Journal of Natural Resource Conservation and Management
Vol. 5, No. 1, pp 37-45, 2024
doi: 10.51396/ANRCM.5.1.2024.37-45

Response of okra plant to foliar application of effective microorganisms solution on an Inceptisol (*Fluventic Haplustept*)

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Received : March 04, 2024
Revised : April 11, 2024
Accepted : April 12, 2024
Published : June 30, 2024

ABSTRACT

To find out the influence of effective microorganisms on growth and yield of okra plant, a field experiment was carried out at coastal deltaic region of Karaikal, U.T. of Puducherry. The experiment consisted of two factors *viz.,* fertilizer levels (no RDF, 75 per cent RDF and 100 per cent RDF) and frequencies of 1 per cent EM spray (no spray, weekly spray and fortnightly spray), totally constituting nine treatments, laid out in FRBD with three replications. Application of 100 per cent RDF recorded the highest fruit yield and this was found to be 109.38 per cent more than the treatment which did not receive fertilizer. Foliar application of 1 per cent EM at fortnightly interval recorded higher fruit yield and this was observed to be 18.02 per cent more than no EM spray and was on par with weekly spray of 1 per cent EM. Significantly higher stubble DMP was recorded in the plot applied with 100 per cent RDF and spraying of EM at fortnightly interval and a similar trend was noticed for plant height, number of branches plant^{-1}, leaf area index, number of fruits plant^{-1}, fruit weight, fruit length, fruit girth and fruit yield plant^{-1}. Among the nine treatment combinations tried, application of 100 per cent RDF and EM spray at fortnightly intervals was found to be beneficial in recording higher fruit yield, stubble DMP, biometric attributes of okra.

***Keywords*:** Okra, Effective microorganisms, INM, Growth attributes, Foliar application

INTRODUCTION

Vegetables are so common in human diet that a meal without vegetable is considered incomplete in every part of the world. They are rich source of minerals, vitamins, fibre and contain a fair amount of protein, carbohydrates and antioxidants thus considered as protective food. India is the second largest producer of vegetables in the world, accounting for 14 per cent of the global vegetable production. At present vegetables are cultivated in about 9.20 million hectares, yielding 200.45 million tonnes (National Horticulture database, 2020-21) in our country. The demand for vegetables by 2030 is projected as 350 million tonnes (Singh *et al.,* 2011). However, the area and production of vegetables have almost plateued since 2005 and the per capita availability of vegetables is estimated at 183 g, as against the recommended dietary allowance of 300 g. This demand supply gap is likely to continue as there is an increasing awareness among public on the health benefits of following vegetarianism. To meet the per capita demand, efforts need to be undertaken to increase vegetable production and productivity through the use of balanced fertilizers with enhanced use efficiency as well through integration of organic sources of nutrient supply. Okra is one of the most important vegetables grown throughout the tropics and warm temperate zones. It is widely cultivated in all over India and its immature tender fruits are used as vegetable. Okra fruit is a good source of vitamin A, B and C. The content of calcium in its fruits is very high (66 mg/ 100g of edible portion) compared to that in other fruit vegetables. It is an excellent source of iodine. It is also rich in protein and mineral nutrients.

Yield of crops could be enhanced through intensification or extensification of farming. The intensification efforts have focused on methods and techniques that provide economic yields without unreasonable increase in cultivation cost. Thus, the most important consideration would be the selection of new technologies that could enhance the availability of plant nutrients and their uptake by crops. One such technology is use of effective microorganisms (EM) solution in agriculture. The concept and technology of Effective microorganism (EM) was developed by Professor Teruo Higa, University of the Ryukyus, Okinawa, Japan. The EM consists of mixed cultures of naturally occurring beneficial microorganisms, the main ones being the species of photosynthetic bacteria (*Rhodopseudomonas plastris*), Lactic acid bacteria (*Lactobacillus plantarum*) and Yeast (*Saccharomyces spp*), which improve crop growth and yield by increasing photosynthesis as well as by producing bioactive substances such as hormones and enzymes (Higa, 2000; Hussain *et al.*, 2002). The EM technology makes it possible to increase crop yields twice or thrice what they are at present and do so without the use of agro chemicals or artificial fertilizers. The produces are also of superior quality. The EM agriculture technique makes it possible to remedy the root causes of low productivity in agriculture and this technology promotes the so called integrated farming system. Several studies have been reported about the EMs potential on plant growth and yield. Most of the Asian countries have been successfully utilizing the EMs for their agriculture industry. In India, the use of EM is not very much popular and there is a lack of suitable scientific reports.

Foliar application of EM results in a large number of beneficial microorganisms at the leaf surface or phyllosphere. It is believed that certain microorganisms in the EM culture including photosynthetic bacteria and N-fixing bacteria can enhance the plant's photosynthetic rate and efficiency and its N-fixing capacity as well (Pati and Chandra, 1981). Through foliar application, microorganisms in EM appear to suppress the development of harmful plant pathogens at the leaf surface, thereby providing a measure of plant protection through biocontrol. Foliar application of effective microorganisms avoids many of the biotic and abiotic factors. Generally, vegetables yields were higher with foliar applied effective microorganisms compared with the chemical fertilizer (Widdiana and Higa, 1998). Xiaohou *et al.* (2001), Nibin *et al.* (2016a) and Prisa (2019) reported that sprinkling with effective microorganisms could increase yield and quality of various crops, fruits and vegetables. Foliar application of EM appears to suppress the occurrence of plant diseases and facilitates the uptake of simple organic molecules that can increase plant growth and yield. Considering the above, the present investigation was taken up to observe the effect of EM solution on growth and yield attributes of okra.

MATERIALS AND METHODS

The field experiment was conducted in field number C_8 of the Eastern Farm of Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal. The farm is located at an altitude of four meters above from the mean sea level between 10°49' and 11°01' N latitude and 78°43' and 79°52' E longitude. The mean annual temperature ranges from a minimum of 24.22 °C to a maximum of 32.68 °C. The mean annual rainfall is 1450 mm. The field soil comes under Surakudy soil series, grouped under *Fluventic Haplustept.*

Initial characterization of the experimental soil was done by adopting the standard procedures and the results are presented in Table 1. The soil is sandy loam in texture belonging to Surakudy soil series, taxonomically grouped under *Fluventic Haplustept*. Initial soil analysis revealed that the soil of the experimental site was neutral (pH, 7.01) with an EC of 0.052 dS m^{-1}. The cation exchange capacity (CEC) was 20.70 cmol (p^+) kg^{-1} with Ca^{2+} as the dominating cation followed by Mg^{2+}, Na^+ and K^+. The organic carbon content was 0.55 per cent. The $KMnO_4$-N, Olsen-P and NH_4OAc-K status indicated that the soil possessed low N and medium P and K.

The field experiment was conducted during *Kharif* (July - October) season. Okra F_1 hybrid Sakthi was used as test crop to study the influence of effective microorganisms on growth and yield of okra. The field experiment was laid out in a factorial randomized block design with three replications. The experiment consisted of two factors *viz.,* fertilizer levels (F) and frequency of EM spray (E), consisting nine treatments including a control without any EM spray and fertilizer application. Three levels of fertilizers include; F_1- No fertilizer, F_2- 75% RDF and F_3- 100% RDF. Three levels of 1% EM spray include; E_1- No spray, E_2- Weekly spray and E_3- Fortnightly spray.

Table 1. Initial characteristics of the experimental soil

Sl. No.	Properties	Values
A. Physical properties		
1.	Textural class	Sandy loam
	Clay (%)	16.65
	Silt (%)	6.25
	Fine sand (%)	33.78
	Coarse sand (%)	41.84
2.	Taxonomic unit	*Fluventic Haplustept*
3.	Bulk Density (Mg m^{-3})	1.24
4.	Particle Density (Mg m^{-3})	2.22
5.	Pore space (%)	44.08
B. Physico-chemical properties		
6.	Electrical conductivity (dS m^{-1})	0.052
7.	pH (1:2.5 soil water suspension)	7.01
C. Chemical properties		
8.	Organic carbon (%)	0.55
9.	Cation Exchange Capacity [cmol (p^+) kg^{-1}]	20.70
10.	Exchangeable Calcium (cmol kg^{-1})	7.98
11.	Exchangeable Magnesium (cmol kg^{-1})	5.43
12.	Exchangeable Sodium (cmol kg^{-1})	4.05
13.	Exchangeable Potassium (cmol kg^{-1})	0.42
14.	$KMnO_4$-N (kg ha^{-1})	221.2
15.	Olsen-P (kg ha^{-1})	18.4
16.	NH_4OAc-K (kg ha^{-1})	122

The EM stock solutions marketed by Maple Orgtech (India) Limited, Kolkata was used in the present study. EM solution contained Lactic acid bacteria ($10^5_<$), Photosynthetic bacteria ($10^1_<$) and Yeast ($10^2_<$). EM solution at 1 per cent concentration was sprayed at weekly and fortnightly interval as per the treatment. A control without EM spray was also maintained. Spraying was taken up from 15th day after sowing. Nitrogen was applied as urea in two equal splits as basal and as top dressing at 25 DAS. Full doses of phosphorus as SSP and potassium as MOP were applied basally as per the treatment. All the intercultural operations were performed uniformly as recommended.

Five plants were selected at random from the sampling area and tagged for recording biometric observations. The observations on fruit length, fruit girth, fruit weight and plant height, number of branches per plant, number of fruits per plant and yield were recorded in those plants. The yield of fruits per plot recorded at each harvest was summed up and converted to yield per hectare per crop.

Statistical analysis

The analytical data were subjected to statistical scrutiny following the procedure outlined by Gomez and Gomez (1976), using AGRES package. The data on yield and growth attributes were statistically analyzed using analysis of variance (ANOVA) in a randomized block design and compared by critical difference at 5 per cent significance level. Pearson's coefficient analysis was used for correlation.

RESULTS AND DISCUSSION

The yield of crop is controlled by many factors which can be categorized under environmental and soil factors. While the present experiment was conducted under the same environment, variations in the soil properties could have determined the ultimate yield of crop. The imposed treatments are expected to modify the soil properties, which may be physical, chemical, physico-chemical or biological as a result of which growth of plant is modified. Any plant, starts its life cycle from the seed and the condition under which it was grown might result in better growth, as evidenced from the dry matter accumulation and expressed through the yield attributes like plant height and number of branches and yield parameters like fruit length, girth, weight and number of fruits. In the present experiment the results had suggested that the imposed treatments could significantly modify both the yield attributes and parameters.

Fruit yield and Dry matter production

The effect of EM on yield of okra is presented in Table 2. Application of different levels of fertilizer and EM spray significantly improved the yield and DMP. The yield was found to range from 6.42 t ha^{-1} in the treatment which received no fertilizer and no spray of EM (F_1E_1) to 16.14 t ha^{-1} in the treatment which received 100 per cent RDF with fortnightly spray of EM solution (F_3E_3). Of the three different fertilizer treatments studied the application of 100 per cent RDF (F_3) was found to be significantly superior with the maximum yield of 15.18 t ha^{-1}. The lowest yield (7.25 t ha^{-1}) was recorded in the treatment which did not receive any fertilizer (F_1). The yield recorded with 100 per cent RDF was 109.38 per cent more than the treatment which did not receive fertilizer. Among different frequency of EM sprays, the maximum yield (12.97 t ha^{-1}) was recorded with fortnightly spray of EM solution which was on par with weekly EM spray. The yield recorded in E_3 was 18.02 per cent more than no EM spray. The study of simple correlation revealed that the yield of okra was having significant and positive correlation with all the biometric characters studied.

Table 2. Effect of treatments on fruit yield and dry matter production

	Fruit yield (t ha $^{-1}$)				DMP (kg ha^{-1})			
	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean
F_1	6.42	7.45	7.90	7.25	1557	1670	1823	1683
F_2	12.85	13.79	14.86	13.83	2806	3035	3131	2990
F_3	13.72	15.68	16.14	15.18	3349	3472	4031	3617
Mean	10.99	12.31	12.97		2571	2726	2995	
	F	E	F × E		F	E	F × E	
S. Ed	0.39	0.39	0.69		142	142	246	
C.D (0.05)	0.84	0.84	NS		302	302	NS	

The application of 100 per cent RDF had recorded the highest dry matter production of 3617 kg ha^{-1}. Significant differences were observed among the various EM spray treatment and spraying of EM at fortnightly interval (E_1) was found to produce higher dry matter of 2995 kg ha^{-1} which was found to be on par with weekly spray of EM (2726 kg ha^{-1}) but differing significantly from no spray of EM (E_1).

The increase in yield and DMP due to application of 100 per cent RDF over 75 per cent RDF and fertilizer control is quite expectable. The yield and DMP increase with the application of 100 per cent RDF might be due to increase in metabolic activity in the plant system because of balanced and increased availability of nutrients required for normal growth, which would have resulted in enhanced carbohydrate synthesis and effective translocation of photosynthates to the developing sink. Similar results were also reported by Venkadeswaran *et al.* (2014a), Nibin *et al.* (2016), Nibin *et al.* (2016a) Rajakumar *et al*. (2017) and Rajakumar and Bagavathi-Ammal (2017).

The higher yield and DMP recorded with 1 per cent EM spray at fortnightly interval could be attributed to the buildup of beneficial microbes in the phyllosphere as EM constitutes lactic acid bacteria, photosynthetic bacteria and yeast as reported by Chantal *et al.* (2010) in cabbage. The activity of beneficial microbes could have been higher which helped in the synthesis of growth promoting substances in turn helping in increased fruit yield and DMP. This falls in line with findings of Wididana and Higa (1993) and Vennila and Jayanthi (2010) in tomato and okra respectively.

The presence of yeast in EM solution could also enriched vitamins, phytohormones, enzymes, amino acids and minerals, thereby exerting a stimulatory effect on cell division and enlargement as well as protein and nucleic acid synthesis and chlorophyll formation. This in turn reflected on plant growth. This corroborates with the findings of Ibreheim (2014) in pea. Further, the presence of biologically active substances of EM capable of producing antimicrobial substances from amino acids secreted by photosynthetic bacteria could suppress harmful microbes and thus provide favourable environment for growth of plants as reported by Shokouhian *et al.* (2013) in almond. The increased yield and DMP due to application of EM might be due to enhanced sub stomatal CO_2 in the leaf as reported by Abbas *et al*. (2014) lend support to the present finding.

Application of fertilizer and EM also resulted in higher plant height, number of branches, number of fruits, fruit length, fruit girth and LAI which could have resulted in higher fruit yield and DMP. This was further supported by positive and significant relationship of fruit yield and DMP with above parameters (Table 3). This was in accordance with Kuppusamy *et al*. (2013) and Rajakumar (2014).

Growth and yield attributes

The economic yield of the crop depends on the growth and yield parameters like days to first flowering, plant height, number of branches plant^{-1}, number of fruits plant^{-1}, fruit weight, fruit length and fruit girth. In other words, a plant which is grown under optimum soil and climate environment is bound to produce healthier plants, which are capable of flowering early with more number of branches, bearing more number of fruits, having higher fruit weight, length and girth. Hence, monitoring growth and yield parameters is an important factor in predicting the final yield of the crop.

Days to first flowering

The differences observed for days to first flowering in okra in the present study was found to be significant only for fertilizer. The treatment which

Table 3. Correlation between yield and various biometric characters (n=9)

Variables	Yield	Days to first flowering	Plant height	No. of branches plant^{-1}	No. of fruits plant^{-1}	DMP	Fruit weight	Fruit length	Fruit girth	LAI
Yield	1.000									
Days to first flowering	0.732*	1.000								
Plant height	0.958**	0.619^{NS}	1.000							
No. of branches plant^{-1}	0.941**	0.583^{NS}	0.983**	1.000						
No. of fruits plant^{-1}	0.926**	0.668*	0.950**	0.973**	1.000					
DMP	0.976**	0.774*	0.956**	0.957**	0.966**	1.000				
Fruit weight	0.956**	0.659^{NS}	0.980**	0.983**	0.972**	0.975**	1.000			
Fruit length	0.864**	0.431^{NS}	0.939**	0.943*	0.929**	0.873**	0.938**	1.000		
Fruit girth	0.911**	0.612^{NS}	0.963**	0.977**	0.982**	0.950**	0.977**	0.964**	1.000	
LAI	0.844*	0.584^{NS}	0.904**	0.936*	0.976**	0.911*	0.919**	0.923**	0.966**	1.000

** Significant at 1 % level * Significant at 5 % level NS Non-significant

received no fertilizer flowered early than fertilizer plots. This might be due to prolonged vegetative phase in plots receiving fertilizer and the stress due to lack of nutrients in fertilizer control plots might have resulted in early flowering.

Plant height

The variations observed for plant height with fertilizer and EM application was found significant (Table 5). Application of 100 per cent RDF and fortnightly spray of EM resulted in higher plant height. This might be attributed to the increased and better availability of nutrients with 100 per cent RDF that could have enhanced the cell division, elongation and formation of more tissues resulting in luxuriant vegetative growth, thereby increasing plant height (Mayer and Anderson, 2003; Vennila and Jayanthi, 2010 and Venkadeswaran *et al*., 2014b, Rajakumar *et al*., 2017). The interaction between fertilizer and EM spray schedule revealed the superiority of 100 per cent RDF plus fortnightly spray of EM. This is in accordance with findings of Ghoname *et al.* (2010) in sweet pepper, Midan and Sorial (2011) in snap bean and Mbouobda *et al.* (2013) in taro. The increased plant height observed might be attributed to the growth regulators produced by the beneficial microbes especially yeast leading to activation of cell division and cell elongation. Further the yeast is also found to have a stimulatory effect on photosynthetic pigments and thereby improves the photosynthesis in plants as reported earlier by Dawood *et al.* (2013) in soya bean. The height of the plant differs significantly among stages of harvest and increased progressively with advancement of age of the crop and is quite expected.

Number of branches per plant

The maximum number of branches (Table 4) was recorded in plants supplied with 100 per cent RDF which might be due to the higher availability of nutrients throughout the growing phase and also due to enhanced carbohydrate synthesis. This falls in line with the findings of Vennila and Jayanthi, (2010). Higher number of branches plants^{-1} were found with fortnightly spray of EM and was on par with weekly spray. Such an increase in number of branches with application of EM was reported earlier

Table 4. Effect of treatments on days to flowering, number of fruits and branches per plant

	Days to flowering				No. of branches per plant				No. of fruits per plant			
	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean	E_1	E_2	E_3	Mean
F_1	42.00	39.66	39.33	40.33	3.33	3.66	4.33	3.77	9.66	10.33	10.66	10.22
F_2	44.33	44.33	42.66	43.77	4.66	5.00	5.33	5.00	11.66	12.33	12.66	12.22
F_3	48.33	45.66	44.66	46.21	5.00	5.66	6.33	5.66	13.00	14.33	15.33	14.22
Mean	44.88	43.21	42.21		4.33	4.77	5.33		11.44	12.33	12.88	
	F	E	F X E		F	E	F X E		F	E	F X E	
S. Ed	1.35	1.35	2.35		0.30	0.30	0.52		0.30	0.30	0.52	
C.D (0.05)	2.88	NS	NS		0.64	0.64	NS		0.64	0.64	NS	

by Mohan (2008) in brinjal, Vennila and Jayanthi (2010) in okra, Ghoname *et al.* (2010) in sweet pepper, Midan and Sorial (2011) in snap bean. The positive effect of EM on this important yield contributing trait would have been the influence of yeast and other beneficial microorganisms present in EM, which enhances amino acids, vitamins, hormones and micro nutrients, the important constituents of protoplasm and chlorophyll, leading to better plant growth as reported by Midan and Sorial (2011). Further, the hormones produced by these microbes promote cell division and enlargement resulting in improved growth and such a report had already been published by Sarhan *et al.* (2011) in brinjal.

Leaf area index

Application of fertilizer and EM spray was found to influence the leaf area index at all the stages of study (Table 5). Recommended doses of fertilizer might have supplied required plant nutrients for growth and development resulting in higher leaf area index. The results of Agbede and Adekiya (2012) and Venkadeswaran *et al*., (2014b) in okra lend support to the present finding. The effect of EM on increased leaf area observed in the present study is in line with the results of Muthaura *et al.* (2010) in pigweed, Sarhan *et al*. (2011) in brinjal and Seran and Shahardeen (2013) in vegetable cowpea. The beneficial microorganisms present in the EM culture would have increased nutrient absorption and enhanced production of auxins and cytokinins resulting in increased leaf area index as reported by Shokouhian *et al*., 2013 in almond. Further, the leaf area increase in response to EM spray might be due to the presence of yeast, which constitutes proteins and vitamins as reported by Ahmed *et al*. (2011) in potato.

The increase in LAI observed with the application of fertilizer and EM spray could lend to enhanced yield as the light absorption capacity of plants is dependent on unit area of leaves, directly influencing the photosynthetic efficiency of plants. Positive association of leaf area index with yield and all the other biometric characters except days to first flowering was observed from correlation analysis (Table 3).

Number of fruits per plant

The influence of varying levels of fertilizer and frequencies of EM spray on number of fruits plant^{-1} was well established in the present study (Table 4). The plants receiving 100 per cent RDF was again found to produce more number of fruits plant^{-1} over 75 per cent RDF and fertilizer control. This was in conformity to the earlier report of Milagrosa and Balaki (1996) in potato, Vennila and Jayanthi (2010), Mal *et al*. (2013) and Venkadeswaran *et al*. (2014a) in okra. This increase in number of fruits plant^{-1} is attributed to the better availability and uptake of nutrients by plants in 100 per cent RDF fertilized plots than other two fertilizer treatments. The number of fruits plant^{-1} observed with fortnightly and weekly spray of EM did not differ significantly but was superior to no EM spray. Spraying of EM containing beneficial microbes like yeast could increase the leaf mineral nutrient contents especially potassium. The enhanced potassium uptake and the influence of photosynthetic bacteria contained in EM had greater role in synthesis and translocation of photosynthates, leading to increased fruit set as reported earlier by Sarhan *et al.* (2011) in brinjal. The

Table 5. Effect of treatments on growth and yield attributes

	Plant height (cm)	LAI	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)
F_1E_1	96.64	0.577	11.19	11.28	4.41
F_1E_2	106.00	0.615	12.14	13.00	4.81
F_1E_3	115.87	0.632	12.76	12.92	4.95
F_2E_1	120.72	0.740	13.68	13.08	5.15
F_2E_2	128.42	0.783	14.72	13.51	5.22
F_2E_3	135.55	0.804	14.45	13.98	5.33
F_3E_1	131.24	0.830	14.59	13.52	5.44
F_3E_2	137.64	0.880	15.31	14.44	5.66
F_3E_3	144.13	0.936	16.37	15.15	6.02
S. Ed	1.27	0.014	0.31	0.31	0.06
C.D (0.05)	2.56	0.029	0.63	0.64	0.12

beneficial microbes contained in EM could also enhanced the synthesis of phytohormones like gibberellic acid (GA_3) and kinetin, which stimulated the formation of chlorophyll, reflecting in higher carbohydrate synthesis. Such an improvement in the growth and physiological attributes of okra plant would have led to the increased number of fruits and this is in accordance with the earlier report of Midan and Sorial (2011) in snap bean and Vennila and Jayanthi (2010) in okra.

Fruit weight

The presence of significant differences in fruit weight for direct effect of all the factors (Fertilizer and EM spray) at different phase of harvest were observed in okra. Increased fruit weight observed in the present study with 100 per cent RDF over 75 per cent RDF and fertilizer control was in conformity to the report of Vennila and Jayanthi (2010) and Venkadeswaran *et al*. (2014a). This might have occurred due to increased photosynthetic area and translocation of photosynthates in plants which subsequently accelerated the formation of more number of large sized fruits with increased fruit weight. These findings are similar to those of Mal *et al*. (2013) in okra. The significance of EM spray at fortnightly interval was observed. Use of EM increasing the weight of economic produce has been reported earlier by El-Fatah *et al.* (2008) in persimmon, Vennila and Jayanthi (2010) in okra fruit and Mbouobda *et al.* (2013) in taro. The foliar application of EM was found to enhance the absorption of nutrients resulting in increased NPK uptake and this could be attributed to the increased fruit weight (Javaid, 2006) in pea. Further, foliar application of EM resulted in large number of beneficial microorganisms at phyllosphere capable of enhancing the photosynthetic efficiency of leaves, leading to better partitioning of assimilates as reported by Wididana and Higa (1993) in tomato.

The individual fruit weight recorded at initial stages were more than the weight recorded at other stages and this could be due to higher foliage volume noticed at this stage than the other two stages resulting in greater photosynthetic activity coupled with uptake of nutrients, translocation and accumulation of photosynthates in plants, which might have resulted in higher fruit weight. Similar finding was also reported by Kuppusamy *et al.* (2013), Rajakumar (2014) and Sreenadha Reddy (2014) in okra.

Fruit length

The observations on fruit length recorded at different pickings had shown similar trend as that of fruit weight wherein, the direct effect of all the three factors (fertilizer levels, frequency of EM spray and stages of harvest) and interaction between fertilizer level and EM spray were significant. The maximum fruit length was observed with application of 100 per cent RDF over 75 per cent RDF and fertilizer control. Increase in fruit length with recommended doses of fertilizers had already been reported by Vennila and Jayanthi (2010), Mal *et al*. (2013) and Venkadeswaran *et al*. (2014a) in okra. Fortnightly and weekly spray of EM resulted in comparable longer fruits than no EM spray. The effect of foliar application of EM improving the fruit length has been documented by Vennila and Jayanthi (2010) in okra, Sivashankary *et al*. (2013) in bitter gourd and Suthamathy and Seran (2013) in vegetable cowpea. The beneficial microorganisms in EM culture including photosynthetic bacteria could have enhanced the plant photosynthetic rate and efficiency resulting in better fruit length (Sivashankary *et al.,* 2013). The synthesis and translocation of carbohydrates from leaves to the developing fruits gets enhanced by the yeast, which is an important component of EM and this could be attributed for increased fruit length as reported earlier by Sarhan *et al.* (2011).

Among the different stages of picking, the fruits harvested at 12th picking was found to be longer than the fruits harvested at initial and final stages of picking. Higher foliage volume and better root activity at this stage could have resulted in greater photosynthetic activity, translocation and accumulation of photosynthates in sink thus contributing for better fruit length at this stage. This falls in line with the findings of Kuppusamy *et al.* (2013), Rajakumar (2014) and Sreenadha Reddy (2014) in okra.

Fruit girth

The present study revealed the significance of various treatments on fruit girth of okra recorded at different stages of picking (Table 5). The maximum fruit girth observed in okra with the application of 100 per cent RDF could be attributed to the better availability of plant nutrients for development of plant parts as well as root system, which would have enhanced the uptake of plant nutrients leading to enhanced fruit girth and this is in conformity with the findings of Vennila and Jayanthi (2010) and Venkadeswaran *et al.* (2014a) in okra. The direct effect of EM spray as well as the two-way interaction of fertilizer levels and EM spray had shown their significance. Such a report has already been published by Fawzy *et al.* (2012) in onion and Suthamathy and Seran (2013) in vegetable cowpea. The yeast present in the effective microorganisms could be responsible for the increased fruit girth as it increases the leaf potash content, which in turn resulted in increased synthesis and translocation of assimilates to the developing fruits as suggested by Sarhan *et al.* (2011) in brinjal. Potassium act as an important regulator in plant system as it is a constituent of 60 different enzymes of the plant system (Latha *et al.,* 2014). Further, the higher proportion and activity of beneficial microbes in EM would have helped in the synthesis and partitioning of growth promoting substances leading to better fruit size and weight as reported by Vennila and Jayanthi (2010).

The fruits harvested at mid-stages were found to have more fruit girth than the other stages. Similar observations were also recorded by Kuppusamy *et al.*, 2013; Rajakumar (2014) and Sreenadha Reddy (2014).

CONCLUSION

From the study it was concluded that among the different treatment combinations, application of 100 per cent RDF and EM spray at fortnightly intervals was found to be beneficial in recording higher fruit yield, DMP, growth and yield attributes in okra.

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