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REVIEW ARTICLE

EFFECTIVE MICROORGANISMS AND THEIR INFLUENCE ON GROWTH AND YIELD CHARACTERS OF CAPSICUM

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ABSTRACT

Capsicum (*Capsicum annuum*L.var. grossum) grows widely in many parts of the world as vegetable and is usually utilized by many communities as a nutritional additive. This study is designed to evaluate the effect of inoculation of effective microorganism (EM) on growth and yield of capsicum in poly house. It comprised of four treatments, replicated and arranged in a complete randomized design. Capsicum inoculated with effective microorganisms and organic manure recorded highest values in all the growth and yield parameters measured. The results from this study demonstrated that growth and yield of capsicum may be improved by inoculating the plants with effective microorganisms, and as a result reduce the use of fertilizers in production of this vegetable hence promoting sustainable agriculture. More studies would be needed to determine the effects of effective microorganisms' inoculation on other capsicum species.

INTRODUCTION

Capsicum (*Capsicum annuum*L.var. grossum) is one of the most important vegetable crops grown extensively throughout the world especially in the temperate countries (Manchanda and Singh, 1987). Sweet pepper is one of the popular vegetables grown throughout India, commonly known as Capsicum, shimlamirch, sweet pepper, green pepper, cherry pepper or bell pepper and it belongs to Solanaceous group of vegetables.

It is very rich in vitamins (A and C) and minerals like calcium, magnesium, phosphorus and potassium. Sweet pepper is more sensitive to environment (especially soil moisture and temperature) and its yield is affected significantly. Capsicum is a cool season crop, but it can be grown round the year using protected structures where temperature and relative humidity (RH) can be manipulated.

This crop requires day temperature of 25-35^{o}C and night temperature of 18-20^{o}C with relative humidity of 50-60%. The plant grows at soil temperatures between 18^{o}C and 35^{o}C. If temperature exceeds 35^{o}C or falls below 12^{o}C, fruit setting is affected (Anonymous, 2009). In India, capsicum is grown for its mature fruits and is widely used in stuffing and baking. It is also used in salad, noodles and soup preparation. In vegetable production water and nutrients are the two most critical inputs and their efficient management is important not only for higher productivity but also for maintaining quality. Among the various irrigation methods used for water application, micro irrigation systems particularly, drip method is most efficient and increasingly adopted worldwide.

Drip irrigation is an irrigation method that saves water by allowing water to drip slowly to the root of plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing and emitters. Dripirrigation has the greatest potential for the efficient use of water and fertilizers. For minimizing the cost of irrigation and fertilizers, adoption of drip irrigation with fertigation is essential which maximize the nutrient uptake while using minimum amount of water and fertilizer. Proper fertigation management requires the knowledge of fertigation rate and nutrient uptake by the crop to ensure maximum crop productivity.

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MATERIALS AND METHODS

Compost preparation

The mixture of effective microorganisms (EM) (1 ml/l), molasses and distilled water were sprayed on rice straw and allowed to stand for three weeks. The resultant manure was used as the media forcapsicum propagation.

Experimental materials and growth conditions

The experiment was conducted in the experimental polyhouse of area 292sq.m located at the instructional farm of Precision Farming Development Centre, KCAET, Tavanur, Malappuram District in Kerala during September-December 2015. The area is located at 10^{o} 51’18” N latitude and 75^{o} 59’ 11” E longitude 8.54 m above mean sea level. Poly house frame worked with stainless, cladding with U.V stabilized polythene sheet (200 microns) is used for the study. It is filled with sandy loamy soils rich in organic matter with good drainage and the pH ranges from 6.5 to 7.5.

The soil in the plot is ploughed thoroughly using mini tiller and left idle for one week after lime application. Variety “Indra” was used for the study. Viable seeds were sown in plastic pots, containing about 2.5 kg of sterilized soil, coir pith and per lite. Seeds were germinated in plastic seedling trays; emerged seedlings were watered on daily basis to maintain the soil moisture content at approximately 60% water holding capacity and transplanted into the field on 10^{th}day.Different beds of treatments are prepared with 35 m length, 1m base width and 0.80m top width. The plants were grown at a spacing of 0.60 m ×0.60 m in Randomized Block Design (RBD) with three replications. Weeding and intercultural operations were done manually in periodic manner. Installed drip irrigation system with screen filter, main, sub- main and lateral tubes and online emitters at an interval of 0.60 m and other accessories required. A 5 HP submersible pump was used to lift water from the bore well and supply to the drip irrigated plot.

The main and sub main pipelines used for drip irrigation were made of PVC pipes of 63 mm and 50 mm diameter respectively. Linear Low Density Poly Ethylene (LLDPE) pipes of 16 mm diameter were used for laterals in the drip irrigation treatments. Drippers of 2 litres per hour (2 lph) capacity were fitted on the laterals at a spacing of 0.60 m. Fertigation pump is used as the fertigation device. The application of fertilizer to various treatments was controlled by using control valves provided in the sub main and lateral flow control valves provided at the off take of laterals. Since the average duration of the crop is 120 days, the fertigation was scheduled as 40 splits with the frequency of once in three days from planting till the end of crop. Weekly foliar application of micronutrients was also provided.

Experimental designs and treatments

The experimental design was a completely randomized design with four treatments: soil only (A), soil plus manure containing effective microorganisms (B), soil plus effective microorganisms without manure (C) and soil plus organic manure only (D). The treatments were replicated three times and the conditions in the poly house are maintained at temperature: min/max 20/41^{o}C and relative humidity: min/max 50/95%. The irrigation schedule is constant (2 l/day) for all the treatments.

Measurement of growth parameters

Plants growth characters such as shoot height, stem diameter, leaf number per plant, leaf area, leaf fresh weight, leaf dry weight and chlorophyll a, b and total chlorophyll contents and yield characters such as fruit weight (kg), fruit length (cm), fruit diameter (cm), number of fruits/plant and yield per plant (kg) were calculated based on treatment and replication wise.

Growth measurements commenced twenty days after seed emergence and seedling establishment. Data was collected at an interval of ten days up to the end of the experiment. Shoot height was measured using a meter rule. The number of fully expanded mature leaves was established by counting. Leaf area was determined according to Jose *et al*. (2000).

AL = 0.73 (LL × WL), where LL is the leaf length and WL is the maximum width measured for all leaves on each plant. The stem diameter was determined using a vernier caliper.

Determination of chlorophyll content

The leaf from the shoot apex from each plant in each treatment was collected for extraction and estimation of chlorophyll. Chlorophyll concentration was determined in 80% acetone extract by use of a spectrophotometer (Arnon, 1949). Absorbence was read against 80% acetone blank at 645 nm and 663 nm. The values of chlorophyll a, chlorophyll b and total chlorophyll content were determined according to Yadegari *et al*. (2007) using the following formula:

$$\text{Chlorophyll a (mg/g)} = \frac{[12.7\times(A663)-2.69\times(A645)]\times V}{(1000\times W)}$$

$$\text{Chlorophyll b (mg/g)} = \frac{[22.9\times(A645)-4.68\times(A663)]\times V}{(1000\times W)}$$

$$\text{Chlorophyll total (mg/g)} = \frac{[20.2\times(A645)+8.02\times(A663)]\times V}{(1000\times W)}$$

Where, W is the fresh mass of the leaf sample taken and V is the total volume of the sample solution.

Data analysis

The data was statistically analyzed using *Microsoft Excel*. Analysis of variance (*ANOVA*) was carried out to determine the significant differences among treatments on parameters measured. The data were presented as mean ± SE.

RESULTS

Growth characters

All the growth characters showed significant difference over control. The character shoot length showed significant difference from control. The treatment- soil with effective microorganisms plus manure had the highest shoot growth compared to all other treatments. The growth increase compared to the control followed by effective microorganisms and organic manure (Table 2). Effective microorganisms' inoculation improved leaf formation among treatments throughout the study period. Plants inoculated with EM and organic manure recorded the highest number of leaves compared to all other treatments and control plants.

Leaf fresh weight and leaf dry weight also increased response to the treatments over the control; however there were significant difference among treatments (Table 1).

The combination with effective microorganism and organic manure showed the highest leaf fresh weight, which was about 46.77% of the control followed by soil with effective microorganisms alone (30.77%) and soil with organic manure (20.49%) in the order.

Table1 Shoot and leaf number increase over the 60 days experimental period.

Treatments	Stem diameter (cm)	Percentage of increase	Leaf area (cm^2)	Percentage of increase	Leaf fresh weight (g)	Percentage of increase	Leaf dry Weight (g)	Percentage of increase
Soil only (Control)	3.21 ± 0.03	0.00	35.56 ± 0.02	0.00	44.75 ± 0.04	0.00	5.25 ±0.04	0.00
Soil + EM + organic manure	3.78 ± 0..03	17.76	65.44 ± 0.01	84.03	65.68 ± 0.05	46.77	14.94 ± 0.01*	184.57
Soil + EM	3.56 ± 0.01	10.90	57.61 ± 0.02	62.01	58.52 ± 0.04	30.77	12.44 ± 0.02*	136.95
Soil + manure	3.44± 0.03	7.17	49.89 ± 0.03	40.30	53.92 ± 0.07	20.49	11.59 ± 0.04*	120.76

*significant at p≤0.05

Table 2 Stem diameter, shoot and root fresh weight, shoot and root dry weightand leaf area increase over 60 days experimental period.

Days since EM inoculation	Treatment	Shoot height (cm)	Percentage of increase	Leaf number per plant	Percentage of increase
20	Soil only (Control)	9.56 ± 0.04	0.00	6.63 ± 0.03	0.00
	Soil + EM +organic manure	12.89 ± 0.01	34.83	10.10 ± 0.04	52.34
	Soil + EM	10.22 ± 0.03	6.90	8.40 ± 0.02	26.70
	Soil + manure	9.87 ± 0.03	3.24	7.51 ± 0.03	13.27
30	Soil only (Control)	16.33 ± 0.05	0.00	11.90 ± 0.03	0.00
	Soil + EM +organic manure	19.37 ± 0.02	18.62	18.70 ± 0.02	57.14
	Soil + EM	17.28 ± 0.04	5.82	15.66 ± 0.01	31.60
	Soil + manure	17.22 ± 0.07	5.45	13.34 ± 0.04	12.10
40	Soil only (Control)	22.93 ± 0.02	0.00	16.55 ± 0.02	0.00
	Soil + EM +organic manure	32.94 ± 0.02	43.65	24.87 ±0.04	50.27
	Soil + EM	27.77 ± 0.03	21.11	21.25 ± 0.02	28.40
	Soil + manure	24.29 ± 0.01	5.93	19.22 ± 0.02	16.13
50	Soil only (Control)	36.74 ± 0.01	0.00	20.98 ± 0.01	0.00
	Soil + EM +organic manure	49.63 ± 0.03	35.08	30.79 ± 0.05	46.76
	Soil + EM	40.05 ± 0.04	9.01	27.98 ± 0.03	33.37
	Soil + manure	39.47 ± 0.01	7.43	26.44 ± 0.05	26.02
60	Soil only (Control)	46.48 ± 0.01	0.00	25.32 ± 0.04	0.00
	Soil + EM +organic manure	65.44 ± 0.04	40.79	38.21 ± 0.02	50.91
	Soil + EM	52.81 ± 0.01	13.62	31.27 ± 0.02	23.50
	Soil + manure	48.94 ± 0.06	5.29	29.16 ± 0.02	15.17

*significant at p≤0.05

Table 3 Effect of EM inoculation on leaf chlorophyll content of capsicum60 days after inoculation (mean ± SE)

Treatment	Chlorophyll a (mg/g fresh weight	Percentage of increase	Chlorophyll b (mg/g fresh weight)	Percentage of increase	Total Chlorophyll (mg/g fresh weight)	Percentage of increase
Soil only (Control)	4.83 ± 0.03	0.00	2.98 ± 0.06	0.00	7.59 ± 0.01	0.00
Soil + EM + organic manure	5.46 ± 0.02*	13.04	3.25 ± 0.07*	9.06	9.17 ± 0.03*	20.82
Soil + EM	5.27 ± 0.01*	9.11	3.18 ± 0.08*	6.71	9.04 ± 0.02*	19.10
Soil + manure	5.15 ± 0.05	6.63	3.01 ± 0.03	1.00	8.85 ± 0.06*	16.60

*significant at p≤0.05

Stem diameter and leaf area showed increased growth among all the treatments over control. There were significant differences in stem diameter growth of the experimental (Table 1) over control plants. Plants inoculated with effective microorganisms and organic manure had the highest stem diameter growth (17.76%)over control plants (soil only) followed by treatments such as soil with effective microorganisms (10.90%) and soil with organic manure (7.17%).Plants inoculated with soil containing effective microorganism and organic manure recorded the highest leaf area growth (84.03%), followed by the treatments containing soil with effective microorganisms (62.01%) and soil with organic manure (40.30%).

Plants inoculated with soil, effective microorganism and organic manure recorded the highest dry weight about 184.57% of the control plants. The variation was significant among all the treatments.

There was a significant difference in the chlorophyll content among all the treatments over control. Capsicum inoculated with effective microorganisms and manure had relatively higher chlorophyll a, chlorophyllb and total chlorophyll content compared to all other treatments (Table 3). Chlorophyll a was also higher than chlorophyll b in all the treatments.

Table4 Effect of EM inoculation on fruit weight (kg), fruit length (cm), fruit diameter (cm) number of fruits/plant and yield per plant (kg)(mean ± SE).

Treatments	fruit weight (kg)	fruit length (cm)	fruit diameter (cm)	number of fruits/plant	yield per plant (kg)
Soil only (Control)	0.114 ± 0.02	8.61 ± 0.05	8.00 ± 0.04	9 ± 0.03	1.06 ± 0.03
Soil + EM +organic manure	0.189 ± 0.01*	12.27 ± 0.03*	15.12 ± 0.01*	19 ± 0.05*	1.78 ± 0.01*
Soil + EM	0.165 ± 0.04*	9.94 ± 0.03	11.23 ± 0.01*	13 ± 0.03*	1. 35 ± 0.02*
Soil + manure	0.144 ±0.02	8.69 ± 0.02	10.55 ± 0.03	10 ± 0.01	1.26 ± 0.05*

*significant at $p \leq 0.05$

Yield characters

All the yield characters studied showed the similar trend in variation among treatments over control. Characters such as fruit weight, fruit diameter, number of fruits per plant and total yield got increased over control. The maximum fruit weight, fruit diameter, number of fruits per plant and total yield per plant were shown by the treatment with soil with effective microorganisms with organic manure followed by soil with effective microorganisms alone and soil with organic manure alone (Table 4.).

DISCUSSIONS

The results from the study indicate that inoculation of capsicum with effective microorganisms increased the measures of growth and yield characters. The shoot height, stem diameter, leaf number, leaf area, leaf fresh and dry weights got increased due to the application of effective microorganisms with the soil along with organic manure. Increased shoot height stem diameter growth probably reflects allocation of resources into shoots rather than roots. Increase in the number of leaves per plant and leaf area is common manifestations in plants that are provided with proper nutrition and this can increase the photosynthetic activity of the plants and thus the growth and productivity of the plant.

For plants, a high rate of net carbon assimilation can result in higher biomass accumulation, favouring future growth and reproduction. The position and distribution of leaves along the shoot influences the sink strength of the plants. During early stages of leaf growth, synthesis of chlorophyll, proteins and structural compounds is high consequential in high catabolic rates to support energy needs by the plants. Inoculation of effective microorganism can increase the available nutrition for plant roots and improve photosynthesis. Singh *et al*. (2003) reported that biological seed and mucilage yield of Is abgol could be increased with application of animal manure and integrated systems due to improved soil physical and chemical properties.

Accumulation of dry matter and its distribution into different plant components is an important consideration in achieving desirable economic yield from crop plants (Singh and Yadav, 1989). Chlorophyll a, b and total chlorophyll content increased in all the treatments, even though the plants inoculated with effective microorganisms had relatively higher chlorophyll contents (Table 4).

Increase in chlorophyll a and b in the capsicum may contribute to increased photosynthetic activity.

The synthesis and degradation of the photosynthetic pigments are normally associated with the photosynthetic efficiency of the plants and their growth adaptability to different environments (Beadle, 1993).Increased leaf chlorophyll contents could in turn lead to increased protein synthesis of the plants and this could have a direct consequence on the plant growth and photosynthesis (Hendry *et al*., 1987). Nitrogen is one of the essential nutrients involved as a constituent of biomolecules such as nucleic acids, coenzymes and proteins (Sharma *et al*., 1995), any deviation in these constituents would inhibit the growth and yield of plants.

Protein concentrations in plants tend to increase with fertility level of the growth medium (Grant and Bailey, 1993).In general effective microorganisms seem to havedirect impact on growth and yield of capsicum in poly house. Previous studies have demonstrated a consistent positive response with the use of effective microorganisms in crop production and indicate the potential of this technology to reduce fertilizer use and increase the yield and quality of many horticulture crops (Higa, 1991).

CONCLUSIONS

The experimental results showed that cultivation of capsicum in soil with effective microorganisms can improve their growth and yields in the poly house. It also provides the year round production of the crop. To prevent the environmental pollution from extensive application of fertilizers, the effective microorganisms could be recommended to farmers to insure the public health and a sustainable agriculture and food security. The data collected proves that the use of effective microorganisms can lead to higher capscium yield. Further research should be done to quantify the several effects of effective microorganisms on growth and yield of other varieties of capsicum. The local community should be sensitized on the use of effective microorganisms to improve farming and thus help alleviate poverty; this should be done through awareness programmes.

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