip of the seedling with the help of a scale and the mean shoot length was expressed in cm. The root length measured from collar region to the tip of primary root with the help of a scale and the mean root length was expressed in cm.

**Seedling vigour index (SVI)**

The vigour index of seedlings was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) and expressed in number by using the below formula.

\[
\text{SVI} = \text{Germination (\%)} \times [\text{Mean shoot length (cm)} + \text{Mean root length (cm)}]
\]

**Fresh weight (mg) of seedling shoot and root**

The fresh weight (mg) of root and shoot of individual seedlings (10 seedlings/replication) were measured.

**Dry weight (mg) of seedling shoot and root**

The dry weight of root and shoot of individual seedlings (10 seedlings/replication) were measured after oven drying at 60° C (when constant weight obtained) for 24 hrs.
The weight of shoot and root was recorded and mean dry weight of seedlings was calculated and was expressed in mg.

**Per cent increase of plant growth promotion over control**

Per cent increase (\(\%\))

\[
\text{Per cent increase (\(\%\))} = \left( \frac{\text{Treatment value} - \text{Control value}}{\text{Control value}} \right) \times 100
\]

**Results and Discussion**

*In vitro efficacy of liquid CMC on tomato seedlings*

*In vitro* study conducted to check out the efficacy of indigenous liquid consortia (CMC-1 and CMC-2) on seed germination, tomato seedling vigour index was carried out by standard filter paper method.

**Per cent germination at 10 DAS**

Tomato seed germination per cent was significantly higher in the seed treatment with CMC-1 (89.17 %) followed by CMC-2 (80.00 %) and chemical control (74.16 %).

The lowest seed germination per cent was observed in control treatment (72.50 %) (Table 1). These results revealed that the CMC-1 significantly increased seed germination per cent (22.99 %) over control treatment (Table 2). The result of the present finding is in harmony with the finding of Murthy *et al.*, (2013) reported that the application of liquid consortia of *Trichoderma* spp., significantly increased the tomato seed germination per cent at 10 DAS.

Maximum seed germination per cent was obtained from seed treated with *T. harzianum* + *T. asperellum* + *T. viride* (92.00 %) followed by *T. harzianum* + *T. asperellum* (90.0 %) as compared to control (73.8 %).

**Seedlings shoot length and root length (cm) at 10 DAS**

Among the tested treatments, significantly maximum shoot length and root length was observed in seed treated with CMC-1 (5.54 cm), (5.84 cm) respectively (Table 1) than the other treatment.

Minimum shoot length and root length was observed in control treatment (3.02 cm) and (3.22 cm) respectively (Table 1).

The CMC-1 significantly increased shoot length (83.44 %) and root length (81.37 %) over control treatment (Table 2).

In corroboration to the present work, the application of liquid consortia of *Trichoderma* spp., significantly increased the shoot length and root length of tomato seedling at 10 DAS (Murthy *et al.*, 2013).

**Seedling vigour index (SVI) at 10 DAS**

Among the tested treatments, significantly maximum seedling vigour index was recorded in seed treated with CMC-1 (1014.75) than the other treatment.

Minimum seedling vigour index was observed in control treatment (452.40) (Table 1). These results revealed that the CMC-1 significantly increased vigour index of tomato seedlings (124.30 %) over control treatment (Table 2).

The finding of present work is in harmony with the finding of Manikandan *et al.*, (2010) recorded plant growth promotion by liquid formulation of *P. fluorescens* Pf1. They found that it significantly promoted tomato plant growth compared to untreated control.

**Fresh weight (mg) of seedling shoot and root at 10 DAS**

Significantly maximum fresh weight of shoot
and root was recorded in CMC-1 (14.44 mg), (0.38 mg) and minimum in control (4.85 mg) and (0.10 mg) respectively (Table 1). These results revealed that the CMC-1 significantly increased shoot fresh weight (197.73 %) and root fresh weight (280.0 %) over control treatment (Table 2). The finding of present work is in agreement with Murthy et al., (2013) reported that application of liquid consortia of Trichoderma spp., significantly increased the fresh weight of shoot at 10 DAS.

**Dry weight (mg) of seedling shoot and root at 10 DAS**

Among the tested treatments, significantly maximum dry weight of shoot and root was recorded in CMC-1 (0.76 mg), (0.05 mg) and minimum in control (0.43 mg) and (0.017 mg) respectively (Table 1). The CMC-1 significantly increased shoot dry weight (76.74 %) and root dry weight (194.12 %) over control treatment (Table 2).

The report of Murthy et al., (2013), that the application of liquid consortia of Trichoderma spp., significantly increased the dry weight of shoot at 10 DAS attests the finding of the present investigation.

**In vivo efficacy of liquid CMC on tomato seedlings**

**In vivo** study was also carried out during 2017-18 and 2018-19 to check out the efficacy of selected liquid consortia (CMC-1 and CMC-2) on seed germination and tomato seedling vigour index in nursery stage.

**Per cent germination at 10 DAS**

Tomato seed germination per cent was significantly higher in the seed treatment with CMC-1 (86.76 %) followed by CMC-2 (78.19 %) and chemical control (73.10 %).

The lowest seed germination per cent was observed in control (71.85 %) treatment (Table 3). The result revealed that the CMC-1 significantly increased seed germination per cent (20.75 %) at 10 DAS over control treatment (Table 7).

The results of the present findings confirms the findings of earlier workers (Raj et al., 2004; Manikandan et al., 2010; Bhakthavatchalu et al., 2013; Eutesari et al., 2013).

**Seedlings shoot length and root length (cm) at 20 DAS and 30 DAS**

Among the tested treatments, significantly longer shoot was recorded in seed treated with CMC-1 (4.88 cm at 20 DAS and 15.22 cm at 30 DAS) than the other treatment (Table 3 and 5). Minimum shoot length was observed in control (2.92 cm at 20 DAS and 11.38 cm at 30 DAS). The CMC-1 significantly increased shoot length (67.12 % at 20 DAS and 33.74 % at 30 DAS) over control treatment (Table 5 and 7).

Maximum root length was recorded in CMC-1 (3.21 cm at 20 DAS and 4.68 cm at 30 DAS) and minimum in control (1.58 cm at 20 DAS and 1.89 cm at 30 DAS). The CMC-1 significantly increased root length (103.16 % at 20 DAS and 147.62 % at 30 DAS) over control treatment (Table 7).

The results of the present findings are in conformity with the findings of earlier workers (Raj et al., 2004; Eutesari et al., 2013; Sandheep et al., 2013).
**Table 1** *In vitro* efficacy of liquid CMC on tomato seed germination (%), seedling shoot length, root length, shoot fresh and dry weight, root fresh and dry weight and vigour index at 10 DAS

| Treatment       | Seed Germination (%) At 10 DAS | Seedling shoot at 10 DAS | Seedling root at 10 DAS | Seedling Vigour index at 10 DAS |
|-----------------|-------------------------------|--------------------------|-------------------------|---------------------------------|
|                 |                               | Shoot Length (cm)         | Shoot Fresh wt. (mg)    | Shoot Dry wt. (mg)              | Root Length (cm) | Root Fresh wt. (mg) | Root Dry wt. (mg) |                               |
| **T1** (CMC-1)  | 89.17 (71.88)*                | 5.54                     | 14.44                   | 0.76                           | 5.84             | 0.38                | 0.050                | 1014.75                        |
| **T2** (CMC-2)  | 80.00 (63.74)                 | 5.00                     | 09.17                   | 0.65                           | 5.21             | 0.25                | 0.030                | 816.80                         |
| **T3** (Chemical control) | 74.16 (59.94)                  | 3.32                     | 05.35                   | 0.45                           | 3.59             | 0.14                | 0.020                | 512.44                         |
| **T4** (Control) | 72.50 (58.68)                 | 3.02                     | 04.85                   | 0.43                           | 3.22             | 0.10                | 0.017                | 452.40                         |
| SEm±            | 3.74 (1.88)                   | 0.13                     | 0.56                    | 0.04                           | 0.17             | 0.05                | 0.00                 | 30.76                          |
| C.V. (%)        | 11.60 (10.85)                 | 7.38                     | 16.35                   | 17.60                          | 9.24             | 13.59               | 14.19                | 10.78                          |
| CD (P=0.01)     | 12.90 (10.52)                 | 0.51                     | 2.27                    | 0.17                           | 0.68             | 0.18                | 0.03                 | 123.76                         |
| CD (P=0.05)     | 11.03 (8.31)                  | 0.37                     | 1.66                    | 0.12                           | 0.50             | 0.14                | 0.02                 | 90.74                          |

*Values in parenthesis are angular transformed values.*
Table 2 *In vitro* efficacy of liquid CMC on per cent increase of tomato seed germination (%), shoot length, root length, shoot fresh and dry weight, root fresh and dry weight and seedling vigour index at 10 DAS

| Treat.       | Seed germination (%) | Shoot Length | Shoot Fresh wt. | Shoot Dry wt. | Root Length | Root Fresh wt. | Root Dry wt. | Seedling vigour index |
|--------------|----------------------|--------------|-----------------|---------------|-------------|-----------------|---------------|-----------------------|
| T<sub>1</sub> (CMC-1) | 22.99               | 83.44        | 197.73          | 76.74         | 81.37       | 280.00          | 194.12        | 124.30                |
| T<sub>2</sub> (CMC-2) | 10.34               | 65.56        | 89.07           | 51.16         | 61.80       | 150.00          | 76.47         | 80.55                 |
| T<sub>3</sub> (Chemical control) | 02.29               | 09.93        | 10.31           | 04.65         | 11.49       | 40.00           | 17.64         | 13.27                 |
| T<sub>4</sub> (Control) | -                    | -            | -               | -             | -           | -               | -             | -                     |

Table 3 *In vivo* efficacy of liquid CMC on tomato seed germination (%) at 10 DAS, seedling shoot length, root length and vigour index at 20 DAS

| Treatment       | Seed Germination (%) at 10 DAS | Seedling shoot length (cm) at 20 DAS | Seedling root length (cm) at 20 DAS | Seedling Vigour index at 20DAS |
|-----------------|---------------------------------|--------------------------------------|--------------------------------------|-------------------------------|
|                 | 2017-18                         | 2018-19 Pooled                       | 2017-18                              | 2018-17 Pooled                | 2017-18 | 2018-19 | Pooled |
| T<sub>1</sub> (CMC-1) | 86.92 (69.06)*                 | 86.61 (68.67)                        | 86.76 (68.82)                        | 4.70                          | 5.06    | 4.88    | 3.19    | 3.23 | 3.21 | 685.80 | 718.00 | 701.90 |
| T<sub>2</sub> (CMC-2) | 78.46 (62.48)                  | 77.93 (62.05)                        | 78.19 (62.26)                        | 3.83                          | 3.92    | 3.87    | 2.20    | 2.41 | 2.30 | 473.11 | 493.30 | 483.20 |
| T<sub>3</sub> (Chemical control) | 73.85 (59.45)               | 72.36 (58.42)                        | 73.10 (58.93)                        | 2.92                          | 2.99    | 2.95    | 1.57    | 1.63 | 1.60 | 331.59 | 334.30 | 332.94 |
| T<sub>4</sub> (Control) | 72.31 (58.46)                 | 71.39 (57.81)                        | 71.85 (58.12)                        | 2.89                          | 2.95    | 2.92    | 1.55    | 1.62 | 1.58 | 321.06 | 326.25 | 323.65 |
| SEm±            | 2.75 (1.88)                    | 2.27 (1.53)                           | 2.44 (1.59)                          | 0.11                          | 0.15    | 0.09    | 0.09    | 0.11 | 0.09 | 18.78 | 15.10 | 14.72 |
| C.V. (%)        | 8.65 (7.41)                    | 7.21 (6.07)                           | 7.73 (6.54)                          | 7.71                          | 10.30   | 6.32    | 10.67   | 12.39 | 10.57 | 10.16 | 7.91   | 7.83  |
| CD (P=0.01)     | 11.06 (7.59)                   | 9.13 (6.16)                           | 9.83 (6.66)                          | 0.45                          | 0.63    | 0.38    | 0.37    | 0.45 | 0.38 | 75.56 | 60.77 | 59.22 |
| CD (P=0.05)     | 8.11 (5.56)                    | 6.70 (4.51)                           | 7.21 (4.88)                          | 0.33                          | 0.46    | 0.28    | 0.27    | 0.33 | 0.28 | 55.40 | 44.56 | 43.42 |

*Values in parenthesis are angular transformed values.

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Table 4 *In vivo* efficacy of liquid CMC on tomato seedling shoot fresh and dry weight, root fresh and dry weight at 20 DAS

| Treatment       | Seedling shoot at 20 DAS | Seedling root at 20 DAS |
|-----------------|--------------------------|-------------------------|
|                 | Fresh wt. (mg) | Dry wt. (mg) | Fresh wt. (mg) | Dry wt. (mg) | Fresh wt. (mg) | Dry wt. (mg) | Fresh wt. (mg) | Dry wt. (mg) |
|                 | 2017-18 | 2018-19 | Pooled | 2017-18 | 2018-19 | Pooled | 2017-18 | 2018-19 | Pooled |
| T<sub>1</sub> (CMC-1) | 107.62 | 114.23 | 110.92 | 06.25 | 06.28 | 06.26 | 10.57 | 10.98 | 10.76 | 0.88 | 0.84 | 0.86 |
| T<sub>2</sub> (CMC-2) | 89.25 | 95.00 | 92.12 | 05.32 | 05.30 | 05.31 | 07.49 | 08.15 | 07.82 | 0.76 | 0.72 | 0.74 |
| T<sub>3</sub> (Chemical control) | 64.54 | 63.15 | 63.84 | 04.66 | 04.40 | 04.53 | 04.47 | 04.57 | 04.52 | 0.41 | 0.53 | 0.47 |
| T<sub>4</sub> (Control) | 61.46 | 62.96 | 62.21 | 04.25 | 04.33 | 04.29 | 04.33 | 04.61 | 04.47 | 0.37 | 0.51 | 0.44 |
| SEm±             | 5.30  | 3.75  | 3.60  | 0.28  | 0.21  | 0.21  | 0.52  | 0.63  | 0.45  | 0.07 | 0.03 | 0.04 |
| C.V. (%)         | 16.16 | 10.95 | 10.72 | 13.64 | 10.18 | 10.07 | 19.15 | 15.84 | 15.92 | 11.27 | 18.18 | 16.25 |
| CD (P=0.01)      | 21.32 | 15.07 | 14.49 | 1.15  | 0.85  | 0.84  | 2.11  | 2.54  | 1.80  | 0.30 | 0.14 | 0.17 |
| CD (P=0.05)      | 15.63 | 11.05 | 10.62 | 0.84  | 0.62  | 0.62  | 1.55  | 1.86  | 1.32  | 0.22 | 0.10 | 0.12 |
Table 5 *In vivo* efficacy of liquid CMC on tomato seedling shoot length, root length and vigour index at 30 DAS

| Treatment            | Seedling shoot length (cm) at 30 DAS | Seedling root length (cm) at 30 DAS | Seedling vigour index at 30 DAS |
|----------------------|-------------------------------------|-------------------------------------|---------------------------------|
|                      | 2017-18    | 2018-19    | Pooled    | 2017-18    | 2018-17    | Pooled    | 2017-18    | 2018-19    | Pooled    |
| T<sub>1</sub> (CMC-1)| 15.08      | 15.37      | 15.22     | 4.79       | 4.57       | 4.68      | 1727.10    | 1727       | 1727.05    |
| T<sub>2</sub> (CMC-2)| 14.15      | 14.75      | 14.45     | 3.24       | 3.36       | 3.30      | 1364.42    | 1411.31    | 1387.86    |
| T<sub>3</sub> (Chemical control) | 11.80      | 11.64      | 11.72     | 1.93       | 1.91       | 1.92      | 1013.96    | 980.48     | 997.22     |
| T<sub>4</sub> (Control) | 11.31      | 11.45      | 11.38     | 1.92       | 1.86       | 1.89      | 956.66     | 950.20     | 953.43     |
| SEM±                | 0.50       | 0.37       | 0.32      | 0.15       | 0.16       | 0.11      | 54.55      | 44.71      | 42.37      |
| C.V. (%)            | 9.35       | 6.90       | 5.97      | 12.85      | 13.26      | 8.99      | 10.56      | 8.64       | 8.20       |
| CD (P=0.01)        | 2.01       | 1.51       | 1.29      | 0.63       | 0.64       | 0.43      | 219.49     | 179.11     | 170.49     |
| CD (P=0.05)        | 1.47       | 1.10       | 0.95      | 0.46       | 0.47       | 0.32      | 160.49     | 131.91     | 125.01     |
### Table 6: In vivo efficacy of liquid CMC on tomato seedling shoot fresh and dry weight, root fresh and dry weight at 30 DAS

| Treatment          | Fresh wt. (mg) at 30 DAS | Dry wt. (mg) at 30 DAS | Fresh wt. (mg) at 30 DAS | Dry wt. (mg) at 30 DAS |
|--------------------|--------------------------|------------------------|--------------------------|------------------------|
|                    | 2017-18                  | 2018-19                | Pooled                   | 2017-18                 | 2018-19                | Pooled                   |
| T1 (CMC-1)         | 1103.70                  | 1178.37                | 1141.03                  | 58.57                   | 65.97                  | 62.27                    | 88.58                   | 98.76                  | 93.67                  | 4.47                    | 5.21                    | 4.84                    |
| T2 (CMC-2)         | 790.00                   | 798.93                 | 794.46                   | 42.60                   | 43.07                  | 42.83                    | 50.66                   | 52.79                  | 51.72                  | 2.73                    | 2.77                    | 2.75                    |
| T3 (Chemical control) | 648.50                  | 631.03                 | 639.76                   | 34.68                   | 30.99                  | 32.83                    | 43.38                   | 41.57                  | 42.47                  | 2.53                    | 2.36                    | 2.44                    |
| T4 (Control)       | 528.90                   | 611.35                 | 570.12                   | 30.65                   | 30.23                  | 30.48                    | 39.40                   | 39.84                  | 39.62                  | 2.24                    | 2.22                    | 2.23                    |
| SEm±               | 42.94                    | 35.04                  | 33.18                    | 2.50                    | 3.14                   | 2.02                    | 4.06                    | 4.06                   | 3.43                   | 0.25                    | 0.28                    | 0.21                    |
| C.V. (%)           | 13.70                    | 10.66                  | 10.34                    | 14.71                   | 10.09                  | 11.80                    | 17.90                   | 12.39                  | 14.79                  | 19.25                   | 16.54                   | 16.67                   |
| CD (P=0.01)        | 172.75                   | 141.0                  | 133.50                   | 10.06                   | 12.66                  | 8.15                     | 16.32                   | 16.35                  | 13.82                  | 0.99                    | 1.11                    | 0.84                    |
| CD (P=0.05)        | 126.67                   | 103.38                 | 97.89                    | 7.37                    | 9.28                   | 5.78                     | 11.92                   | 11.99                  | 10.13                  | 0.73                    | 0.81                    | 0.61                    |
**Table 7** *In vivo* efficacy of liquid CMC on per cent increase of tomato seed germination (%), shoot length, root length, shoot fresh and dry weight, root fresh and dry weight and seedling vigour index

| Treat. | Seed germination (%) At 10 DAS | Per cent increase of plant growth promotion over control | Seedling shoot | Seedling root |
|--------|--------------------------------|-------------------------------------------------|---------------|--------------|
|        | Length                         | Fresh wt. | Dry wt. | Length | Fresh wt. | Dry wt. | Seedling Vigour index |
|        | At 20 DAS | At 30 DAS | At 20 DAS | At 30 DAS | At 20 DAS | At 30 DAS | At 20 DAS | At 30 DAS |
| T₁ (CMC-1) | 20.75 | 67.12 | 33.74 | 78.30 | 100.14 | 45.92 | 104.30 | 103.16 | 147.62 | 100.14 | 95.45 | 117.04 | 116.87 | 81.14 |
| T₂ (CMC-2) | 08.82 | 32.53 | 26.98 | 48.08 | 39.44 | 23.78 | 40.52 | 45.57 | 74.60 | 74.94 | 30.54 | 68.18 | 23.32 | 49.30 | 45.56 |
| T₃ (Chemical control) | 01.74 | 01.03 | 02.99 | 02.62 | 12.21 | 05.59 | 07.71 | 01.26 | 01.59 | 01.12 | 07.19 | 06.82 | 09.42 | 02.87 | 04.59 |
| T₄ (Control) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

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Seedling vigour index (SVI) at 20 DAS and 30 DAS

Significantly higher seedling vigour index was recorded in CMC-1 (701.90 at 20 DAS and 1727.05 at 30 DAS) and also significantly increased vigour index of tomato seedlings (116.87 % at 20 DAS and 81.14 % at 30 DAS) over control treatment (Table 3, 5 and 7).

The finding of present work is in conformity with the findings of earlier workers (Raj et al., 2004; Bhakthavatchalu et al., 2013; Sudharani et al., 2014).

Fresh weight (mg) of seedling shoot and root at 20 DAS and 30 DAS

Significantly maximum fresh weight of shoot was recorded in CMC-1 (110.92 mg at 20 DAS and 1141.03 mg at 30 DAS) and significantly increased shoot fresh weight (78.30 % at 20 DAS and 100.14 % at 30 DAS) over control treatment (Table 4 and 6).

Among the tested treatments, significantly higher fresh weight of root was recorded in CMC-1 (10.76 mg at 20 DAS and 93.67 mg at 30 DAS) than the other treatment. The CMC-1 significantly increased root fresh weight (140.71 % at 20 DAS and 136.42 % at 30 DAS) over control treatment (Table 4, 6 and 7).

The finding of present work is in agreement with the findings of earlier workers (Sandheep et al., 2013; Kumar et al., 2015; Khan et al., 2018).

Dry weight (mg) of seedling shoot and root at 10 DAS and 30 DAS

Significantly maximum dry weight of shoot was recorded in CMC-1 (6.26 mg at 20 DAS and 62.27 mg at 30 DAS) and minimum in control (4.29 mg at 20 DAS and 30.48 mg at 30 DAS). These result revealed that CMC-1 significantly increased shoot dry weight (45.92 % at 20 DAS and 104.30 % at 30 DAS) over control treatment (Table 4, 6 and 7).

Significantly higher dry weight of root was recorded in seed treated with CMC-1 (0.86 mg at 20 DAS and 4.84 mg at 30 DAS) and significantly increased root dry weight (95.45 % at 20 DAS and 117.04 % at 30 DAS) over control treatment (Table 4, 6 and 7).

The finding of present work is in confirmation with the findings of earlier workers (Eutesari et al., 2013; Sandheep et al., 2013; Kumar et al., 2015; Khan et al., 2018).

In this present investigation, an attempt has been made to study the efficacy of indigenous liquid CMC on tomato seedlings in the plant growth promotion aspect in which effective results were obtained with CMC-1 in both in vitro as well as in vivo experiments. The improvement in tomato seed germination might be due to reserve mobilization of food materials. The increase in mean tomato seedling dry weight upon CMC-1 treatment may be due to higher metabolic activity that leads to the better mobilization efficiency of stored food that might contribute for the better growth of seedlings which in turn result in increased seed germination, shoot length and root length and hence increase in the mean seedling dry weight. The increase in seedling vigour index upon CMC-1 treatment may be due to increased seed germination percentage, shoot length, root length and dry weight of tomato seedlings.

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