STUDIES ON THE EFFECT OF SEAWEED GEL ON GROWTH AND YIELD OF TOMATO (*Solanum lycopersicon.*Mill)

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TAMIL NADU AGRICULTURAL UNIVERSITY

COIMBATORE – 641 003

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STUDIES ON THE EFFECT OF SEAWEED GEL ON GROWTH AND YIELD OF TOMATO (*Solanum lycopersicon*.Mill)

Thesis submitted in part fulfillment of the requirements for the Degree of **MASTER OF SCIENCE IN HORTICULTURE** (Specialization in Vegetable Crops) to the Tamil Nadu Agricultural University, Coimbatore.

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON THE EFFECT OF SEAWEED GEL ON GROWTH AND YIELD OF TOMATO (*Solanum lycopersicon.*Mill)"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN HORTICULTURE** to the Tamil Nadu Agricultural University, Coimbatore is a record of **bonafide** research work carried out by **Miss. P. SELVAKUMARI** under my supervision and guidance and that no part of the thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

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Date:

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(P.Selvakumari)

ABSTRACT

STUDIES ON THE EFFECT OF SEAWEED GEL ON GROWTH AND YIELD OF TOMATO (*Solanum lycopersicon* Mill.)

By

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Degree : **Master of Science (Horticulture) – Vegetable Science**

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2009

Investigation was undertaken to study the effect of seaweed gel on growth and yield of tomato at College Orchard, Horticultural College and Research Institute, Coimbatore during 2008-09. There were ten treatments including one absolute control. The trail was laid out in a Randomized Block Design with three replications.

The results showed that treatment T_7 receiving NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray recorded highest plant height, number of leaves, number of branches and leaf area index. Early flower opening was also recorded in T_7.

Physiological and biochemical attributes such as total soluble protein, chlorophyll content, chlorophyll stability index, IAA oxidase activity, peroxidase activity and relative water content were recorded more in T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray).

Leaf nitrogen, phosphorus and potassium contents were found higher in the plants under T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray).

Individual fruit weight, fruit yield per plant, yield per plot and yield per hectare was found more in T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray).

Marginal reduction in the soil bulk density, particle density, porosity and pH and considerable improvement in available nitrogen, phosphorus and potassium were recorded after the application of macro nutrients along with seaweed gel. However, total bacteria, fungi and actinomycetes were higher in T_7 receiving NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray.

The benefit cost ratio was highest (1:2.73) in T_7 receiving NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray followed by treatment T_6 (1:2.53) receiving NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray.

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CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicon* Mill.) is one of the most important fruit vegetable commercially grown throughout the world. It belongs to the family solanaceae. Tomato occupies prime position among different vegetables grown in the world due to its wider adaptability both in open and protected conditions. Tomato is one of the most "protective food" because of its nutritive and therapeutical values. It is a good source of vitamin A, C and potassium. Lycopene, the pigment which imparts red colour to tomato is a potential antioxidant and prevent some form of cancer by minimizing the damage caused by free radicals. It is used in the preparation of processed products like ketch-up, sauce, chutney, soup, paste, puree *etc*. Because of its versatile use particularly the therapeutical values, short crop duration and high yield per unit area, the area under its cultivation is increasing day by day.

Tomato is popularly grown throughout India and the major tomato producing states are Maharashtra, Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Madhya Pradesh and Assam. Our national production of tomato is 9,361,800 mt from an area of about 534.5(in 000' ha) with an average productivity of 17.5 mt ha^{-1}.

Inorganic fertilizer plays a vital role in commercial cultivation of tomato to obtain higher yield and further remain as an important source of plant nutrient. But increasing cost of the chemical fertilizers is also limiting its optimal use. It is obvious that fertilizer requirement varies with the soil type, crop variety and climate. Indiscriminate use of chemical fertilizers can build up toxic concentration of salts in the soil, thus creating chemical imbalances and leads to environmental hazards by leaching.

Organic manures are considered to be sources of complete plant food as they provide both macro and micro nutrients. In addition to balanced nutrient supply, organics release nutrients more slowly as it decomposes and supplies the plant nutrients over a longer period (FFTC, 1991). Though the usefulness of organic manuring is well known, its requirement of high quantity and inadequate availability, farmers experience practical difficulties. In the current practice of farming, extensive application of chemical fertilizers causes depletion of soil nutrients as well as results in a serious imbalance of

crop nutrients in agro ecosystems. Hence, search for bioorganic inputs for sustainable crop productivity has been emphasized. Liquid fertilizers derived from seaweeds have been found to increase the vegetative growth and yield of several crops (Ramamoorthy *et al.*,2006 and 2007; Sivasankari *et al*., 2006a and 2006b; Xavier and Jesudass, 2007). In the recent past the extract of seaweeds *viz.*, *Ascophyllum nodosum* is used as a stimulant for earlier germination, increased root length, shoot height (Poincelot, 1993). The seaweed extract application has pronounced effect on the chlorophyll content and also imparting resistance to fungal, bacterial diseases and insect pests. Application of seaweed extract at regular intervals produced a vigorous root system than control (Smith and Van Staden, 1992; Mooney *et al*.,, 1986).

Seaweed extracts contain natural plant growth regulators (PGR) such as auxins and cytokinins which control the growth and structural development of plants. The PGRs in seaweed are present in very small quantities in the level of parts per million. However, the Indole compounds present in the seaweed extract helps in the development of roots and buds and cytokinins promote plant growth. When it is applied to foliage, the leaves rejuvenate stimulating photosynthesis. So, Seaweed extract with formulation results in higher yield.

Seaweed extracts supplies major nutrients *viz*., nitrogen, phosphorous and potassium as well as trace minerals *viz.*, Zn, Mn, Mg, Fe, etc. The trace elements present in Seaweed extract are naturally in chelated form and are readily available to the plants. Seaweed extract promotes the general health of the plant including drought tolerance. The fruits and vegetables grown by the application of seaweed extract have longer shelf life and frost resistance. Seaweed extract promote stronger stem and leaf growth. It accelerates photosynthesis and further develops healthy foliage. Seaweed extract induces flowering, increases fruit size, yield and improves the quality of the produce. With this background, the present experiment was formulated to with the following objectives.

- ✓ To study the effect of seaweed base O6 EM and MA GEL on the growth of tomato
- ✓ To study the effect of the product on biochemical and physiological characters in tomato
- ✓ To study the effect of the product on yield attributing characters and cost economics
- ✓ To study the effect of the product on pre and post harvest soil nutrient status

CHAPTER II

REVIEW OF LITERATURE

In tomato (*Solanum lycopersicon* Mill) various improvements in conventional production practices to enhance yield has been exhausted. Of late many workers have directed their efforts to use of bio-organics to improve yield and quality which are reviewed in this chapter.

2.1. Effect of seaweed extract

Seaweeds are used as fertilizer in the form of fresh, dry manure, compost and liquid extracts and it substitute conventional synthetic fertilizers (Crouch and Vanstaden, 1993) in many situations.

Seaweeds contain high potash content (Chapman and Chapman, 1980; Naganathan *et al.,* 2008) and carbohydrates (Gangatharan, 1998; Roslin, 2001; Devi Rajeshwari *et al.,* 2008; Eswaran *et al.,* 2008; Anitha *et al.,* 2008) and amino acids (Sobha *et al.,* 2001; Jacquelline Leyman, 2002; Kumaresan *et al.,* 2007; Nedumaran *et al.,* 2008).

Seaweed liquid fertilizer contain macro and micro nutrients (Crouch and Vanstaden, 1993; Thirumalthangam *et al.,* 2004; Naganathan *et al.,* 2008), Growth promoting hormones (Hong *et al.,* 1995; Mostafa *et al.,*1999; Rengasamy, 2004; Arumugam *et al.,* 2008; Rajalakshmi *et al.,* 2008) *viz.,* cytokinin like substances in sea algae (Hussian *et al.,* 1973; Finnie and Van Staden, 1985; Mooney and Van Staden, 1986) and gibberellins like substances (Wildgoose *et al.,* 1978; Kingman and Moore, 1982; and Kannathasan *et al.,* 2008); vitamins, fatty acids and trace elements (Bhosle *et al.,* 1975; Williams *et al.,*1981; Ryan Drum, 2005) and antioxidants (Arnold *et al.,* 1993; Ananthi *et al.,* 2008; Karthikeyan *et al.,* 2008 and Phenyl acetic acid (PAA) (Taylor and Wilkinson, 1977).

Seaweeds have bioactive substances (Sreenivasa Rao and Parekh, 1981; Caccamese *et al.,* 1981 and 1985; Pesando and Caram, 1984; Padmini Sreenivasa Rao *et al.,* 1986; Bhakuni *et al.,* 1992; Padmakumar and Ayyakannu, 1997; Padmakumar, 2002;

Vanitha *et al.,* 2003; Banuselvi *et al.,* 2007 and Veeragurunathan *et al.,* 2008) and also fatty acids like Lauric acid, tridecanoic acid, oleic acid, linolenic acid etc., (Venkataraman Kumar *e t al.,* 2008 and Gandhiyappan *et al.,* 2001).

Apart from these seaweeds also contain some soluble salts like Na, Ca, Mg, Cl_2, N, SO_4 and minor amount of Fe, Cu, Mn, B, Zn, P, iodine, bromine and ascorbic acid (Chennubhotla *et al.,* 1987; Rama Rao, 1992 and Sudha *et al.,* 2008. Application of seaweed has a pronounced effect on seed germination and nutrient uptake in crop plants by inducing the production of cytokinin which is an important factor for protein synthesis and cell division.

Seaweed application also increases the chlorophyll content and resistance to fungal, bacterial and insect attack. One of the most pronounced effects of seaweed application on plants is the development of vigorous root system. But the final question that needs to be addressed is that the commercial seaweed products are economically viable alternative to N, P and K fertilizers and other soil additives.

2.1.1. Height of the Plant and Number of Branches

Commercial product of the water extract of *Ascophyllum nodosum* was tested for the control of *Meloidogyne incognita* infesting aubergines *invitro* and in pot trials. Both tests showed a significant reduction in *Meloidogyne incognita* populations in treated plants with an increase in plant growth characters, Goswami (1992). KELPAK 60 (Seaweed extract) as foliar spray at regular intervals improved the plant root growth compared to control (Smith & Van, 1992). Application of an algal (*Ascophyllum nodosum*) extract at 3.3 g l^{-1} showed increased root and shoot growth and total fresh weight (15 – 25 %) over control in maize, Gendy (1993). Application of seaweed (*Ascophyllum nodosum)* extract solution at one per cent to roots resulted in earlier germination and produced transplants with increased root length and shoot length compared to control in tomato, Poincelot (1993). Application of one per cent solution of 'ROOT PLUS' (a commercial product containing *Ascophyllum nodosum)* showed increased shoot height, diameter flowering and earliness than control in marigold plant, Russo *et al.* (1994). Aljuburi and Almastry (1995) recorded an increased Relative Growth Rate through foliar application of one per cent seaweed extract in tomato.

Hameed *et al.* (1995) obtained an increased RGR of lime seedlings by the application at one per cent seaweed extract. Enhanced leaf chlorophyll content of tomato plants when treated with seaweed extract and it was dependent on the betaines present in it, Blunden and Jenkins (1996).

2.1.2. Days to 50 % Flowering

Application of ROOT PLUS (*Ascophyllum nodosum*) at one per cent solution was resulted in increased flowering and earlier flowering of Broccoli, Poincelot (1994). Similarly, in tomato cv. Early Girl, number of fruits was increased with the application of one per cent ROOT PLUS.

2.1.3. Yield characters

Application of seaweed extract (*Ascophyllum nodosum)* at one per cent solution increased the yield from 15.2 to 29.1 % and also improved the pulp consistency and shelf life in tomato, Povolny (1976). Heckman (1994) reported that application of ROOT PLUS at two per cent solution in the soil before transplanting increased the fresh cabbage yield by 13 %. Passam *et al.* (1995) reported that foliar spray of maxicrop concentration (50 ml/l) increased the crop yield and fruit quality in cucumber. The number of fruits per plant, fruit yield per plant and per plot significantly increased with the application of 1680 ppm seaweed extract. Seaweed extract at 1120 ppm promoted the growth of tomatoes regardless of the season (Saravanan, 1997). Foliar application of seaweed increased yield in many crops (Albertz and Young, 1983); *Spatoglossum asperum* (Dhargalkar and Untawale, 1983 in vegetables); *Sargassum* (Ramarao, 1990 in cowpea) and *Entromorpha intestinalis* (Manimala and Rengasamy, 1993 in paddy). Seaweed used as a foliar spray can increase the amount of limiting nutrients leading to higher biomass (Abetz, 1980).

Seaweed liquid fertilizers are now available in commercial forms namely Maxicrop, Algifert, Goemar-GA 14, Sea spray, Seasol, SM3, Aptex and Seacrop 16 are used in agriculture for crop improvement as seed treatment as well as foliar spray. The foliar application of seaweed liquid fertilizers extracted from different species of seaweeds. Finnie and Van Staden, (1985) reported that seaweed liquid fertilizers are

applied during vegetative phase showed beneficial effect. The commercially available seaweed concentrates namely Goemar-GA 14 applied as foliar spray at the concentration of 3.3 g l^{-1} increased the total fresh weight of maize seedlings (Jeannin *et al.*,1991).

Increased fresh weight and dry weight by the foliar application of other seaweed extracts were reported in Goemar GA-14 – SLF (Featonby Smith and Van Staden, 1983a in sugar beet); *Hypnea musciformis* (Kannan and Tamilselvan, 1994 in black gram and Kannathasan *et al.*, 2008 in peanut) and *Gracilaria corticata* (Murugalakshmi Kumari *et al.*, 2002 in black gram and cumbu). Sujatha *et al.*, (2007) reported that seaweed extract (*Sargassum polycystum*) was applied as seed treatment (0.75 %) and foliar spray (2.5 %) at vegetative and flowering stage increased the growth and yield parameters of black gram. The commercial liquid fertilizer obtained from brown algae – *Sargassum* acted as growth promoter and also increased the yield at lower concentrations of 10, 15 and 20 % in tomato and bhendi (Selvaraj *et al.*, 2004). Similar findings were observed in *Macrocystis integrifolia* and *Ecklonia maxima* (Temple and Bomke, 1989 in beans). The yield and productivity was increased by foliar application of seaweed concentrate was observed in Kelpak (Beckett and Van Staden, 1990 in wheat) and *Chaetomorpha linum* and *Gracilaria verrucosa* (Sethi and Adhikary, 2008 in black gram, tomato, brinjal and chilli).

2.1.4. Physiological and biochemical response of seaweeds

Povolny (1976) reported that application of seaweed extract (Algifert and Algifertl) at one per cent solution increased the yield from 15.2 to 29 % and improved the pulp consistency and shelf life of tomato. Frones (1995) reported that in Naveline orange, Goemar an aqueous extract of *Ascophyllum nodosum* applied at the beginning of flowering and at full bloom resulted in reduced acidity, increased TSS content but juice content was unaltered. The application of seaweed extract enhanced the amount of photosynthetic pigments, *Gracilaria edulis* in cowpea and black gram (Lingakumar *et al.*, 2002) and *Spyridia hypnoides* (Sobithabai *et al.*, 2007 in bhendi).

Whapmam *et al.* (1993) observed that application of SLF obtained from brown seaweed *Ascophyllum nodosum* increased the chlorophyll content of cucumber cotyledons and tomato plants. Similar effect was observed in *Spyridia hypnoides*

(Blunden *et al.,* 1997 in tomato and french bean; *Gracilaria sp.* (El-Sheikh and El-saied, 1999 in field bean; Thirumalthangam *et al*., 2003 and 2004 and Balakrishnan *et al.*, 2007 in cluster bean).

Asir Selin Kumar *et al.* (2008) reported that the seaweed extract liquid of *Spyridia hypnoides* and *Syringodium spp* increased the chlorophyll a and b contents in maize and paddy. Similar findings were observed in *Ulva lactuca* (Lingakumar *et al.,*2006 in cluster bean and black gram); *Gracilaria corticata* (Balakrishnan *et al.,*2007 in cluster bean).

Chandrasekaran *et al.* (2006) reported that low concentration of seaweed extract (*Sargassum wightii*) enhanced the leaf area in green gram. Similar results were reported in *Entromorpha clathratha* (Kannan and Tamilsevan, 1990 in green gram); *Stoechospermum marignatum* (Rathinavel *et al.,* 2005 in cluster bean); *Turbinaria decurrens* (Sivasankari, 2006 b in cowpea); *Caulerpa racemosa* (Xavier and Jesudass, 2007 in cluster bean).

The seaweed extract prepared from *Sargassum* (20%) as seed treatment had significant increase in chlorophyll, carotenoid, protein, sugar and lipid content (Selvaraj *et al.,* 2004 in bhendi and tomato). Similar findings were observed in *Cladophora sp*. (Mostafa *et al.,* 1999 in faba bean); *Sargassum longifolium* (Rajalakshmi *et al.,* 2008 in brinjal).

Decrease in free amino acid, oxidizing enzyme activity, amylase and proline accumulation after the application of *Gracilaria edulis* extract at 70% in bhendi was reported by Ramasubramanian *et al.* (2004). Similar results were observed in *Sargassum* sp. (Lingakumar *et al.,* 2004 in maize and black gram) and *Spyridia hypnoides* (Asir Selin Kumar *et al.,* 2005 in rice).

Ramamoorthy *et al.* (2006) observed that *Sargassum polycystum* seaweed extract increase dehydrogenase activity and lower lipid peroxidation in cowpea. The accumulation of total chlorophyll, carotenoid and protein content was increased by foliar application was observed in *Caulerpa racemosa* (Blunden *et al.,* 1991 in tomato and French bean and Anantharaj and Venkatesalu, 2002 in horse gram).

2.1.5. Root characters

Van Staden (1992) reported that application of seaweed extract improved the root growth significantly. Finnie and Van Staden (1985) reported that application of seaweed concentrate at 6 -10 ml significantly increased the root extension and root elongation of tomato. Nelson and Van Staden (1984) reported that application of seaweed in cucumber plant showed increased root growth. Poincelot *et al. (*1993) reported that application of 'ROOT PLUS' (a commercial growth stimulant containing *Ascophyllum nodosum* extract) at one per cent solution increased the root length and shoot height compared to control of tomato. Gendy (1993) reported that application of an algal *(Ascophyllum nodosum*) extract at 3.3 g l^{-1} showed increased root and shoot growth and total fresh weight (15 – 25 %) over control in maize.

2.2. Vermicompost

Owing to high nutrient content, vermicompost enhances beneficial soil microflora thereby increasing the plant growth. Application of vermicompost is widely practiced by the farmers and has been recommended as one of the best organic manures for crops.

Earthworms have important functions by virtue of their feeding and general behavioral activities like burrowing, feeding, digestion, excretion with decomposing microorganisms and supporting further decomposition of bio-degradable matters. They can decompose complex waste matter into simpler forms. The influence of earthworm cast on nitrogen metabolism has been indirectly made evident by the increased protein content in plants (Jat and Mahesh Kumar, 2002).

Vermicasting is black granular excreta of earthworms, rich in plant nutrients, vitamins, antibiotics and plant growth hormones which enhance the ability to absorb atmospheric moisture, thus providing considerable water economy (Anonymous, 2002).

2.2.1. Vermicompost on soil quality

Vermicompost is rich in both macronutrients and micronutrients besides having many plant growth promoting substances, humus forming microbes and nitrogen fixers (Bano *et al.,* 1987). Improvements in enzymatic and microbial activities have been reported due to vermicompost which helps in enhancing soil fertility (Jambhekar and

Bhinday, 1992). The vermicompost is an aerobically degraded organic matter which undergoes chemical disintegration by the enzymatic activity in the gut of worms and so also enzymes of the associated microbial population (Kale *et al.*, 1992). The high humus content of vermicompost also helps to enhance the soil characteristics and thereby the productivity (Anonymous, 1996). Sadanandan *et al.* (1998) reported an increased available N, P, K and micronutrients due to application of FYM, neem cake, leaf compost and vermicompost in black pepper. Vermicompost contains major and minor nutrients for the plants in available forms besides enzymes, antibiotics, vitamins, beneficial micro organisms and other plant growth hormones and have definite advantage over other organic manures in respect of quality and shelf life of produce (Meerabai and Raj, 2001).

2.2.2. Effect of vermicompost on yield parameters

Vermicompost contains a good amount of macro and micronutrients. It also serves as a very good base for establishing and multiplication of beneficial symbiotic microbes which helps in fixing nitrogen in the soil, besides enhancing availability of phosphate and nitrogen and uptake of phosphate by plants (Kale *et al*., 1992). The growth, yield and biochemical constituents of okra were found to be the maximum in the plot supplemented with vermicompost (Manonmani and Anand, 2002) The biometric parameters of chilli varied significantly among the treatments of vermicompost alone and admixed with FYM, green manures, neem cake and N:P:K. The better yield parameters were observed in vermicompost treatments (Hiramani Yadav and Vijayakumari, 2003). Neena Dhiman and Battish (2002) reported that application of vermicompost and FYM each at 400 g to potted capsicum plants gave maximum yield in terms of number of fruits, weight of fruits and fruit length.

Subbiah *et al.* (1999) reported that application of FYM @ 25 t ha^{-1} increased the yield of bhendi by 57 per cent in the absence of inorganic nitrogen application. Ushakumari *et al.* (1999) recorded the highest yield in bhendi when vermicompost @ 12 t ha^{-1} was applied along with recommended dose of NPK. Anburani *et al.* (2006) reported that application of vermicompost @ 5 t ha^{-1} combined with panchagavya 3 % and humic acid 0.2 % registered the highest number of fruits, dry weight of fruits and total herbage yield in *Solanum nigrum.*

2.2.3. Effect of vermicompost on quality parameters

Vermicompost contains major and minor nutrients in plant available forms, enzymes, antibiotics, vitamins, beneficial micro organisms and other plant growth hormones and have definite advantage over other organic manures in respect of quality and shelf life of produce (Meerabai and Raj, 2001).

In tomato, 75 % N supplied as vermicompost with azospirillum was superior in the production of primary branches (7.9), plant height (76.4 cm), dry matter production (1735 kg ha^{-1}) and increased the fruit qualitative characters such as titrable acidity (0.72 %), ascorbic acid content (23 mg 100 g^{-1}), total solids (5.4 %), crude fibre (0.42 %), crude protein (1.7 %), reducing sugar (3.47g $100g^{-1}$), non reducing sugar (0.37 g $100g^{-1}$) and lycopene (3.9 mg $100g^{-1}$) over control (Kannan *et al*., 2006).

Ketkar (1993) reported that the contribution of nitrogen from different organic manures *viz.,* FYM, goat manure; vermicompost and poultry manure was compared and found that poultry manure proved to be a better source.

Sadanandan *et al.* (1998) also obtained the improvement of soil physical properties particularly decreased bulk density by applying FYM, neem cake, leaf compost and vermicompost in six year old black pepper. Application of organic manures, FYM, neem cake, leaf compost and vermicompost resulted in increased available NPK and micronutrients. The plants supplied with vermicompost at 8 kg $plant^{-1}$ along with 50 % RDF recorded the highest chlorophyll content in Jasmine leaves (Patil *et al*., 2004). The growth, yield and biochemical constituents of okra were found to be maximum in the plot which is supplemented with vermicompost (Manonmani and Anand, 2002). According to Goswami *et al*., (2001), the increase in yield of tomato was observed in vermicompost treatment added at the rate of 20, 30 and 40 t ha^{-1}. Plant growth, root length, shoots length and shoot biomass were improved with 100 % vermicompost application on tomato plants (Atiyeh *et al.,* 2000). Chan and Griffths (1988) opined that microbial population was improved with vermicompost. According to Rola *et al.* (2000), total N content was increased greatly after the introduction of earthworm in cow's manure.

CHAPTER III
MATERIALS AND METHODS

An experiment on the "Studies on the effect of Seaweed gel on growth and yield of tomato (*Solanum lycopersicon* Mill)" was carried out at the College Orchard, Department of Vegetable Crops, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during the period of 2008-09. The details of the materials used, methods adopted for field study and analytical procedures followed during the present investigation are furnished in this chapter.

3.1 Materials

3.1.1. Field location

Latitude	:	11°09' N
Longitude	:	76°57' E
Altitude	:	426.76 m above MSL
Maximum temperature	:	34.1°C
Minimum temperature	:	24.3°C
Mean annual rainfall	:	650 mm
Average relative humidity	:	83.25 per cent

The weather data recorded during the crop growth period (2008-09) was obtained from Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore and are given in Annexure I.

3.1.2. Soil composition

The soil of the experimental field is red sandy loam in texture. Composite soil samples were collected initially from 15 to 30 cm depth before sowing and analyzed for physical and chemical properties.

3.1.3. Crop and Variety

The tomato hybrid COTH 2 was used in the research study.

Seaweed extract

O6 EM and MA GEL is a proprietory product of Bio Organic Technology (SNAP Natural and Alginate Products Ltd., Ranipet, Tamilnadu). O6 is a stabilized gel type sea algae base concentrate containing a consortium of beneficial bacteria, which acts as a microbial innoculant in the soil. EM (Effective Micro organism) consists of both aerobic and anaerobic beneficial bacteria such as photosynthetic bacteria, nitrogen fixing bacteria and phosphate solubilizing bacteria. MA (Micro Algae) is an efficient N-fixing Micro Algae, such as *Chroococus turgidus*. O6 EM and MA is easy to dissolve in water. It can be sprayed on the soil (or) mixed with irrigation water to enrich the soil. Hence it ensures healthy plant and better harvest. Soil drenching was done at five stages *viz.*, initial, vegetative, flowering, fruiting and harvesting stage. Foliar application was also done at three stages viz., vegetative, flowering and fruiting stage.

Vermicompost

Vermicompost is yet another form of organic manure, born out of the process of recycling organic wastes into nutrient rich compost where earthworms are the agents for undertaking this recycling process. At the time of bed preparation, vermicompost @ 2.5 t ha^{-1} was applied.

3.2. Methods

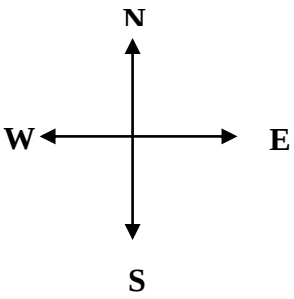
3.2.1. Experimental Details

The experiment was laid out in Randomized Block Design with ten treatment combinations replicated thrice. The plot size was 4 m x 3 m and spacing followed was 60 cm x 45 cm. The details of the treatments are as follows.

T1	NPK @ 200:300:200 kg per ha (control)
T2	T1 + O6 EM and MA GEL@7.5 kg $acre^{-1}$
T3	T1 + O6 EM and MA GEL@10 kg $acre^{-1}$
T4	T1 + O6 EM and MA GEL@12.5 kg $acre^{-1}$
T5	T2 + O6 EM and MA GEL 1% spray
T6	T3 + O6 EM and MA GEL 1% spray
T7	T4 + O6 EM and MA GEL 1% spray
T8	Vermicompost (2.5 t ha^{-1})
T9	Vermicompost (2.5 t ha^{-1}) + O6 EM and MA GEL@12.5 kg $acre^{-1}$
T10	Vermicompost (2.5 t ha^{-1}) + O6 EM and MA GEL@12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray

3.2.1.1. Land Preparation

The land was prepared during the month of July 2008. The soil was brought to fine tilth by giving four deep ploughing. Weeds, stubbles and roots were removed. At the time of last ploughing, FYM was applied at the rate of 10 t ha^{-1}. After leveling, beds were formed to accommodate the treatments. The field layout was prepared as shown in the Fig.1 and depicted in plate.



R1	R2	R3
T_2	T_1	T_6
T_4	T_3	T_1
T_7	T_{10}	T_2
T_1	T_9	T_{10}
T_3	T_2	T_8
T_{10}	T_4	T_5
T_9	T_5	T_4
T_8	T_7	T_9
T_6	T_8	T_7

Fig.1 Field Layout of the Experiment

Design : RBD No. of treatments: 10

Spacing : 60 x 45 cm No. of replications: 3

Plot size : 4 x 3 m

3.2.1.2. Mulching

Black polythene mulch sheet of 50 gauge thickness was laid in the bed to keep the beds free of weeds to the maximum extent and to conserve the soil moisture. Paired row system of planting was followed and then the holes are put on either side of the mulching sheet covering the bed at recommended spacing of 60 cm X 45 cm.

3.2.1.3. Application of organic manures

Recommended dose of FYM (10 t ha^{-1}) was applied as basal and the soil was ploughed for thorough mixing.

3.2.1.4. Application of Inorganic Fertilizers

Fertilizers at the rate of 200:300:200 kg ha^{-1} were applied as urea (435 kg), superphosphate (1875 kg) and Muriate of potash (333 kg) as source of N, P and K respectively.

The full dose of phosphorus and potash fertilizers and half of the dose of nitrogenous fertilizers were applied at the time of transplanting and the remaining half dose of nitrogenous fertilizer was applied 25 days after transplanting as top dressing.

3.2.1.5. After Cultivation

Manual weeding was done at 30, 60, 90 days after planting. Drip irrigation was resorted for irrigating the field. All the plant protection measures were taken as and when necessary.

3.2.1.6. Staking

The plants were staked with bamboo poles of one metre height at 30 days after planting to prevent lodging as the hybrid is semi determinate.

3.2.1.7. Harvesting

The crop was harvested when it started showing signs of maturity *viz.*, breaker stage. Totally 6-7 harvests were made at five days interval.

3.2.2. Sampling Technique

Ten plants in each treatment per replication were tagged randomly for recording the observations on vegetative, flowering, fruiting and harvesting stage. The mean values were subjected to statistical analysis as per the method suggested by Panse and Sukatme (1961).

3.2.3. Observations

3.2.3.1 Vegetative characters

3.2.3.1.1 Plant height

The height of the plant from the cotyledonary node to the tip was measured at the time of final harvest and expressed in cm.

3.2.3.1.2 Number of primary branches

The number of branches borne on the main stem was counted and expressed as number of branches per plant.

3.2.3.1.3 Number of leaves

The total number of leaves was recorded for five randomly selected plants and the mean was worked out and expressed in number.

3.2.3.1.4 Leaf area index

Leaf Area Index was calculated using the following formula (Williams, 1946).

$$LAI = \frac{\text{Leaf area per plant}}{\text{Land area occupied by the plant}}$$

3.2.3.2 Flowering characters

3.2.3.2.1 Days to first flowering

The number of days taken from planting to anthesis of first flower was recorded and expressed in days.

3.2.3.2.2 Days to 50 per cent flowering

The number of days taken for flowering of 50 per cent of population was counted and expressed in days.

3.2.3.3 Root characters

3.2.3.3.1 Root length

The length of root (hypocotyls to the tip of the tap root) was measured in cm, to represent the root length and the average was arrived for each treatment and expressed in cm.

3.2.3.4 Physiological and biochemical attributes

3.2.3.4.1 Soluble protein

The soluble protein content was estimated at 660 nm using Foline Ciocalteau reagent by following the procedure described by (Lowry *et al.,* 1971) and expressed in mg $g^{-1}$of fresh weight of leaves.

3.2.3.4.2 Chlorophyll content

The total chlorophyll content, chlorophyll 'a' and chlorophyll 'b' content taken from the leaves were determined by following the method of (Yoshida *et al.,* 1971) and expressed in mg $g^{-1}$of fresh weight.

$$\text{Chlorophyll a} = 12.7 \times (A_{663}) + 2.69 \times (A_{645}) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll b} = 22.9 \times (A_{645}) + 4.68 \times (A_{663}) \times \frac{V}{1000 \times W}$$

$$\text{Total chlorophyll} = 20.2 \times (A_{645}) + 8.02 \times (A_{663}) \times \frac{V}{1000 \times W}$$

3.2.3.4.3 Chlorophyll stability index (CSI)

CSI was assessed following the method of Murty and Majumder (1962). Two samples (each one g) of the fresh leaves were placed in test tubes with 20 ml of distilled water and one set was heated in a water bath for 60 minutes at 65^0C. Leaf tissues of both the heated and unheated check were removed from the distilled water, blotted and transferred to mortar containing acid washed sand and 80 per cent acetone, ground to a pulp and allowed to settle. The filtrate was decanted into a Buchner funnel mounted on a suction flask containing Whatman No.1 filter paper. A small amount of 80 per cent acetone was added to the mortar and the tissue was ground again before pouring the contents into the funnel, where, washing with acetone was continued until the tissue

appeared grey. The filtrate was brought to 100ml volume with 80 per cent acetone and light absorbance was taken at 663 nm immediately with a Spectronic Colorimeter. Absorbance percentage was employed for arriving the data.

3.2.3.4.4. IAA oxidase activity

The enzyme IAA oxidase activity in the leaf sample was determined as per the method of Parthasarathy *et al.* (1970) colorimetrically at 540 nm. The OD values was referred to a standard curve using auxin (IAA -10 to 100 μg^{-1} hr^{-1}) and expressed in (μg of unoxidised auxin hr^{-1}) of the fresh sample.

3.2.3.4.5. Peroxidase activity

Peroxidase activity was measured by the method of Perur (1962) and the enzyme activity was measured in μ moles H_2O_2 100 mg^{-1} min^{-1} on fresh weight basis.

3.2.3.4.6. Relative Water Content

Relative water content was determined by the method of Barrs and Weatherly (1962). Turgid weight was determined by taking the leaf samples in petridishes containing water for four hours (Bennett *et al*., 1981). It was worked out and expressed in percentage.

$$\text{RWC (\%)} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Turgid weight} - \text{Dry weight}} \times 100$$

3.2.3.5 Nutritional status

The leaf samples collected from four plants of same replication of a treatment were pooled. The leaf samples were dried in shade and then oven dried at 60^0C for 18-24 hours. The dried leaves were chopped and powdered in stainless steel mixer grinder and then used for analysis. The estimation was carried out at three different stages *viz.*, initial, flowering, fruiting stage of the experiment.

3.2.3.5.1 Leaf Nitrogen

Nitrogen content of leaf sample was estimated by Microkjeldhal method (Humphries, 1956).

3.2.3.5.2 Leaf Phosphorus

The phosphorus content was estimated in a triple acid extract by adopting Vanadomolybdate phosphoric yellow colour method (Jackson, 1973) and expressed in per cent.

3.2.3.5.3 Leaf Potassium

The potassium content was estimated by reading in the flame photometer values of triple acid extract (Jackson, 1973).

3.2.3.6 Yield characters

3.2.3.6.1 Fruits per plant

The number of fruits in each harvest was counted and total number of fruits from all harvests was expressed as number of fruits per plant.

3.2.3.6.2 Average fruit weight

Weight of individual fruit was measured randomly from each treatment at each harvest and the mean of all the harvests was pooled and expressed in grams.

3.2.3.6.3 Yield per plant

The weight of all the fruits harvested in each plant was weighed and expressed in grams

3.2.3.6.4 Yield per plot

The weight of all the fruits harvested in each plot was weighed and the mean expressed in kilograms.

3.2.3.6.5 Yield per hectare

The weights of all the harvests were finally pooled and the mean was expressed in tonnes.

3.2.3.6.6 Equatorial and polar diameter of the fruit

Polar diameter of the fruit was measured by taking the length from distal end to proximal end of the fruit. Equatorial diameter was measured by taking circumference of the fruit and expressed in cm.

3.2.3.6.7 Shelf life

One kg fruits of uniform maturity (Breaker stage) was selected randomly from each treatment per replication. These fruits were kept in trays under ambient storage temperature (25-30°C). The number of days taken for 30 per cent moisture loss and 35 per cent spoilage was noted and expressed as number of days of shelf life (Abound, 1974).

3.2.3.7 Quality traits

3.2.3.7.1 Total soluble solids

Total soluble solids content of the five randomly selected fruits was estimated using Zeiss hand refractometer and the mean expressed in °Brix.

3.2.3.7.2 Titrable acidity

Titrable acidity in tomato was estimated by AOAC method (1975). Five gram of tomato pulp was mixed with 50 ml of hot distilled water and titrated against 0.1N NaOH using phenolphthalein as indicator. The appearance of stable pale pink color was the end point. The titrable acidity as per cent citric acid was calculated using the formula.

$$\frac{\text{Titre value x } 0.0064}{\text{Weight of the sample (g)}} \text{ x } 100$$

3.2.3.7.3 Ascorbic acid

Ascorbic acid content of the fruit was estimated by following the method of AOAC (1975) and expressed as mg 100 g^{-1} of fruit pulp.

3.2.3.7.4 Total sugars

Total sugars of the fruits was estimated by the method suggested by AOAC (1975) using Fehling's solution and expressed in per cent.

3.2.3.7.5 Lycopene

Lycopene was estimated as per the method given by Ranganna (1979). Ten grams of sample was extracted with acetone. The acetone extract was transferred to a separating funnel containing 15 ml of petroleum ether and mixed gently. The lower acetone phase was diluted with water containing five per cent sodium sulphate and then

transferred to another funnel. The extraction was repeated with petroleum ether until it was colourless. Anhydrous sodium sulphate was added to the pooled petroleum ether extracts and the volume was made up to 100 ml with petroleum ether. An aliquot of 5 ml was diluted to 50 ml and the colour was read at 503 nm in a spectrophotometer against petroleum ether as blank. The lycopene content of the sample was expressed as mg per 100 g and calculated by the formula.

$$\frac{3.1206 \times \text{O.D. value of sample} \times \text{Volume make up} \times \text{Dilution} \times 100}{1.0 \times \text{weight of sample} \times 1000}$$

3.2.3.8 Soil health

The soil samples were collected randomly from four place of the experimental field. A 'V' shape cut was made to a depth of 15 cm at each sampling place. About 1.5 cm thick slices of soil were collected in clean polythene bags. The samples collected from two places of same replication of each treatment were mixed thoroughly and the quantity was reduced by quartering for analysis. The estimation was carried out at initial and final stage of the experiment.

3.2.3.8.1 Soil Physical properties

Physical properties of soil were determined at two different periods *viz.*, start of the experiment and end of the experiment.

Bulk density and particle density

The bulk density and particle density were determined by cylinder method and expressed in g cc^{-1} (Piper, 1966).

$$\text{Bulk density (g cc}^{-1}\text{)} = \frac{\text{Weight of oven dry soil (g)}}{\text{Volume of air dry soil (cm}^3\text{)}}$$

$$\text{Particle density (g cc}^{-1}\text{)} = \frac{\text{Weight of oven dry soil (g)}}{\text{Volume of solid soil particles (cm}^3\text{)}}$$

Porosity

Porosity was calculated and expressed in percentage

$$\text{Porosity} = \left\{1 - \frac{\text{Bulk density}}{\text{Particle density}}\right\} \times 100$$

3.2.3.8.2 Soil Chemical properties

Soil pH

pH of the soil was determined in 1:2 soil water suspension using pH meter as per the procedure described by Jackson (1973).

Soil EC

The electrical conductivity (EC) was measured in 1:2 soil water suspension using Electrical Conductivity Bridge as per the procedure described by Jackson (1973) and expressed in $dSm^{-1.}$

Available Nitrogen

The available nitrogen was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kilogram ($kg\ ha^{-1}$).

Available Phosphorus

The method described by Olsen *et al.* (1954) was adopted for estimating the available phosphorus of the soil and expressed as $kg\ ha^{-1}$.

Available Potassium

The equilibrium extraction method (Toth and Prince, 1949) using neutral ammonium acetate was employed. The potassium content was estimated using flame photometer and expressed as $kg\ ha^{-1}$.

3.2.3.8.3. Soil biological properties

The total bacteria, fungi and actinomycetes in soil samples were assessed by the following procedure.

The enumeration of microbial population in the soil was made after serially diluting the soil and plating the appropriate dilutions in different agar media. Ten gram of soil samples was transferred to 100 ml of sterile water blanks contained in the 250 ml Erlenmeyer flask and shaken well in a rotary shaker for 5-10 min. Using sterile pipette

10 ml of the suspension was transferred to 90 ml of sterile water and likewise serial dilutions were continued until dilutions of 106 were obtained. Aliquots of 1 ml of appropriate dilutions were plated in the nutrient agar, Martin's Rose Bengal agar and Kenknight's agar medium respectively for total bacteria, fungi and actinomycetes. The plates were incubated at room temperature (30 ± 2°C) for 3 days for bacteria, 5 days for fungi and 7 days for actinomycetes. The colonies were counted and expressed as colony forming unit (cfu) per g of dry soil.

S. No.	Organism	Dilution used	Medium used	Incubation period (days)	Colony characters
1	Bacteria	10^{-6}	Nutrient agar medium	1	Individual single colony forming units
2	Fungi	10^{-3}	Rose Bengal agar medium	3	Cushiony growth
3	Actinomycetes	10^{-2}	Ken knight's agar medium	7	White powdery mass of spores with pin pointed raised centre

Nutrient agar (Manual of Microbiological Methods by the Society of American Bacteriologist**, 1957)**

Glucose - 5.0 g

Peptone - 5.0 g

NaCl - 5.0 g

Beef extract - 3.0 g

Agar - 15.0 g

Tap water - 1000 ml

pH - 7.0

Martin's Rose Bengal agar (Martin, 1950)

Glucose	-	10.0 g
Peptone	-	5.0 g
$K_2H\ PO_4$	-	1.0 g
Rose Bengal	-	0.035 g
Agar	-	15.0 g
pH	-	6.8-7.0
Distilled water	-	1000 ml

Three milliliters of 1 per cent solution of streptomycin sulphate prepared in sterile distilled water was added to 11 of the sterilized medium just prior to plating.

Kenknight's agar (Allen, 1953)

Dextrose	-	1.0 g
K_2HPO_4	-	0.1 g
$NaNO_3$	-	0.1 g
KCl	-	0.1 g
$MgSO_4$	-	0.1 g
Agar	-	15.0 g
Distilled water	-	1000 ml
pH	-	7.0

3.2.3.9 BENEFIT COST RATIO

Cost of cultivation

The expenditure incurred from sowing to harvest was worked out and expressed as rs. ha^{-1}.

Gross return

Total income obtained from the crop was worked out, considering the current market price that prevailed during the experimentation.

Benefit cost ratio (BCR)

The benefit cost ratio was worked out by using the formula suggested by Palaniappan (1985).

$$BCR = \frac{\text{Gross return (Rs. ha}^{-1})}{\text{Total cost of cultivation (Rs. ha}^{-1})}$$

Statistical Analysis

The recorded data on crop was statistically analyzed based on the procedure given by Gomez and Gomez (1984) to find out the treatment differences. Critical differences were worked out at 5 per cent probability level where, the treatment differences were significant.

CHAPTER IV

EXPERIMENTAL RESULTS

The experiment to study the effect of seaweed gel on growth, yield and harvest quality of tomato was carried out during 2008-2009 at College Orchard, Horticultural College and research institute, Coimbatore. The results of the observations recorded and analyzed during the course of study are presented below.

4.1. Growth parameters

4.1.1. Vegetative characters

4.1.1.1 Plant height (cm) (Table.1 and Fig.1) (Plate. 5)

In the first season in all the three stages (30, 60 and 90 days after planting) of observation, all the treatments recorded an increasing trend in plant height (Table.1 and Fig.1). The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg acre-1 + O6 EM and MA GEL 1% spray) produced significantly taller plants and recorded 45.54 cm, 65.2 cm and 93.2 cm of plant height on 30, 60, 90 days after planting respectively followed by (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$+ O6 EM and MA GEL 1% spray) which recorded 40.24 cm, 62.6 cm, 87.6 cm respectively. The lowest plant height was recorded in T_1 (Control) with 38.5cm, 58.5 cm and 84.6 cm respectively at all the respective stages.

Similar trend was obtained in the second season also. The treatment T_7 registered the higher mean value of 65.1 cm when compared to all the other treatments. The lowest mean value of 54.9 cm was recorded in T_1 (Control).

4.1.1.2. Number branches per plant (Table. 2 and Fig.2)

Number of branches per plant differed significantly among the treatments at all the growth stages from 30, 60, 90 days after planting in the first season (Table.2). Number of branches progressively increased at all stages of crop growth. Plants treated with (T_7) had significant influence on number of branches per plant and recorded more branches per plant in all the stages (6.3, 10.8 and 13.8) respectively followed by (T_6) which recorded 5.3, 10.3 and 12.8 respectively. The treatment T_1 (Control) recorded the lowest number of leaves per plant at all the five stages of crop growth with the values of 3.5, 8.7 and 11.9.

Similar trend was obtained in the second season also. The treatment T_7 registered the higher mean value of 9.8 when compared to all the other treatments. The lowest mean value of 7.4 was recorded in T_1 (Control).

4.1.1.3. Number of leaves per plant (Table. 3)

Number of leaves per plant differed significantly among the treatments at all the growth stages from 30, 60, 90 days after planting in the first season (Table. 3). Number of leaves progressively increased at all stages of crop growth. Plants treated with (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) had significant influence on leaf number per plant and recorded more leaf number per plant in all the stages (27.4, 59.4 and 76.9) respectively followed by (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray) (T_6) which recorded 25.3, 57.8 and 74.8 respectively. The treatment T_1 (Control) recorded the lowest number of leaves per plant at all the five stages of crop growth with the values of 19.7, 49.3 and 67.3.

Similar trend was obtained in the second season also. The treatment T_7 registered the higher mean value of 52.4 when compared to all the other treatments. The lowest mean value of 43.5 was recorded in T_1 (Control).

4.1.1.4. Leaf area index (Table. 4)

In the first season significant differences were noted with regard to Leaf area index (Table.4). The treatment T_7 recorded significantly higher LAI value (3.36) followed by the treatment T_6 which recorded (3.06). The treatment T_1 (Control) had recorded lowest LAI (2.33).

In the second season the treatment T_7 registered the highest LAI (2.98) followed by T_6 NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with 2.98, 2.73 respectively. The treatment T_1 (control) recorded the minimum LAI of 2.18.

4.1.2. Flowering characters

4.1.2.1. Days to first flowering (Table. 5 and Fig.3)

In the first season significant differences were noted with regard to days taken for first flowering (Table.5). The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray) recorded earliest flower opening (25.1.days) followed by the treatment T_6 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray) which recorded (27.1 days). The treatment T_1 (Control) had taken the longest duration for bud opening (27.9 days).

In the second season, treatment T_7 registered the earlier flower opening (27.7 days) followed by T_6 with 28.2 days. The treatment T_1 (control) recorded the highest duration of 30.4 days.

4.1.2.2. Days to 50 % flowering (Table. 6 and Fig.4)

In the first season significant differences were noted with regard to days taken for 50% flowering in the first season (Table.6). The treatment T_7 recorded earliest flower opening (36.4 days) followed by the treatment T_6 which recorded (38.9 days). The treatment T_1 (Control) had taken the longest duration for 50 % flowering (42.3days).

The treatment T_7 registered the earlier flower opening (38.4 days) followed by T_6 with 40.0 days. The treatment T_1 (control) recorded the highest duration of 44.2 days in the second season.

4.1.3. Root characters

4.1.3.1. Root length (cm) (Table.7 and Fig.5) (Plate. 8)

Significant differences were observed in the mean root length between treatment and also between seasons (Table.7). The mean root length varied from 16.5 cm in T_1 to 29.9 cm in T_7 and from 15.7 cm in T_1 29.6 cm in T_7 in the first and second season respectively. In both the seasons, the treatment T_7 recorded more root length and T_1 recorded the lowest root length. The mean of two season showed that T_7 recorded more root length of 29.7 cm followed by the treatment T_6 (25.8 cm) and T_{10} (23.9 cm).

4.2. Physiological and Biochemical attributes

4.2.1. Total soluble protein (mg g^{-1}) (Table.8 and Fig.6)

The treatments exhibited perceptible differences on soluble protein content at different stages of crop growth in both the sites. There was significant difference between the treatments on total soluble protein (Table.8). The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray recorded the highest total soluble protein (29.39 mg g^{-1}). This was followed by the treatment T_6 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with total soluble protein (28.54 mg g^{-1}). The lowest soluble protein was recorded in the treatment T_1 (Control) with a value of 26.39 mg g^{-1}

In the second season treatment T_7 registered more soluble protein of 27 mg g^{-1} followed by T_6 with 26.07 mg g^{-1}. The treatment T_1 (control) recorded the minimum soluble protein of 23.68 mg g^{-1}.

4.2.2. Chlorophyll contents (mg g^{-1}) (Table.9, 10 & 11 and Fig.7)

Chlorophyll content of leaves differed significantly in all the stages of both the sites. There were significant differences among the treatments on chlorophyll contents (Table.9, 10 & 11). The mean chlorophyll a, b and total chlorophyll contents were highest in T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with maximum values of 2.52, 1.25, 3.56 mg g^{-1} respectively. Whereas T_1 (Control) recorded minimum values of 1.66, 0.83 and 2.49 mg g^{-1} of a, b and total chlorophyll respectively in the first season. Similar trend was observed in the second season. Thus, the treatment T_7 differed significantly from all other treatments in both the seasons.

4.2.3. Chlorophyll stability index (per cent) (Table.12)

The available chlorophyll stability index was recorded at three stages. There was significant difference between the treatments on chlorophyll stability index (Table.12). The treatment T_7 recorded the highest chlorophyll stability index (89.1 per cent). This was followed by the treatment T_6 (NPK @ 200:300:200 kg ha^{-1} O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with chlorophyll stability index (87.9 per cent). The lowest chlorophyll stability index was recorded in the treatment T_1 (Control) with a value of 82.1 per cent.

The treatment T_7 registered more chlorophyll stability index in the second season of 88.4 per cent followed by T_6 with 86.7 per cent. The treatment T_1 (control) recorded the minimum chlorophyll stability index of 80.8 per cent.

4.2.4. IAA oxidase activity (µg $g^{-1}h^{-1}$) (Table.13 and Fig.8)

The available IAA oxidase activity was recorded at three stages. There was significant difference between the treatments on IAA oxidase activity (Table.13). The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray recorded the highest IAA oxidase activity of (4.09 µg $g^{-1}h^{-1}$). This was followed by the treatment T_6 with IAA oxidase activity (3.81 µg g^{-1} h^{-1}). The lowest IAA oxidase activity was recorded in the treatment T_1 (Control) with a value of 3.43 µg $g^{-1}h^{-1}$

The treatment T_7 registered more IAA oxidase activity of 3.84 µg $g^{-1}h^{-1}$ followed by T_6 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with 3.57 µg g^{-1} h^{-1}. The treatment T_1 (control) recorded the minimum IAA oxidase activity of 3.18 µg g^{-1} h^{-1}in the second season.

4.2.5. Peroxidase activity (µ moles H_2O_2 100 mg^{-1} min^{-1}) (Table.14)

In both the sites the treatments significantly influenced the peroxidase activity over different growth stages. There was significant difference between the treatments on peroxidase content (Table.14). The treatment T_7 recorded the highest peroxidase content (0.143 µ moles H_2O_2 100 mg^{-1} min^{-1}). This was next followed by the treatment T_6 with peroxidase activity content (0.130 µ moles H_2O_2 100 mg^{-1} min^{-1}). The lowest peroxidase content was recorded in the treatment T_1 (Control) with a value of 0.073 µ moles H_2O_2 100 mg^{-1} min^{-1} in the first season.

The treatment T_7 registered more peroxidase activity of 0.132 µ moles H_2O_2 100 mg^{-1} min^{-1} followed by T_6 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with 0.120 µ moles H_2O_2 100 mg^{-1} min^{-1}. The treatment T_1 (control) recorded the minimum peroxidase activity of 0.063 µ moles H_2O_2 100 mg^{-1} min^{-1} in the second season.

4.2.6. Relative water content (per cent) (Table.15)

There was significant difference between the treatments on relative water content (Table.15). The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray) recorded the highest relative water content (65.68 per cent). This was next followed by the treatment T_6 (NPK @ 200:300: 200 kg ha^{-1} O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray) with relative water content (63.99 per cent).The lowest relative water content was recorded in the treatment T_1 (Control) with a value of 56.92 per cent..

The treatment T_7 registered more relative water content of the treatment T_7 registered more relative water content of 64.12 per cent followed by T_6 with 62.80 per cent. The treatment T_1 (control) recorded the minimum relative water content of 56.84 per cent in the second season.

4.2.7. Total Soluble Solids (TSS) (^{o}brix) (Table.16)

The significant difference was observed in TSS of fruit between treatment and seasons and their interactions, though the mean value of TSS ranged from 4.38^o brix in T_1 to 5.02^o brix in T_7 in the first season and from 4.29^o brix in T_1 to 4.99^o brix in T_7 in the second season (Table.16). The mean value of TSS ranged from 4.33^{o}brix in T_1 to 5.0 ^{o}brix in T_7 in pooled analysis.

4.2.8. Titrable acidity (per cent) (Table.17)

Significant difference in acidity of fruits was noticed between treatments. But seasons and their interactions were not significant (Table.17). The mean values ranged from 0.49 (T1) to 0.56(T_7) per cent in the first season and from 0.47 (T_1) to 0.54 (T_7) per cent in the second season.

4.2.9. Ascorbic acid (mg 100 g^{-1}) (Table.18 and Fig.9)

The mean values of ascorbic acid content of tomato fruits varied significantly between treatment and interactions (Table.18). They were not significant between seasons. Ascorbic acid content ranged from 22.65mg 100 g-^{1} (T_1) to 26.87 mg 100 g^{-1} (T_7) in the first season and from 22.06 mg 100 g^{-1} (T_1) to 26.65 mg 100 g-^{1} in second

season. Mean of two season showed that T_7 recorded the highest ascorbic acid content of 26.76 mg 100 g^{-1} followed by T_6 (26.23 mg 100g^{-1}) and T_{10} (25.66 mg 100 g^{-1}). The lowest ascorbic acid was recorded in the treatment T_1 (22.35 mg 100 g^{-1}).

4.2.10. Total sugar (per cent) (Table.19)

The mean values of total sugar of tomato fruits varied significantly between treatment and interactions (Table.19). The first season mean values of total sugar content ranged from 2.51 per cent (T_1) to 3.21 per cent (T_7) and from 2.14 per cent (T_1) to 2.75 per cent (T_7) in second season. Mean of the two season showed that the treatment T_7 recorded the highest total sugar content of 2.98 per cent followed by T_6 (2.71 per cent) and T_{10} (2.69 per cent). The lowest sugar content was recorded in the treatment T_1 (2.31 per cent).

4.2.11. Lycopene (mg 100^{-1} g) (Table.20 and Fig.10)

The mean values of lycopene of tomato fruits varied significantly between treatment and interactions (Table.20). The first season mean values of lycopene content ranged from 6.40 mg 100 g^{-1} (T_1) to 7.34 mg 100 g^{-1} (T_7) and from 6.20 mg 100 g^{-1} (T_1) to 7.01 (T_7) in second season. Mean showed that the treatment T_7 recorded the highest lycopene content of 7.17 mg 100 g^{-1} followed by T_6 6.82 mg 100 g^{-1} and T_{10} 6.63 mg 100^{-1} g. The lowest lycopene content was recorded in the treatment T_1 6.30 mg 100 g^{-1}.

4.3. Leaf nutrient content

4.3.1. Nitrogen (per cent) (Table.21)

Leaf nitrogen content in per cent was recorded at three stages which were significantly influenced by the application of inorganic nutrients along with seaweed gel in the first season (Table.21). The highest mean leaf nitrogen content (3.39 per cent) was recorded in the treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray), which was closely followed by T_6 NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with 3.25 per cent .The treatment T_1 (Control) recorded the lowest content of 2.99 per cent.

In the second season, T_7 registered the highest nitrogen content of (3.29 per cent) followed by T_6 NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with 3.24 per cent. The treatment T_1 (control) recorded the minimum nitrogen content of 2.95 in the second season.

4.3.2. Phosphorus (per cent) (Table.22)

There was significant difference between the treatments on phosphorus content in the first season (Table.22). The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray) recorded the highest phosphorus content (0.45 per cent). T_6 NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray) was on par with phosphorus content (0.43per cent). The lowest phosphorus content was recorded in the treatment T_1 (Control) with a value of 0.35 per cent.

The treatment T_7 registered the highest phosphorus content of (0.42 per cent) followed by T_6 NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with 0.40 per cent. The treatment T_1 (control) recorded the minimum nitrogen content of 0.35 per cent in the second season.

4.3.3. Potassium (per cent) (Table.23)

Leaf potassium content differed significantly among the treatments in the first season (Table.23). The highest value of potassium content (3.53 per cent) was noticed in the treatment T_7. This was closely followed by T_6 with a value of 3.45 per cent. The treatment T_1 (Control) registered the lowest potassium content of 3.14 per cent

The treatment T_7 registered the highest potassium content of (3.50 per cent) followed by T_6 which was on par with potassium content 3.43 per cent. The treatment T_1 (control) recorded the minimum nitrogen content of 3.14 per cent in the second season.

4.4. Yield characters

4.4.1 Fruits per plant (Table.24 and Fig.11) (Plate. 6)

Fruits per plant differed significantly among the treatments in the first season (Table.24). The number of fruits was recorded more in the treatment (50.3) T_7

(NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray. This was closely followed by T_6 with a value of 48.3 and they are statistically on par with T_{10}.

The treatment T_7 registered the highest fruit number per plant of (49.85) followed by T_6 NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with 48.3 and they are statistically on par with $T_{10.}$ The treatment T_1 (control) recorded the minimum number of fruits per plant of 41.2 in the second season.

4.4.2. Average fruit weight (g) (Table.25) (Plate. 7)

Average fruit weight differed significantly among the treatments in the first season (Table.25). The fruit weight was recorded more in the treatment (55.31g) in T_7. This was closely followed by T_6 NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with a value of 54.34 g and they are statistically on par with T_{10} and $T_{9.}$

The treatment T_7 registered the highest fruit weight of (54.98 g) followed by T_6 with 52.89 g. The treatment T_1 (control) recorded the minimum fruit weight of 47.63 g in the second season.

4.4.3. Fruit yield per plant (kg) (Table.26 and Fig.12)

Significant differences were observed in the mean fruit yield per plant between treatment and also between seasons (Table.26). The mean fruit yield varied from 2.09 kg in T_1 to 2.74 kg $plant^{-1}$ in T_7 and from 2.23 kg in T_1 to 2.78 kg $plant^{-1}$ T_7 in the first and second season respectively. In both the seasons, the treatment T_7 recorded the highest yield and T1 recorded the lowest yield. Mean of two season showed that T_7 recorded fruit yield per plant of 2.76 kg followed by the treatment T_6 (2.56 kg) and T_{10} (2.54 kg).

4.4.4. Yield per plot (kg) (Table.27)

Yield per plot differed significantly among the treatments in the first season (Table.27). Yield per plot was maximum in T_7 (69.5 kg) This was significantly different from other treatments. This was closely followed by T_6 with 65.5 kg.

The treatment T_7 registered more yield per plot of (68.5 kg) followed by with 62.3 kg. The treatment T_1 (control) recorded the minimum yield per plot of 52.3 kg in the second season.

4.4.5. Yield per hectare (tonne) (Table.28)

In the first season yield per hectare differed significantly among the treatments (Table.28). The yield per hectare was recorded more in the treatment (86.2 tonnes) T_7. This was significantly different from other treatments. This was closely followed by T_6 with 79.8 tonnes.

The treatment T_7 registered more yield per hectare of (85.6 tonnes) followed by T_6 with 77.8 tonnes. The treatment T_1 (control) recorded the minimum yield per hectare of 65.3 tonnes in the second season.

4.4.6. Shelf life (Days) (Table.29 and Fig.13)

The first season mean values of shelf life ranged from 10.2 (T_1) to 15.4 days (T_7) and from 8.0 days (T_4) to 10.4 days (T_7) in second season (Table.29). Pooled analysis showed that the treatment T_7 recorded the highest shelf life of 12.8 days followed by T_6 (11.7 days) and T_{10} (11.3 days). The lowest shelf life was recorded in the treatment T_1 (9.2 days).

4.4.7. Equatorial and polar diameter of the fruit (cm) (Table.30)

The mean values of equatorial diameter of fruits were formed to vary significantly between treatments and seasons (Table30). The mean value of fruit diameter varied between 5.72 cm (T_1) and 6.93 cm (T_7) and 5.67 cm (T_1), 6.64cm (T_7) in the first and second season. The two seasons pooled analysis showed that the mean value of fruit was highest in the treatment T_7 (6.79 cm) followed by T_6 (6.32 cm) and T_{10} (6.16 cm) and they were statistically on par. Among the season, the greater fruit diameter was recorded in the first season (6.93cm) than in the second season (6.64 cm)

The mean values of polar diameter ranged between 3.76 cm (T_1) to 4.93(T_7) in the first season and from 3.34 cm (T_1) to 4.58 cm (T_7) in the second season. The treatment T_7 recorded the highest polar diameter of 4.76 cm in the pooled analysis

also and was followed by T_6 (4.50) and T_{10} (4.39) and all the three were statistically on par with the treatment T_7; the treatment T_1 recorded the lowest diameter of 3.55 cm.

4.5. Soil physical properties (Table.31 and 32)

The treatments failed to exert significant differences among themselves on bulk density, particle density, porosity at various stages of crop growth excepting at summer season in which the treatment T_6, T_7 relatively recorded physical properties and were on par with each other.

4.6. Soil chemical properties

4.6.1. Soil pH (Table. 33)

None of the treatments could exert any significant effect on available soil pH at various stages of the crop growth (Table 33).

4.6.2 Soil EC (dsm^{-1}) (Table. 34)

Soil EC differed significantly among the treatments at all the three stages of analysis. The treatment T_7, recorded the lowest soil EC (0.20, 0.18 and 0.17 at 30 DAT, 60 DAT, 90 DAT respectively) followed by T_6 (0.23, 0.20 and 0.19 dsm^{-1} at 30DAT, 60 DAT, 90 DAT respectively). The treatment T_1 registered the highest soil EC at all the three stages (0.32, 0.34 and 0.33 at 30 DAT, 60 DAT, 90 DAT respectively) (Table. 34).

4.6.1. Soil nutrient status

4.6.1.1. Available nitrogen (Kg ha^{-1}) (Table. 35)

The available nitrogen content was recorded at initial and final stage of the experiment which was significantly influenced by the application of inorganic nutrients along with seaweed gel (Table 35). There is no significant difference between the treatments in the initial stage. In the final stage the highest mean nitrogen content (231.87 Kg ha^{-1}) was recorded in the treatment T_7, which was closely followed by T_6 with 228.77 Kg ha^{-1}. The treatment T_1 (Control) recorded the lowest content of 222.21 Kg ha^{-1}. Similar trend were noticed in the second season also.

4.6.1.2. Available Phosphorus (Kg ha^{-1}) (Table. 36)

The available phosphorus content was recorded at initial and final stage of the experiment. There was significant difference between the treatments on phosphorus content (Table. 36). There is no significant difference between the treatments in the initial stage. In the final stage the treatment T_7 recorded the highest phosphorus content (18.48 Kg ha^{-1}). This was next followed by the treatment T_6 with phosphorus content (17.57 Kg ha^{-1}). The lowest phosphorus content was recorded in the treatment T_1 (Control) with a value of 16.46 Kg ha^{-1}. Similar trend were noticed in the second season also.

4.6.1.3. Available Potassium (Kg ha^{-1}) (Table. 37)

The available potassium content was recorded at initial and final stage of the experiment (Table. 37). None of the treatments could exert any significant effect on available soil potassium in initial and final stage of the crop growth.

4.7. Microbial population

4.7.1. Bacteria (cfu $\times 10^5$ g^{-1} of soil) (Table. 38 and Fig.14)

Application of seaweed gel along with macronutrients produced significant differences among the treatments for bacterial population in the first season (Table.38). The treatment, T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray registered the highest bacterial population of 54.31 cfu $\times$ 10^5 g^{-1} of soil which was followed by T_6 (50.43 (cfu $\times 10^5$ g^{-1} of soil). The lowest bacterial population was noticed in the control T_1 (41.44 (cfu $\times 10^5$ g^{-1} of soil).

In the second season treatment T_7 registered the highest bacterial population of (52.14) followed by T_6 NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray with 49.22. The treatment T_1 (control) recorded the minimum bacterial population of 39.48 (cfu $\times 10^5$ g^{-1} of soil).

4.7.2. Fungi (cfu $\times 10^3$ g^{-1} of soil) (Table. 39 and Fig.15)

Influence of seaweed gel along with macronutrients exhibited differences among the treatments for the fungal population in the first season (Table.39). The treatment, T_7

registered the highest fungi population of 8.72 cfu $\times 10^3$ g^{-1} of soil which was followed by T_6 with 7.99. The lowest fungi population was noticed in the control (T_1) with 6.71 cfu $\times 10^3$ g^{-1} of soil irrespective of the stages.

The treatment T_7 registered the highest fungal population of (8.39) followed by T_6 with 7.97 cfu $\times 10^3$ g^{-1}. The treatment T_1 (control) recorded the minimum fungal population of 6.32 cfu $\times 10^3$ g^{-1} in the second season.

4.7.3. Actinomycetes (cfu × 10^2 g^{-1} of soil) (Table. 40 and Fig.16)

Significant differences in the actinomycetes population was registered in the soil due to the effect of seaweed gel and macronutrients application in the first season (Table. 40). The treatment, T_7 registered the highest actinomycetes population of 5.22 cfu × 10^2 g^{-1} of soil. The lowest actinomycetes population was noticed in the control (T_1) with 2.72 cfu × 10^2 g^{-1} of soil.

The treatment T_7 registered the highest actinomycetes population of 4.56 cfu × 10^2 g^{-1} of soil followed by T_6 with 3.70 cfu × 10^2 g^{-1} of soil. The treatment T_1 (control) recorded the minimum actinomycetes population of 2.49 in the second season.

4.8. Cost economics (Table. 41)

Significant differences exhibited among the different treatments for economics (Table.41). The treatment, T_7 registered the highest benefit - cost ratio of 2.73 which was followed by T_6 (2.53) and T_{10} (2.52). The lowest benefit - cost ratio was noticed in the treatment T_1 (2.14).

CHAPTER V
DISCUSSION

Tomato (*Solanum lycopersicon*. Mill) has a prime position among the popular vegetable in India. In the recent past, the productivity of tomato has increased several fold which could be attributed to the cultivation of high yielding and fertilizer responsive varieties and F_1 hybrids and also by adoption of improved horticultural techniques. Seaweed extract, a commercial product of *Ascophyllum nodosum* is proved to be an economically viable alternative to chemical fertilizer and other soil additives. One of the most pronounced effect of seaweed application on plants is development of vigorous root system, which have way to higher yields (Nelson and Van Staden, 1984). The seaweed application has also been shown to enhance the chlorophyll content (Featonby Smith and Van Staden, 1983). In the present study, tomato hybrid COTH 2 check was chosen and grown during winter and summer of 2008-09. The effect of spraying and drenching of seaweed extract was studied in different concentration. The results on growth, yield and quality parameters are discussed here under.

5.1. Growth Parameters

The growth parameters decide the ultimate yield of the plant. In the present study, parameters like plant height, branches per plant, fruits per plant are discussed below. The effect of seaweed gel at (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) promoted plant growth in tomato. In seaweed gel prime physiological response is the better availability of cytokinin, which is important in improving cell division and through specific protein synthesis that ultimately lead to better growth. In addition to this, auxins, IAA in particular supplied through the same seaweed gel enhanced adventitious root formation as well as better growth. Cytokinin also promoted production of laterals by inducing the axillary bud sprouting.

The mechanism of auxin action is that auxin cause an increase in the plasticity of cell wall through their participation in reaction. Aljuburi and Almarsry (1995) attributed that auxin marginally increased Relative Growth Rate in Balady lime seedlings. In foliar sprays, an auxin containing product “ROOT PLUS” resulted in taller plants than fertilizer treatment in Broccoli (Russo *et al.,* 1994), Rylski (1972), attributed auxins accelerated

apical dominance and bud development and cell elongation in chillies to GA3. The plants treated with *Ascophyllum nodosum* showed increase in plant growth characters (Goswami, 1992). In addition to inorganic application, foliar spray of seaweed gel enhanced the growth rate of plants since it contains humic acid, vitamins and beneficial microorganisms in the liquid formulation. The observations of the present investigation are similar with the earlier reports of Piccolo *et al*. (1993), Bohme and Papadopoulos (1999) in tomato. Application of seaweed extract as a foliar spray enhance the growth of the plants by the growth promoting substances available to the plants through absorption and translocation (Ramamoorthy *et al*., 2007)

With regard to number of branches per plant, among several treatments tried (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) resulted in higher number of branches in both the seasons when compared to control. Increased number of plants were obtained with the application of seaweed gel by Heckman (1994), while increased shoot growth and total fresh weight (15-20 %) over control was observed by (Gendy 1993).

Plant height, number of branches, leaf area index, number of leaves recorded more in (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) Micro and macro elements present in the seaweed extract were responsible for the enhancement of the growth of wheat plants (Beckett and Van Staden, 1990). The growth parameters increased at lower concentrations of seaweed extract. Similar results were recorded in *Padina* which induced maximum seedling growth in *Cajanus cajan* (Mohan *et al.,* 1994), *Phaseolus mungo* (Lingakumar *et al.,* 2004).

Increased dry matter may be due to the increased carbohydrate accumulation resulting from a more efficient photosynthetic activity brought about by the anatomical modifications. Nelson and Van Staden (1984) obtained that application of KELPAK 60 a seaweed extract concentration was showed to have increased plant dry mass in cucumber. Poincelot *et al*.(1993) reported that application of 'ROOTS' a patent product containing *A. nodsum* at one per cent increased root length and shoot height compared with control in tomato plants.

Earliness is one of the important favourable phenomena since early crop fetches a premium price in the market. From the analysis of the data it was found that application of seaweed extract (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) induced early flowering as compared to control in both winter and summer season. The early flowering and fruiting in the treated plants might be due to the fact that such plants were able to build suitable carbohydrate reserves early. As far as seaweed gel concerned earlier flowering is might be due to the availability of cytokinins, the accumulation of which in lateral buds would have made them more effective sink in the diversion of photoassimilates as well as other flower inducing plant hormones which ought to have ultimately resulted in better flowering and in turn yield.

There is considerable evidence that auxins act primarily in a catalytic or regulatory capacity in some plants (Chhonkar and Singh, 1959). In tomato Sinnadurai and Amuti (1971) found that flowering increased when night temperature were cooler (71-74^{0}F) though tomato is day neutral with regard to flowering under long days. Poincelot (1994) observed that application of 'ROOT PLUS' (*Ascopyllum nodosum*) at one per cent resulted in increased flowering and early flowering in Broccoli, tomato *cv.* Early Girl.

The fruit set percentage was influenced by seaweed gel in present studies (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) recorded the highest fruit setting percentage in first season (winter) and in the second season (summer) also increased percentage of fruit set when compared to control.

The cytokinin available in seaweed gel might have directed the photosynthates towards developing fruits there by increasing the total number of fruits retained. The plant growth regulators altered the physiology of plants and enhanced fruit set during winter as well as summer season. The increase or decrease in fruit set in any crop is attributed to the physiological response of the plant through the hormonal balance. Pollination followed by fertilization in several species is pre-requisites for fruit set. At the time of anther dehiscence the auxin level of the flowers fall off rapidly. But once

the pollination and fertilization occur the auxin level of the flower is restored and thus flower is not shed (Nitch, 1952). Poincelot (1994) found that application of 'ROOT PLUS', a patent compound containing seaweed extract (*Ascophyllum nodosum*) at 1 per cent level resulted in earlier flowering and better fruit set in bedding plants.

In tomato, poor fruit set is major problem by adverse weather conditions and high night temperature. The reduced flower drop can also be attributed to the prevention of abscission in treated plants due to increase in the auxin level of the flower at fruit set. It would normally shed due to low level of flower auxin as postulated by Johnson (1956) in case of tomato with CPA spray. The maintenance of optimum level of auxins at critical stages through seaweed gel would have helped in better fruit set as well as retention to carry towards to maturity.

5.2. Leaf Nutrient status

The nutritional diagnosis of tomato showed an increased level of nitrogen, phosphorous and potassium in the treatment (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7). The range of tissue nitrogen was found to vary between 3.66 to 4.06 per cent at the flowering stage. The variation was minor, though significant among the treatment and higher tissue content of nitrogen was seen at higher fertilizer levels. These findings were in agreement with Hwang (1994).

Tissue phosphorous showed considerable variation among the treatments. Phosphorous content of leaves was related with nitrogen content. It might be due to the fact that at high nitrogen content there was more vegetative growth and better quality, which resulted in more uptake and utilization of phosphorous as reported by Verma *et al*. (2003) in carnation.

Potassium content showed considerable variation among the treatments and was recorded more in the treatment (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7). The increase in K content at high nitrogen levels may be attributed to the fact that with high rate of photosynthesis, the amount of inorganic nutrients might be correspondingly high. This facilitates the

conversion of photosynthates into numerous metabolites for vegetative growth as reported by Mengel and Kirkby (1987). Moreover, Uri *et al*. (1990) opined that K content more than four per cent was associated with stems that were less brittle.

5.3. Physiological parameter

The chlorophyll a, b and total chlorophyll content was highest in the treatment (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7). The variation in chlorophyll content of the leaf might be due to the spray of seaweed gel. Similar variation for chlorophyll content among different cultivars might be due to genetic constitution of the cultivars as postulated by Patil (2001) in carnation. Blunden *et al.* (1997) had reported the enhanced leaf chlorophyll content of plants treated with low concentration of seaweed liquid fertilizer (SLF) due to the presence of betaines. The enhanced effect might be due to the synthesis of plant growth regulators, trace elements, high nitriability of organic nitrogen and quick decomposing nature of seaweed extract (Gupta and Shukla, 1967).

In the present study, the treatment registered increased chlorophyll content (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ O6 EM and MA GEL 1% spray. It is obvious that nitrogen forms an important part of the chlorophyll molecule and when present in sufficient amounts promote healthy growth, increases the photosynthetic activity results in increasing the yield and this was in agreement with the previous works by Jaisinghani *et al.* (1964). In early stages, increased absorption of nutrients would have caused the accumulation of more amount of chlorophyll pigment which helps the synthesis of enhanced amounts of photosynthates and in the later stages these photosynthates might have been mobilized to form carbohydrates, which are further utilized for bud development. The present findings are in consonance with the observations of Paricha *et al*. (1977). In addition, the inorganic fertilizers treatment combination with foliar spray of seaweed gel would have also enhanced the chlorophyll pigment mainly by its ability to fix atmospheric nitrogen (which had direct correlation with the chlorophyll content). In the present work, chlorophyll a, b and total chlorophyll increased under the application of seaweed extracts. One view is that increase in chlorophyll is due to increase in magnesium content which is constituent of chlorophyll

as said by El-Sheikh and EI-Shaeid, 1999. This is supported by earlier studies in *Vicia faba* (El-Sheikh and El-Saied, 1999), *Vigna catajung* and *Dolichus biflorus* (Anantharaj and Venkatesalu, 2001; 2002).

Other parameters such as soluble protein, peroxidase activity, IAA oxidase activity, chlorophyll stability index, relative water content recorded more in the treatment (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7). This may be due to the presence of various elements, more enzymatic activity in the plants, more photosynthetic efficiency and there by resistance to pest and diseases which in turn increase the yield. The enhanced biochemical constituents might be due to absorption of most of the necessary elements in the seaweed extract applied plants (Anantharaj and Venkatesalu, 2001).

5.4. Yield parameters

High fruit yield is the ultimate aim of tomato growers in order to realize maximum economic return. Higher yield is the result of better fruit set and development and finally maturity of individual fruit. This is achieved not only by increased fruit set but also by the lesser fruit drop.

The most pronounced effects of seaweed extract application to tomato plants is the development of vigorous root system, which is often expressed as higher yields due to more cytokinin synthesized and translocated to axillary buds. Normally in tomato plants there is a disproportionate development of shoot and root system towards shoot, thus leading to a very high S/R ratio. On the contrary, the seaweed extract was able to cause a drastic drift towards the growth of roots by encouraging the root system. This would have helped in the synthesis of more and more cytokinins and translocation of the same to the axillary buds converting most of them in to the reproductive growth, which was very well obvious from the data on the total number of fruits.

Treatment with 'ROOT PLUS' a patent compound containing seaweed extract resulted in taller plants and earlier, increased flowering and fruiting than fertilizer treatment (Poincelot, 1993). Similarly, increased fruit yield (29 per cent) was recorded by the application of seaweed extract at 1 per cent by Povolny (1976) in number of fruits per plant which is one of the important contributing traits for yield in tomato was found to be

influenced by seaweed extract (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) during both the seasons when compared to untreated control, the higher doses of seaweed extract increased the fruit number. This could have been due to the hormonal balance brought about inside the plant system at a higher concentration. It may also be due to interaction of higher concentration of chemical with the environmental factors prevailed at different seasons. Individual fruit weight is another component trait that influences yield was also found to be altered by the different treatment (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) and vermicompost + 06 EM and MA gel @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray recorded higher fruit yield in both the seasons.

It was quite interesting to note that when the concentration of seaweed extract was increased there was a reduction in individual fruit weight. Generally in tomato, the number of fruits and individual fruit weight which was major component trait that decide the yield exhibit a negative relationship with one another. The higher concentration of seaweed extract bringing about reduction of in both these yield components could possibly due to decrease in partitioning efficiency of the plants which would have been brought about through a hormonal imbalance especially that of kinetin group. Chandra and Shivaraj (1972) and Warade and Singh (1977) attributed increased weight and yield of fruit in the treated plants to the fact that they remained physiologically more active to build up sufficient food materials and reserve for developing flowers and fruits. In the presence of that substances the plants could produce flowers early with greater fruit set, increased number of fruits with more fruit weight that ultimately led to the high yield (Mote *et al.*, 1975 and Chandra *et al.*, 1976).

Fruit yield per plant was influenced by seaweed extract (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) recording the highest yield per plant in winter and season. The difference in concentration of chemical to influence better yield could possibly be due to interaction of chemical with the seasonal variation existed in weather parameters like light intensity, temperature etc., Increased fruit yield (29 per cent) per plant was reported with application of seaweed extract 1 per cent by Povolny (1976).

The total yield per plot was significantly increased by application of seaweed gel (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) in both winter and summer season which would have brought about by increased fruit set and better fruit weight through better canopy establishment, better interception of light through significant reduction in interplant competition for solar energy and soil nutrition. This would have increased efficiency of plants to do photosynthesis and translocation of assimilates to the points of fruit set. Seaweed extract would also have increased yield through enhanced availability of cytokinins, the accumulation of which in lateral buds would have made them effective sink in the diversion of photoassimilates as well as other flower inducing hormones which ought to have ultimately resulted in better flowering and in turn yield. Similar findings were also reported by Pramod Kumar *et al*. (2000).

5.5. Quality parameters

In the present study, the fruit diameter was influenced by application of seaweed gel (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) recorded higher fruit girth as compared to control in both the seasons. When the concentration of seaweed extract was increased the fruit diameter was also reduced. However, lower concentration was superior in increasing fruit size when compared to control. The skin thickness of fruits decides the transport quality influenced by seaweed extract. (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) recorded significantly thicker skin in both the seasons. Thicker skin would render the fruits more tolerable to transport stress.

In tomato fruit quality is judged by TSS, pH, acidity and ascorbic acid content of the juice. These qualitative traits becomes much more important when produce goes to industry for the development of products such as tomato jam, juice, sauce, ketchup and puree. In the present study (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) were found to be most effective treatment in increasing juice content of fruits in both the seasons. It was reported that in tomato, puffiness was induced by a high level of auxins in the early stage of fruit development and it was corrected when CCC was applied which reduced the auxin to optimum level (Takashi and Tadashi, 1978).

When TSS of fruit juice was considered it was found that the same was influenced by seaweed extract. They registered higher TSS in both the seasons. In the Naveline orange, 'GEOMAR' a product containing seaweed extract resulted in increased TSS content (Frones 1995). Better quality of tomato fruits in terms of the highest TSS content of 5-8^{o} brix through 1500 ppm CCC spray was reported by Phookan *et al*. (1991). The results of the present study are in agreement with the above report. In this, (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg acre^{-1} + O6 EM and MA GEL 1% spray(T_7) recording the highest TSS.

Acidity is yet another factor that decides the quality of fruit juice. A proper blend of soluble solids and acidity gives the flavour for the resultant production of any fruit namely jams, sauce, ketchup etc. Besides for the product preparation, tomato is also used as a substitute for tamarind in day to day kitchen preparation especially by south Indian wives. Hence, the acidity seems to be the most important quality trait for tomato as a fresh market produce used in culinary preparation. Being the result of complex chemical reaction, the organic acids are synthesized and these incorporate the sour taste to the juice. Organic acids synthesis is influenced by the hormonal balance inside the plant system. High acidity may also cause a set back in quality by shifting the sugar acid ratio to a much lower level. So maintenance of proper acidity, simultaneously increasing the soluble solids would go a long way not only for the production of better table tomato for culinary purpose but also for processed products like tomato jam, sauce, ketchup etc.

Treatment with seaweed gel resulted in a drastic drift to lower down the acidity. The highest drop in it was seen under (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg acre^{-1} + O6 EM and MA GEL 1% spray(T_7) followed by (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 10 kg acre^{-1} + O6 EM and MA GEL 1% spray (T_6). It was observed that seaweed gel at specific concentration can tilt the overall quality by significant increasing the TSS with simultaneous slight reduction of acidity thus resulting in optimum soluble solid / acid ratio.

Frones (1995) reported lowering the acidity in Naveline Orange through "GEOMAR" (seaweed extract) spray. The specific requirement of tomato juice for

processed product would not be less than 4-5 per cent TSS and maximum of 0.45 per cent acidity. Thus for acidic genotypes it would be better to go for foliar spray like seaweed extract to increase the pH without sacrificing the TSS or sometimes increasing the later.

Ascorbic acid or vitamin C is one of the most important qualitative traits especially in the human nutrition point of view. Just like any other organic acid, the synthesis and destruction in the plant system and ultimate availability of it in the fruit juice depends upon the hormonal balance. Another view is that enhanced chlorophyll concentration with seaweed extracts used in the present study increase sugar contents in both shoot and root systems of *Cyamopsis tetragonoloba*. This is supported by earlier studies in Vicia faba (El-Sheikh and El-Saied, 1999), *Vigna catajung* and *Dolichus biflorus* (Anantharaj and Venkatesalu, 2001; 2002).

5.6. Cost economics

Cost economics plays a pivotal role in any crop production practice from the farmer's point of view, where the ultimate goal is to make the grower to get more profit with lesser input.

From the details of the economics of cultivation, it could be concluded that the treatment (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray(T_7) recorded the highest net return which could be recommended for tomato cultivation. Hence, it is apt to conclude that the combined application of inorganic fertilizers along with seaweed gel significantly influenced the growth, yield and quality in turn enhanced the net return of tomato hybrid COTH 2.

CHAPTER VI

SUMMARY

Investigations were carried out to study the "Effect of seaweed gel on the growth and yield of tomato" hybrid COTH 2 in kharif and summer season under irrigated conditions. The findings of the experiment are summarized below.

1. Plant height, number of branches per plant, number of leaves and leaf area index were significantly increased in the treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray) in both the seasons.
2. Significant reduction in the days to first flowering and days to 50 per cent flowering were observed in the treatment T_7 in both the seasons.
3. Number of roots was increased significantly in the treatment T_7 in both the season.
4. Total soluble protein, chlorophyll contents, chlorophyll stability index, IAA oxidase activity, peroxidase activity and relative water content were increased by T_7.
5. Application macronutrients along with seaweed gel combination (T_7) significantly increased the leaf nitrogen, phosphorus and potassium content. The highest being in the treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray in both the season.
6. In both the season, fruits per plant differed significantly in the treatment T_7.
7. Individual fruit weight was found to be maximum in the plants treated with NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) in both the seasons.
8. Fruit yield per plant was increased to significant extent due to the treatment T_7 and might be due to the manipulation brought about in the balance of vegetative and reproductive growth of the plants through the optimum hormonal balance in better photosynthetic efficiency and partitioning efficiency.
9. The economic yield per plot was highest in the treatment T_7 (NPK @ 200:300: 200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray during summer as well as winter. Yield per hectare also showed the same trend.

10. Equatorial and polar diameter of the fruit and shelf life of the fruit was found to be maximum in the plants treated with NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray in both the seasons when compared to control.
11. Quality traits like TSS, titrable acidity, ascorbic acid, total sugar and lycopene were increased to a significant extent by the application of NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) when compared to untreated control.
12. Available soil nitrogen, phosphorus were significantly increased by the application of NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL @ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray (T_7) when compared to control.
13. The population of bacteria, fungi and actinomycetes were also found significantly higher due to the treatment T_7.
14. The economic analysis revealed that the benefit cost ratio was found highest in the treatment T_7 registered 1: 2.73 while the untreated control registered 1: 2.14.

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RESEARCH FINDINGS

STUDIES ON THE EFFECT OF SEAWEED GEL ON THE GROWTH AND YIELD OF TOMATO (*Solanum lycopersicon.*Mill)

Name of the Student **Name of the Chairman**

P. SELVAKUMARI **Dr. K. VENKATESAN**

2009

Field experiment was conducted at College Orchard, Department of Vegetable crops, Horticultural College and Research Institute, Coimbatore from September 2008 to May 2009 to study the effect of seaweed gel on the growth and yield of tomato(*Solanum lycopersicon.*Mill) var. COTH 2.

Morphological characters

The combined application of inorganic chemicals and seaweed gel resulted a significant improvement in plant growth and flowering in tomato under open condition. The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL@ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray recorded more plant height, number of branches, leaf number and leaf area index.

Physiological and Biochemical characters

The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL@ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray recoreded significant physiological characters *viz.*, total soluble protein, chlorophyll content, chlorophyll stability index, IAA oxidase activity, peroxidase activity, relative water content, total soluble solids, titrable acidity, ascorbic acid, total sugar and lycopene while the lowest physiological character was found in the control.

Leaf nutrient content

The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL@ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray had recorded the highest N, P and K content in plant.

Yield characters

The treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL@ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray recorded more number of fruits per plant, single fruit weight, fruit yield per plant, yield per plot and yield per hectare.

Soil physical and chemical properties

Slight reduction in the soil bulk density, particle density, porosity and pH and considerable improvement in available nitrogen, phosphorus and potassium were recorded after the application of macro nutrients along with seaweed gel. However, total bacteria, fungi, actinomycetes, infection rate were higher in T_7 receiving (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL@ 12.5 kg $acre^{-1}$ +O6 EM and MA GEL 1% spray.

Cost economics

Considering the economics of cultivation, the treatment T_7 (NPK @ 200:300:200 kg ha^{-1} + O6 EM and MA GEL@ 12.5 kg $acre^{-1}$ + O6 EM and MA GEL 1% spray recorded the highest net return but the total cost is also higher.

Table 1. Effect of treatments on the plant height (cm) of Tomato

Treatments	Plant height(cm)				Plant height (cm)			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	38.5	58.5	84.6	60.5	31.6	51.6	81.5	54.9
T_2	39.5	59.4	85.6	61.5	35.4	55.4	81.6	57.4
T_3	39.8	61.2	88.6	63.2	37.2	57.2	83.2	59.2
T_4	39.5	59.2	85.2	61.3	36.2	56.6	86.6	59.8
T_5	38.6	58.6	87.6	61.6	34.6	54.6	84.8	58.0
T_6	40.2	62.6	87.6	63.5	34.4	54.4	91.1	59.9
T_7	45.5	65.2	93.2	67.0	41.6	61.2	92.6	65.1
T_8	35.6	55.6	85.5	58.9	34.5	54.5	80.6	56.5
T_9	38.6	58.2	89.2	62.0	34.2	54.2	84.2	57.5
T_{10}	38.4	58.4	89.6	62.1	35.2	55.2	85.2	58.5
Grand mean	38.9	58.9	86.2		35.0	54.7	84.3	
SEd	0.76	1.15	1.69		0.68	1.07	1.65	
CD(P=0.05)	1.60	2.43	3.56		1.44	2.26	2.65	

Table 2. Effect of treatments on the number of branches of Tomato

Treatments	Number of branches				Number of branches			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	3.5	8.7	11.9	8.0	3.2	8.2	11.2	7.4
T_2	3.9	8.9	11.9	8.2	3.4	8.4	11.4	7.7
T_3	3.8	8.7	11.7	8.1	3.6	8.6	11.6	7.9
T_4	4.1	9.1	12.2	8.4	3.0	8.2	11.4	7.5
T_5	4.5	10.2	13.0	9.2	4.0	9.5	12.5	8.6
T_6	5.3	10.3	12.8	9.4	4.8	9.8	12.8	9.1
T_7	6.3	10.8	13.8	10.3	5.8	10.3	13.3	9.8
T_8	5.1	10.3	11.8	9.0	4.2	9.2	12.2	8.5
T_9	6.1	9.5	12.0	9.2	4.6	9.7	12.6	8.8
T_{10}	4.7	10.6	12.7	9.3	5.4	9.0	12.4	8.9
Grand mean	4.6	9.6	12.2		4.1	8.9	11.9	
SEd	0.09	0.18	0.24		0.08	0.17	0.23	
CD(P=0.05)	0.19	0.39	0.50		0.17	0.37	0.49	

Table 3. Effect of treatments on the number of leaves of Tomato

Treatments	Number of leaves				Number of leaves			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	19.7	49.3	67.3	45.4	17.7	47.3	65.4	43.5
T_2	20.4	50.3	69.3	46.6	18.3	48.3	67.4	44.7
T_3	20.4	51.2	69.4	47.0	18.9	49.7	67.5	45.4
T_4	21.7	52.3	70.3	48.1	19.7	50.6	68.4	46.2
T_5	21.9	53.9	70.5	48.8	19.9	51.2	68.8	46.6
T_6	25.3	57.8	74.8	52.6	23.7	55.2	72.3	50.4
T_7	27.4	59.4	76.9	54.6	25.6	57.3	74.3	52.4
T_8	21.8	54.7	71.8	49.4	19.5	52.5	69.1	47.0
T_9	24.8	57.5	71.2	51.2	22.1	55.8	69.3	49.1
T_{10}	25.6	57.4	72.4	51.8	23.1	55.4	70.3	49.6
Grand mean	22.6	53.7	70.5		20.6	51.6	68.4	
SEd	0.44	1.06	1.38		0.41	1.02	1.34	
CD(P=0.05)	0.94	2.22	2.91		0.86	2.14	2.82	

Table 4. Effect of treatments on leaf area index at different growth stages of Tomato

Treatments	Leaf area index				Leaf area index			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	1.09	2.47	3.45	2.33	1.01	2.27	3.28	2.18
T_2	1.24	2.68	3.67	2.53	1.20	2.49	3.43	2.37
T_3	1.42	2.95	3.98	2.78	1.39	2.75	3.78	2.64
T_4	1.64	2.76	3.74	2.71	1.21	2.54	3.51	2.42
T_5	1.68	2.84	3.76	2.76	1.26	2.60	3.57	2.47
T_6	1.78	2.98	4.43	3.06	1.46	2.86	3.89	2.73
T_7	1.98	3.45	4.65	3.36	1.64	2.99	4.32	2.98
T_8	1.74	2.83	4.12	2.89	1.32	2.63	3.80	2.58
T_9	1.75	2.93	4.10	2.91	1.48	2.84	3.83	2.71
T_{10}	1.87	2.89	4.05	2.93	1.57	2.91	4.03	2.83
Grand Mean	1.59	2.84	3.95		1.33	2.65	3.69	
SEd	0.032	0.056	0.077		0.027	0.052	0.072	
CD (p = 0.05)	0.068	0.118	0.163		0.057	0.110	0.152	

Table 5. Effect of treatments on the days to first flowering in tomato

Treatments	Days to first flowering		
	Kharif	Summer	Mean
T_1	27.9	30.4	29.1
T_2	27.5	30.3	28.9
T_3	27.6	30.2	28.8
T_4	26.8	29.7	28.3
T_5	27.1	28.9	28.0
T_6	26.1	28.2	27.1
T_7	25.1	27.7	26.4
T_8	27.4	28.8	28.2
T_9	26.9	28.1	27.5
T_{10}	26.9	27.9	27.4
Grand mean	26.5	28.6	
SEd	0.52	0.56	
CD(P=0.05)	1.09	1.18	

Table 6. Effect of treatments on the days to 50 % flowering in tomato

Treatments	Days to 50 % flowering		
	Kharif	Summer	Mean
T_1	42.3	44.2	43.3
T_2	41.7	43.4	42.5
T_3	39.7	41.4	40.5
T_4	40.2	42.1	41.1
T_5	41.9	43.9	42.9
T_6	38.9	40.0	39.5
T_7	36.4	38.4	37.4
T_8	41.2	43.4	42.3
T_9	39.8	40.6	40.2
T_{10}	39.2	40.9	40.0
Grand mean	39.6	41.3	
SEd	0.77	0.81	
CD(P=0.05)	1.63	1.70	

Table 7. Effect of treatments on the root length (cm) in tomato

Treatments	Root length(cm)		
	Kharif	Summer	Mean
T_1	16.5	15.7	16.1
T_2	18.4	17.3	17.8
T_3	18.9	17.8	18.3
T_4	19.3	18.4	18.8
T_5	20.6	19.4	20.0
T_6	26.3	25.4	25.8
T_7	29.9	29.6	29.7
T_8	21.3	20.3	20.8
T_9	22.5	21.6	22.0
T_{10}	24.1	23.8	23.9
Grand mean	20.6	21.5	
SEd	0.43	0.41	
CD(P=0.05)	0.90	0.87	

Table 8. Effect of treatments on the total soluble protein (mg g^{-1}) in tomato

Treatments	Total soluble protein (mg g^{-1})				Total soluble protein (mg g^{-1})			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	25.38	27.43	26.38	26.39	23.54	25.32	22.18	23.68
T_2	26.31	28.54	27.39	27.41	24.82	26.43	23.64	24.96
T_3	26.43	28.32	27.64	27.46	24.12	26.98	23.91	25.00
T_4	26.81	28.91	27.42	27.71	24.32	26.86	25.64	25.60
T_5	27.42	29.56	28.48	28.48	25.43	27.53	24.36	25.77
T_6	27.91	29.18	28.54	28.54	25.75	27.84	24.64	26.07
T_7	28.46	30.54	29.18	29.39	26.49	28.53	25.99	27.00
T_8	26.31	28.34	27.91	27.52	25.74	27.21	24.35	25.75
T_9	27.49	29.19	28.43	28.37	25.18	27.76	24.31	25.75
T_{10}	27.54	29.36	28.49	28.46	24.92	26.54	25.93	25.79
Grand mean	26.65	28.56	27.62		24.70	26.74	24.17	
SEd CD(P=0.05)	0.524 1.102	0.561 1.179	0.543 1.142		0.486 1.021	0.525 1.103	0.474 0.996	

Table 9. Effect of treatments on the chlorophyll 'a' and chlorophyll 'b' (mg g^{-1} fw) in tomato (kharif)

Treatments	Chlorophyll a (mg g^{-1} fw)				Chlorophyll b (mg g^{-1} fw)			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	1.45	1.86	1.68	1.66	0.73	0.93	0.84	0.83
T_2	1.64	1.96	1.75	1.78	0.82	0.98	0.87	0.89
T_3	1.76	1.98	2.03	1.92	0.88	0.99	1.01	0.96
T_4	1.76	1.99	2.32	2.02	0.88	0.99	1.16	1.01
T_5	1.99	2.21	2.01	2.07	0.99	1.10	1.01	1.03
T_6	2.32	2.45	2.13	2.30	1.16	1.22	1.06	1.14
T_7	2.56	2.67	2.32	2.52	1.28	1.33	1.16	1.25
T_8	2.15	2.25	2.01	2.14	1.07	1.12	1.01	1.06
T_9	2.16	2.32	2.11	2.19	1.08	1.16	1.05	1.09
T_{10}	2.24	2.34	2.15	2.24	1.12	1.17	1.07	1.12
Grand mean	1.97	2.17	2.02		0.98	1.08	1.01	
SEd	0.041	0.042	0.042		0.012	0.024	0.022	
CD(P=0.05)	0.08	0.09	0.08		0.04	0.04	0.04	

Table 10. Effect of treatments on the chlorophyll 'a' and chlorophyll 'b' (mg g^{-1} fw) in tomato (summer)

Treatments	Chlorophyll a (mg g^{-1} fw)				Chlorophyll b (mg g^{-1} fw)			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	1.42	1.85	1.62	1.63	0.63	0.81	0.67	0.70
T_2	1.53	1.65	1.34	1.51	0.75	0.73	0.64	0.71
T_3	1.65	1.73	1.54	1.64	0.65	0.77	0.93	0.78
T_4	1.78	1.89	1.64	1.77	0.78	0.75	0.87	0.8
T_5	1.95	2.04	1.89	1.96	0.85	0.87	0.89	0.87
T_6	2.14	2.32	2.14	2.20	0.89	0.79	0.91	0.86
T_7	2.43	2.56	2.32	2.44	0.84	0.96	0.9	0.90
T_8	2.13	2.34	2.12	2.19	0.74	0.86	0.85	0.82
T_9	2.17	2.36	2.09	2.20	0.82	0.89	0.86	0.86
T_{10}	2.21	2.32	2.16	2.23	0.91	0.91	0.83	0.88
Grand mean	1.91	2.07	1.86		0.77	0.82	0.82	
SEd	0.031	0.045	0.043		0.012	0.014	0.011	
CD(P=0.05)	0.08	0.08	0.08		0.03	0.03	0.03	

Table 11. Effect of treatments on the total chlorophyll (mg g^{-1} fw) in tomato

Treatments	Total chlorophyll (mg g^{-1} fw)				Total chlorophyll (mg g^{-1} fw)			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	2.18	2.79	2.52	2.49	2.05	2.66	2.29	2.33
T_2	2.46	2.94	2.62	2.67	2.28	2.38	1.98	2.21
T_3	2.64	2.97	3.04	2.88	2.30	2.50	2.47	2.42
T_4	2.64	2.98	3.12	3.03	2.56	2.64	2.51	2.57
T_5	2.98	3.31	3.02	3.10	2.80	2.91	2.78	2.83
T_6	3.48	3.67	3.19	3.45	3.03	3.11	3.05	3.06
T_7	3.50	3.70	3.48	3.56	3.34	3.47	3.15	3.32
T_8	3.22	3.37	3.02	3.20	2.87	3.20	2.97	3.01
T_9	3.24	3.48	3.16	3.29	2.99	3.25	2.95	3.06
T_{10}	3.36	3.51	3.22	3.36	3.05	3.28	3.06	3.13
Grand mean	2.93	3.22	3.03		2.69	2.90	2.68	
SEd	0.052	0.064	0.063		0.051	0.053	0.052	
CD(P=0.05)	0.12	0.13	0.12		0.11	0.12	0.11	

Table 12. Effect of treatments on the chlorophyll stability index (%) in tomato

Treatments	Chlorophyll stability index(%)				Chlorophyll stability index(%)			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	81.8	83.9	80.4	82.1	80.1	82.9	79.4	80.8
T_2	82.9	84.1	81.8	82.9	81.9	83.8	80.4	82.0
T_3	83.7	85.3	82.3	83.8	82.3	84.3	81.9	82.8
T_4	84.3	86.4	83.8	84.8	83.2	85.3	82.6	83.7
T_5	84.8	86.3	83.9	85.0	83.7	85.9	82.8	84.1
T_6	87.3	89.7	86.8	87.9	86.8	88.0	85.4	86.7
T_7	88.8	91.2	87.4	89.1	88.3	90.7	86.4	88.4
T_8	85.2	87.4	84.2	85.6	84.3	86.4	83.2	84.6
T_9	87.3	89.3	86.4	87.7	85.6	87.3	81.3	84.7
T_{10}	86.3	88.3	85.2	86.6	86.4	88.9	84.3	86.5
Grand mean	84.1	86.1	83.1		83.2	85.2	81.7	
SEd	1.64	1.68	1.62		1.63	1.67	1.60	
CD(P=0.05)	3.46	3.54	3.42		3.42	3.51	3.36	

Table 13. Effect of treatments on the IAA oxidase activity (unoxidised auxin µg $g^{-1}h^{-1}$) of tomato

Treatments	IAA oxidase activity (unoxidised auxin µg $g^{-1}h^{-1}$)				IAA oxidase activity (unoxidised auxin µg $g^{-1}h^{-1}$)			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	3.21	3.45	3.64	3.43	2.80	3.27	3.49	3.18
T_2	3.38	3.52	3.74	3.54	2.74	3.37	3.52	3.21
T_3	3.21	3.74	3.92	3.62	3.02	3.48	3.63	3.37
T_4	3.48	3.61	3.82	3.63	2.89	3.50	3.79	3.39
T_5	3.47	3.61	3.85	3.64	3.07	3.49	3.67	3.41
T_6	3.52	3.89	4.03	3.81	3.21	3.68	3.82	3.57
T_7	3.84	4.02	4.43	4.09	3.45	3.97	4.12	3.84
T_8	3.21	3.65	3.86	3.57	2.98	3.49	3.68	3.38
T_9	3.49	3.74	3.99	3.74	2.87	3.65	3.97	3.48
T_{10}	3.27	3.87	4.25	3.79	2.98	3.54	3.98	3.50
Grand mean	3.3633	3.6620	3.9017		2.9620	3.4977	3.7200	
SEd	0.0666	0.0718	0.0767		0.0584	0.0692	0.0733	
CD(P=0.05)	0.1399	0.1509	0.1612		0.1226	0.1454	0.1539	

Table 14. Effect of treatments on the peroxidase activity (µ moles H_2O_2 100 mg^{-1} min^{-1}) in tomato

Treatments	Peroxidase activity (µ moles H_2O_2 100 mg^{-1} min^{-1})				Peroxidase activity (µ moles H_2O_2 100 mg^{-1} min^{-1})			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	0.070	0.063	0.086	0.073	0.056	0.062	0.071	0.063
T_2	0.078	0.086	0.098	0.087	0.062	0.073	0.084	0.073
T_3	0.093	0.072	0.113	0.092	0.072	0.068	0.097	0.079
T_4	0.106	0.087	0.122	0.105	0.077	0.084	0.092	0.084
T_5	0.103	0.112	0.108	0.107	0.086	0.093	0.109	0.096
T_6	0.126	0.118	0.146	0.130	0.108	0.117	0.135	0.120
T_7	0.131	0.146	0.154	0.143	0.122	0.132	0.144	0.132
T_8	0.084	0.084	0.091	0.086	0.068	0.068	0.089	0.075
T_9	0.076	0.102	0.128	0.102	0.083	0.094	0.115	0.097
T_{10}	0.127	0.096	0.113	0.112	0.071	0.077	0.112	0.086
Grand mean	0.098	0.095	0.114		0.079	0.085	0.103	
SEd	0.003	0.003	0.003		0.003	0.002	0.003	
CD(P=0.05)	0.007	0.007	0.007		0.006	0.004	0.006	

Table 15. Effect of treatments on the relative water content (%) in tomato

Treatments	Relative water content (%)				Relative water content (%)			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	54.81	58.54	57.43	56.92	54.95	58.83	56.75	56.84
T_2	56.74	60.54	59.04	58.77	57.23	60.20	58.43	58.62
T_3	57.25	61.68	60.43	59.78	57.43	60.32	59.63	59.12
T_4	58.47	62.43	61.34	60.74	58.93	64.23	60.42	61.19
T_5	58.32	62.85	61.43	60.86	59.36	65.81	61.40	62.19
T_6	61.91	65.72	64.35	63.99	59.46	65.21	63.75	62.80
T_7	63.54	67.28	66.23	65.68	60.74	66.42	65.20	64.12
T_8	58.31	62.13	61.03	60.49	58.64	64.82	60.32	61.26
T_9	59.46	63.26	62.36	61.69	59.45	65.21	60.40	61.68
T_{10}	60.43	64.83	63.45	62.90	59.89	65.65	62.43	62.65
Grand mean	58.15	62.10	60.90		57.84	62.84	60.08	
SEd	1.142	1.22	1.19		1.136	1.233	1.181	
CD(P=0.05)	2.401	2.56	2.51		2.386	2.591	2.482	

Table 16. Effect of treatments on the total soluble solids (^{o}brix) in tomato

Treatments	TSS(^{o}brix)		
	Kharif	Summer	Mean
T_1	4.38	4.29	4.33
T_2	4.63	4.50	4.56
T_3	4.72	4.71	4.71
T_4	4.73	4.72	4.72
T_5	4.78	4.65	4.73
T_6	4.86	4.83	4.84
T_7	5.02	4.99	5.00
T_8	4.73	4.67	4.70
T_9	4.80	4.80	4.80
T_{10}	4.86	4.82	4.84
Grand mean	4.68	4.63	
SEd	0.091	0.091	
CD(P=0.05)	0.193	0.191	

Table 17. Effect of treatments on the titrable acidity (%) in tomato

Treatments	Titrable acidity (%)		
	Kharif	Summer	Mean
T_1	0.49	0.47	0.48
T_2	0.49	0.47	0.48
T_3	0.49	0.48	0.49
T_4	0.52	0.49	0.51
T_5	0.51	0.50	0.50
T_6	0.53	0.49	0.51
T_7	0.56	0.54	0.55
T_8	0.51	0.49	0.50
T_9	0.51	0.51	0.51
T_{10}	0.50	0.49	0.50
Grand mean	0.50	0.49	0.50
SEd	0.009	0.009	
CD(P=0.05)	0.020	0.020	

Table 18. Effect of treatments on the Ascorbic acid (mg 100 g^{-1}) of the fruit in tomato

Treatments	Ascorbic acid (mg 100 g^{-1})		
	Kharif	Summer	Mean
T_1	22.65	22.06	22.35
T_2	22.87	22.08	22.47
T_3	22.98	22.14	22.56
T_4	24.76	23.83	24.29
T_5	24.98	23.87	24.42
T_6	26.34	26.12	26.23
T_7	26.87	26.65	26.76
T_8	25.65	24.75	25.20
T_9	25.53	25.21	25.37
T_{10}	25.87	25.45	25.66
Grand mean	24.52	23.90	
SEd	0.483	0.471	
CD(P=0.05)	1.016	0.991	

Table 19. Effect of treatments on the total sugar (%) in tomato

Treatments	Total sugar (%)		
	Kharif	Summer	Mean
T_1	2.51	2.14	2.31
T_2	2.49	2.17	2.33
T_3	2.63	2.31	2.47
T_4	2.81	2.40	2.60
T_5	2.85	2.49	2.67
T_6	2.91	2.51	2.71
T_7	3.21	2.75	2.98
T_8	2.70	2.53	2.61
T_9	2.71	2.54	2.62
T_{10}	2.81	2.59	2.69
Grand mean	2.73	2.41	
SEd	0.054	0.047	
CD(P=0.05)	0.113	0.099	

Table 20. Effect of treatments on the lycopene (mg 100^{-1} g) in tomato

Treatments	Lycopene (mg 100^{-1} g)		
	Kharif	**Summer**	**Mean**
T_1	6.40	6.20	6.30
T_2	6.61	6.30	6.45
T_3	6.71	6.40	6.55
T_4	6.81	6.40	6.59
T_5	6.72	6.50	6.60
T_6	6.92	6.72	6.82
T_7	7.34	7.01	7.17
T_8	6.58	6.56	6.57
T_9	6.72	6.50	6.61
T_{10}	6.83	6.43	6.63
Grand mean	6.67	6.41	
SEd	0.130	0.126	
CD(P=0.05)	0.274	0.266	

Table 21. Effect of treatments on the leaf nitrogen (%) in tomato

Treatments	Leaf nitrogen (%)				Leaf nitrogen (%)			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	2.58	3.66	2.73	2.99	2.54	3.68	2.64	2.95
T_2	2.59	3.78	2.69	3.02	2.58	3.75	2.71	3.01
T_3	2.88	3.68	2.67	3.07	2.71	3.71	2.67	3.03
T_4	2.96	3.63	2.66	3.08	2.94	3.66	2.67	3.09
T_5	2.86	3.68	2.73	3.09	2.84	3.85	2.69	3.12
T_6	3.02	3.93	2.80	3.25	2.98	3.92	2.83	3.24
T_7	3.22	4.06	2.89	3.39	2.99	3.99	2.91	3.29
T_8	2.97	3.71	2.73	3.13	2.82	3.82	2.81	3.15
T_9	2.87	3.78	2.76	3.14	2.85	3.85	2.81	3.17
T_{10}	2.93	3.73	2.80	3.15	2.84	3.89	2.81	3.18
Grand mean	2.85	3.71	2.70		2.77	3.76	2.71	
SEd	0.055	0.073	0.053		0.053	0.074	0.053	
CD(P=0.05)	0.117	0.154	0.112		0.11	0.155	0.112	

Table 22. Effect of treatments on the leaf phosphorus (%) in tomato

Treatments	Leaf phosphorus (%)				Leaf phosphorus (%)			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	0.35	0.41	0.31	0.35	0.33	0.41	0.31	0.35
T_2	0.37	0.41	0.31	0.36	0.34	0.42	0.32	0.36
T_3	0.36	0.45	0.31	0.37	0.36	0.43	0.34	0.37
T_4	0.36	0.43	0.33	0.38	0.34	0.41	0.35	0.38
T_5	0.41	0.43	0.34	0.39	0.38	0.45	0.35	0.39
T_6	0.43	0.45	0.41	0.43	0.36	0.51	0.34	0.40
T_7	0.48	0.50	0.39	0.45	0.39	0.50	0.37	0.42
T_8	0.42	0.44	0.31	0.39	0.34	0.41	0.31	0.35
T_9	0.43	0.41	0.34	0.38	0.35	0.44	0.31	0.37
T_{10}	0.39	0.46	0.39	0.42	0.37	0.45	0.35	0.39
Grand mean	0.39	0.43	0.34		0.35	0.43	0.33	
SEd	0.008	0.009	0.007		0.007	0.009	0.007	
CD(P=0.05)	0.017	0.020	0.016		0.015	0.020	0.016	

Table 23. Effect of treatments on the leaf potassium (%) in tomato

Treatments	Leaf potassium (%)				Leaf potassium (%)			
	Kharif				Summer			
	30 DAT	60 DAT	90 DAT	Mean	30 DAT	60 DAT	90 DAT	Mean
T_1	2.98	3.71	2.72	3.14	2.95	3.74	2.73	3.14
T_2	2.98	3.74	2.73	3.15	2.97	3.72	2.73	3.15
T_3	2.95	3.75	2.77	3.17	2.94	3.75	2.75	3.16
T_4	3.06	3.76	2.82	3.21	3.02	3.82	2.80	3.21
T_5	3.04	3.86	2.80	3.23	3.05	3.80	2.83	3.22
T_6	3.53	3.91	2.91	3.45	3.43	3.94	2.93	3.43
T_7	3.75	3.98	2.85	3.53	3.54	3.99	2.98	3.50
T_8	3.21	3.77	2.84	3.27	3.05	3.79	2.82	3.23
T_9	3.48	3.74	2.83	3.35	3.24	3.80	2.81	3.28
T_{10}	3.42	3.90	2.90	3.40	3.22	3.82	2.88	3.31
Grand mean	3.20	3.76	2.78		3.10	3.77	2.79	
SEd	0.063	0.075	0.056		0.062	0.076	0.056	
CD(P=0.05)	0.132	0.157	0.118		0.130	0.159	0.117	

Table 24. Effect of treatments on the number of fruits per plant in tomato

Treatments	Number of fruits per plant		
	Kharif	Summer	Mean
T_1	42.4	41.2	41.6
T_2	45.6	44.6	45.1
T_3	47.3	46.3	46.7
T_4	47.1	46.6	46.8
T_5	48.3	47.2	47.7
T_6	50.1	48.3	49.2
T_7	50.3	49.8	50.0
T_8	42.5	41.3	41.9
T_9	48.1	47.4	47.7
T_{10}	49.8	48.7	49.1
Grand mean	46.6	45.6	
SEd	0.91	0.89	
CD(P=0.05)	1.93	1.88	

Table 25. Effect of treatments on the single fruit weight (g) in tomato

Treatments	Single Fruit Weight(g)		
	Kharif	Summer	Mean
T_1	49.87	47.63	48.75
T_2	50.63	48.79	49.71
T_3	50.43	49.87	50.15
T_4	52.34	50.76	51.55
T_5	53.24	51.28	52.26
T_6	54.34	52.89	53.61
T_7	55.31	54.98	55.14
T_8	52.39	50.74	51.56
T_9	53.43	51.26	52.34
T_{10}	53.54	52.73	53.13
Grand mean	51.86	50.42	
SEd	1.019	0.990	
CD(P=0.05)	2.140	2.081	

Table 26. Effect of treatments on the yield per plant in tomato

Treatments	Yield per plant (kg)		
	Kharif	Summer	Mean
T_1	2.09	2.23	2.16
T_2	2.11	2.27	2.19
T_3	2.30	2.38	2.34
T_4	2.31	2.43	2.37
T_5	2.35	2.44	2.39
T_6	2.49	2.62	2.56
T_7	2.74	2.78	2.76
T_8	2.34	2.50	2.42
T_9	2.38	2.51	2.44
T_{10}	2.48	2.61	2.54
Grand mean	2.44	2.33	
SEd	0.048	0.046	
CD(P=0.05)	0.101	0.097	

Table 27. Effect of treatments on the yield per plot in tomato

Treatments	Yield per plot (kg)		
	Kharif	Summer	Mean
T_1	55.8	52.3	54.0
T_2	56.8	52.8	54.8
T_3	59.5	57.5	58.5
T_4	60.8	57.8	59.3
T_5	61.0	58.8	59.9
T_6	65.5	62.3	63.9
T_7	69.5	68.5	69.0
T_8	62.5	58.5	60.5
T_9	62.8	59.5	61.1
T_{10}	65.3	62.0	63.6
Grand mean	61.1	58.2	
SEd	1.20	1.15	
CD(P=0.05)	2.53	2.41	

Table 28. Effect of treatments on the yield per hectare (tones) in tomato

Treatments	Yield per hectare (tonnes)		
	Kharif	Summer	Mean
T_1	69.8	65.3	67.5
T_2	71.0	66.0	68.5
T_3	74.4	71.8	73.1
T_4	76.0	72.2	74.1
T_5	76.3	73.5	74.9
T_6	81.9	77.8	79.8
T_7	86.9	85.6	86.2
T_8	78.1	73.1	75.6
T_9	78.5	74.3	76.4
T_{10}	81.6	77.5	79.5
Grand mean	76.4	72.7	
SEd	1.50	1.43	
CD(P=0.05)	3.16	3.01	

Table 29. Effect of treatments on the shelf life (days) in tomato

Treatments	Shelf life (days)		
	Kharif	Summer	Mean
T_1	10.2	8.0	9.2
T_2	11.3	8.1	9.6
T_3	11.2	8.4	9.8
T_4	12.8	8.2	10.4
T_5	12.2	9.9	11.0
T_6	13.4	10.2	11.7
T_7	15.4	10.4	12.8
T_8	12.4	9.5	10.8
T_9	12.6	9.9	11.2
T_{10}	12.7	9.7	11.3
Grand mean	12.2	9.1	
SEd	0.24	0.18	
CD(P=0.05)	0.51	0.38	

Table 30. Effect of treatments on the Equatorial and Polar diameter (cm) of the fruit in tomato

Treatments	Equatorial diameter (cm)			Polar diameter (cm)		
	Kharif	Summer	Mean	Kharif	Summer	Mean
T_1	5.72	5.67	5.69	3.76	3.34	3.55
T_2	5.86	5.76	5.81	3.93	3.43	3.68
T_3	5.34	5.22	5.28	3.93	3.65	3.79
T_4	5.13	5.04	5.08	3.38	3.23	3.30
T_5	6.14	6.02	6.08	4.27	4.12	4.19
T_6	6.43	6.21	6.32	4.86	4.15	4.50
T_7	6.93	6.64	6.79	4.93	4.58	4.76
T_8	5.82	5.73	5.77	4.38	4.13	4.25
T_9	6.16	5.87	6.01	4.58	4.12	4.35
T_{10}	6.17	6.15	6.16	4.41	4.37	4.39
Grand mean	5.89	5.76		4.19	3.86	
SEd	0.118	0.114		0.085	0.075	
CD(P=0.05)	0.249	0.240		0.178	0.158	

Table 31. Effect of treatments on soil Physical characters at different stages in tomato (kharif)

Treatments	Bulk density ($g\ cc^{-1}$)		Particle density ($g\ cc^{-1}$)		Porosity (%)	
	Initial*	Final**	Initial*	Final**	Initial*	Final**
T_1	1.65	1.67	3.02	3.03	42.46	42.53
T_2	1.69	1.70	3.04	3.04	42.75	42.50
T_3	1.68	1.69	3.08	3.10	41.72	41.27
T_4	1.68	1.68	3.05	3.06	40.67	41.23
T_5	1.69	1.65	3.04	2.98	42.50	43.16
T_6	1.71	1.73	3.03	3.05	41.57	42.72
T_7	1.74	1.67	3.07	3.01	43.00	42.85
T_8	1.65	1.67	3.06	3.08	41.34	41.26
T_9	1.66	1.68	3.05	3.10	42.67	42.55
T_{10}	1.72	1.69	3.04	3.07	42.39	42.46
Grand Mean	1.66	1.66	3.00	3.01	41.55	41.70
S Ed	0.03	0.03	0.05	0.06	0.81	0.81
CD (p = 0.05)	NS	NS	NS	NS	NS	NS

*** Before application ** after harvest**

Table 32. Effect of treatments on soil Physical characters at different stages in tomato (summer)

Treatments	Bulk density ($g\ cc^{-1}$)		Particle density ($g\ cc^{-1}$)		Porosity (%)	
	Initial*	Final**	Initial*	Final**	Initial*	Final**
T_1	1.66	1.68	3.04	3.05	42.56	42.64
T_2	1.64	1.67	3.05	3.06	42.85	42.31
T_3	1.66	1.69	3.06	3.10	41.29	41.43
T_4	1.61	1.68	3.07	3.08	40.74	41.29
T_5	1.67	1.70	3.05	2.98	42.06	43.63
T_6	1.72	1.74	3.04	3.05	41.79	42.39
T_7	1.76	1.78	3.08	3.10	43.29	42.36
T_8	1.65	1.67	3.08	3.09	41.30	41.45
T_9	1.62	1.64	3.04	3.07	42.59	42.62
T_{10}	1.69	1.74	3.05	3.08	42.39	42.64
Grand Mean	1.64	1.67	3.01	3.02	41.53	41.72
S Ed	0.03	0.03	0.05	0.06	0.81	0.82
CD (p = 0.05)	0.06	0.07	NS	NS	NS	NS

*** Before application ** after harvest**

Table 33. Effect of treatments on soil pH at different stages of tomato

Treatments	30DAT	60DAT	90 DAT
T_1	6.69	6.65	6.56
T_2	6.55	6.49	6.44
T_3	6.57	6.50	6.47
T_4	6.58	6.51	6.50
T_5	6.45	6.32	6.30
T_6	6.36	6.31	6.29
T_7	6.49	6.47	6.44
T_8	6.46	6.44	6.42
T_9	6.78	6.73	6.71
T_{10}	6.52	6.50	6.49
Grand Mean	6.46	6.41	6.38
S Ed	0.13	0.13	0.12
CD (p = 0.05)	NS	NS	NS

Table 34. Effect of treatments on EC (dSm^{-1}) at different stages of tomato

Treatments	30DAT	60DAT	90 DAT
T_1	0.32	0.34	0.33
T_2	0.27	0.29	0.28
T_3	0.29	0.31	0.30
T_4	0.24	0.23	0.22
T_5	0.25	0.25	0.24
T_6	0.23	0.20	0.19
T_7	0.20	0.18	0.17
T_8	0.26	0.24	0.22
T_9	0.30	0.27	0.26
T_{10}	0.28	0.25	0.23
Grand Mean	0.27	0.25	0.24
S Ed	0.004	0.004	0.004
CD (p = 0.05)	0.01	0.01	0.01

Table 35. Effect of treatments on soil available nitrogen (kg ha^{-1}) at different stages of tomato

Treatments	Available nitrogen (kg ha^{-1}) (Kharif)			Available nitrogen (kg ha^{-1}) (Summer)		
	Initial *	Final**	Mean	Initial *	Final**	Mean
T_1	229.80	214.63	222.21	245.74	220.49	233.11
T_2	230.43	220.01	225.22	245.42	223.82	234.62
T_3	229.75	217.39	223.57	244.83	229.11	236.97
T_4	228.49	220.32	224.40	244.93	231.67	238.30
T_5	229.43	217.94	223.68	245.90	230.94	238.42
T_6	230.90	226.64	228.77	244.31	236.64	240.47
T_7	231.43	232.32	231.87	243.89	245.46	244.67
T_8	228.75	219.65	224.20	245.73	231.34	238.53
T_9	230.45	217.39	223.92	244.38	232.87	238.62
T_{10}	229.54	219.84	224.69	245.63	236.32	240.97
Grand mean	226.90	217.74		241.88	228.84	
SEd	4.454	4.279		4.750	4.504	
CD(P=0.05)	NS	8.99		NS	9.46	

*** Before application ** After harvest**

Table 36. Effect of treatments on soil available phosphorous (kg ha^{-1}) at different stages of tomato

Treatments	Available nitrogen (kg ha^{-1}) (Kharif)			Available nitrogen (kg ha^{-1}) (Summer)		
	Initial *	Final**	Mean	Initial *	Final**	Mean
T_1	17.65	14.76	16.20	19.56	15.90	17.73
T_2	17.37	13.39	15.38	19.32	14.38	16.85
T_3	17.41	15.94	16.67	19.97	17.28	18.62
T_4	17.49	16.57	17.03	18.46	15.53	16.99
T_5	17.95	13.93	15.94	18.36	17.92	18.14
T_6	17.38	17.76	17.57	18.37	16.94	17.65
T_7	17.99	18.98	18.48	19.92	20.96	20.44
T_8	17.35	15.36	16.35	19.29	17.54	18.41
T_9	17.73	16.29	17.01	19.52	16.47	17.99
T_{10}	17.32	15.28	16.30	19.75	16.54	18.14
Grand mean	17.33	15.62		19.00	16.72	
SEd	0.340	0.308		0.372	0.330	
CD(P=0.05)	NS	0.64		NS	0.69	

*** Before application ** After harvest**

Table 37. Effect of treatments on soil available potassium (kg ha^{-1}) at different stages of tomato

Treatments	Available nitrogen (kg ha^{-1}) (Kharif)			Available nitrogen (kg ha^{-1}) (Summer)		
	Initial *	Final**	Mean	Initial *	Final**	Mean
T_1	443.94	420.92	432.43	454.39	432.34	443.36
T_2	442.39	423.73	433.06	453.29	440.39	446.84
T_3	443.84	426.28	435.06	454.2	434.92	444.56
T_4	442.38	428.81	435.59	453.92	439.82	446.87
T_5	443.85	432.78	438.31	454.87	439.21	447.04
T_6	443.64	434.75	439.19	453.92	443.67	448.79
T_7	443.95	439.75	441.85	454.72	450.73	452.72
T_8	442.13	425.73	433.93	454.29	442.47	448.38
T_9	441.29	429.54	435.41	453.68	443.78	448.73
T_{10}	443.92	421.29	432.60	454.64	447.64	451.14
Grand mean	437.37	422.78		448.28	435.75	
SEd	8.587	8.307		8.802	8.565	
CD(P=0.05)	NS	NS		NS	NS	

*** Before application ** After harvest**

Table 38. Effect of treatments on the bacterial population of Tomato

Treatments	Bacteria population (cfu × $10^5 g^{-1}$ of soil)					Bacteria population (cfu × $10^{-5} g^{-1}$ of soil)				
	Kharif					Summer				
	30 DAT	60 DAT	90 DAT	120 DAT	Mean	30 DAT	60 DAT	90 DAT	120 DAT	Mean
T_1	32.91	47.38	50.65	34.83	41.44	30.10	45.32	48.71	33.82	39.48
T_2	35.93	42.38	52.38	37.82	42.13	33.13	40.43	50.12	35.84	39.88
T_3	37.92	47.82	55.32	38.2	44.82	35.48	45.35	53.72	36.82	42.84
T_4	38.54	42.85	52.84	36.16	42.59	34.37	45.13	50.76	39.42	42.42
T_5	37.84	43.82	53.84	38.94	43.61	35.16	41.82	51.62	38.85	41.86
T_6	43.84	47.32	67.56	43.02	50.43	42.30	46.68	65.10	42.81	49.22
T_7	47.28	59.3	62.84	47.83	54.31	45.49	57.33	60.44	45.32	52.14
T_8	42.84	47.29	52.34	45.23	46.92	34.29	42.56	52.36	40.93	42.53
T_9	43.86	51.82	54.21	40.93	47.70	41.64	45.64	50.61	43.2	45.27
T_{10}	45.82	53.29	55.35	42.25	49.17	43.32	51.35	53.72	41.23	47.40
Grand Mean	40.15	47.69	55.01	39.99		37.04	45.56	53.02	39.31	
SEd	0.798	0.939	1.084	0.793		0.73S	0.897	1.045	0.779	
CD (p = 0.05)	1.677	1.973	2.277	1.666		1.551	1.884	2.195	1.637	

Table 39. Effect of treatments on the fungi population (cfu × $10^{-3}g^{-1}$ of soil) of Tomato

Treatments	Fungi population (cfu × $10^{3}g^{-1}$ of soil)					Fungi population (cfu × $10^{-3}g^{-1}$ of soil)				
	Kharif					Summer				
	30 DAT	60 DAT	90 DAT	120 DAT	Mean	30 DAT	60 DAT	90 DAT	120 DAT	Mean
T_1	5.23	7.59	8.34	5.69	6.71	4.62	7.42	7.16	6.09	6.32
T_2	5.37	7.83	8.49	5.76	6.86	5.32	7.41	8.21	5.56	6.62
T_3	4.88	8.83	8.23	6.02	6.99	4.68	8.33	7.86	5.83	6.67
T_4	4.82	7.31	7.34	6.10	6.39	5.00	7.56	8.06	5.98	6.65
T_5	4.92	8.73	8.45	6.45	7.14	4.73	8.22	8.24	6.25	6.86
T_6	5.99	9.01	9.95	7.01	7.99	5.98	8.96	9.96	6.98	7.97
T_7	6.46	9.89	10.62	7.93	8.72	6.18	9.33	10.34	7.74	8.39
T_8	5.83	8.49	8.59	6.74	7.41	5.65	8.07	8.35	6.57	7.16
T_9	5.63	8.48	9.45	7.24	7.70	5.41	8.24	8.79	7.02	7.36
T_{10}	5.83	8.93	9.43	7.32	7.87	5.46	8.45	10.01	7.03	7.73
Grand Mean	5.42	8.39	8.77	6.53		5.23	8.09	8.58	6.42	
SEd	0.107	0.166	0.173	0.129		0.104	0.159	0.169	0.126	
CD (p = 0.05)	0.225	0.348	0.364	0.272		0.218	0.335	0.356	0.265	

Table 40. Effect of treatments on the actinomycetes population (cfu × 10^2 g^{-1} of soil) of Tomato

Treatments	Actinomycetes population (cfu × $10^{-2}g^{-1}$ of soil)					Actinomycetes population (cfu × $10^{-2}g^{-1}$ of soil)				
	Kharif					Summer				
	30 DAT	60 DAT	90 DAT	120 DAT	Mean	30 DAT	60 DAT	90 DAT	120 DAT	Mean
T_1	1.89	3.22	3.67	2.10	2.72	2.06	2.56	3.01	2.34	2.49
T_2	2.65	3.23	3.56	2.85	3.07	2.43	2.47	3.22	2.46	2.64
T_3	3.54	3.34	3.78	3.76	3.60	3.10	2.68	3.56	3.28	3.15
T_4	2.54	2.94	4.04	2.74	3.06	2.20	2.44	3.89	2.45	2.74
T_5	2.43	3.02	3.43	2.64	2.88	1.68	3.16	3.47	1.98	2.57
T_6	2.87	4.56	5.43	3.08	3.98	2.53	4.53	5.01	2.73	3.70
T_7	3.78	5.65	6.54	4.93	5.22	3.51	4.89	6.13	3.71	4.56
T_8	2.89	3.89	4.35	3.01	3.53	2.65	2.59	4.01	2.84	3.02
T_9	2.34	4.35	5.45	2.64	3.69	2.43	4.26	4.98	2.63	3.57
T_{10}	2.54	4.44	5.43	2.76	3.79	2.45	4.28	5.11	2.67	3.62
Grand Mean	2.71	3.81	4.51	3.01		2.47	3.34	4.18	2.67	
SEd	0.054	0.077	0.091	0.060		0.049	0.069	0.085	0.053	
CD (p = 0.05)	0.113	0.162	0.192	0.126		0.104	0.144	0.179	0.112	

Table 41. Effect of treatments on yield and their economics in tomato

Treatments	Yield of tomato per ha (kg)	Quantity of chemicals (kg)required per ha	Cost of chemical required per ha(Rs.)	Gross income per hectare (Rs.)	Net income per hectare (Rs.)	Cost benefit ratio
T_1	67,500	-	-	3,37,500	1,80,091	1:2.14
T_2	68,500	7.5	1162	3,42,500	1,83,929	1:2.17
T_3	73,100	10	1550	3,65,500	2,06,541	1:2.32
T_4	74,100	12.5	1937	3,70,500	2,11,154	1:2.35
T_5	74,900	8	800	3,74,500	2,16,291	1:2.37
T_6	79,800	10.5	1240	3,99,000	2,40,351	1:2.53
T_7	86,200	13	2015	4,31,000	2,71,576	1:2.73
T_8	75,600	-	-	3,78,800	2,21,391	1:2.40
T_9	76,400	12.5	1937	3,82,000	2,22,654	1:2.42
T_{10}	79,500	13	2015	3,97,500	2,38,076	1:2.52

Quantity of spray solution required: 500 litres/ spray 1500 litres per hectare for 3 sprays
Quantity of seaweed gel required for drenching: 25kg per hectare for 5 sprays
Rate of seaweed gel: Rs. 155/kg (Rs.0.15/g)
Cost of tomato: Rs. 5.kg
Cost of cultivation: Rs. 1,57,409/ha

ANNEXURE - I

LIST OF ABBREVATIONS AND THEIR EXPLANATIONS

Abbreviations		Expansion
@	-	at the rate of
%	-	per cent
^{0}C	-	degree celsius
BCR	-	benefit cost ratio
CD (0.05)	-	critical difference at 5 per cent level
cm	-	centi metre
DAP	-	days after transplanting
DAT	-	days after transplanting
EC	-	electrical conductivity
Fig.	-	figure
FYM	-	farm yard manure
g	-	gram
g^{-1}	-	per gram
ha	-	hectare
ha^{-1}	-	per hectare
K	-	potassium
Kg	-	kilogram
Kg $plot^{-1}$	-	kilogram per plot
LAI	-	leaf Area Index
mg	-	milligram
min	-	minutes
N	-	nitrogen

P	-	phosphorus
pH	-	power of hydrogen ion
plant^{-1}	-	per plant
ppm	-	parts per million
q	-	quintal
Rs.	-	rupees
SEd	-	standard error of mean deviation
sp.	-	species
t	-	tonne
TSS	-	total soluble solids
SLF	-	seaweed liquid fertilizer
et al.	-	co workers
cfu	-	Colony forming unit

ANNEXURE-II

COST OF CULTIVATION FOR HYBRID TOMATO COTH 2 (PER HECTARE)

SI.No	Details	Unit/Rs	Amount (Rs.)
1.	Cost of seeds	200 Rs/10 g	20,000/-
2.	Nursery beds	2 labours (150/male)	300/-
3.	Sowing	1 labour (80/female)	80/-
4.	Maintenance		500/-
Main field preparation			
5.	Chisel ploughing	350/hr	1,500/-
6.	Disc ploughing	350/hr	950/-
7.	Cultivator	275/hr	1,200/-
8.	Rotovator	450/hr	900/-
9.	Leveling	350/hr	900/-
10.	FYM	25 tonnes (Rs.500/tonnes)	12,500/-
11.	Beds		1,500/-
12.	Planting	20 labours (80/female)	1,600/-
13.	Chemical fertilizers (250:250:250 kg NPK/ha)		
	Basal application (50:250:50 kg NPK/ha)		
	Urea		532/-
	SSP		5,437/-
	MOP		500/-

Contd…

SI.No	Details	Unit/Rs	Amount (Rs.)
	Remaining fertilizer was applied through fertigation as straight fertilizer		
	Urea		2,125/-
	SSP		-
	MOP		2,002/-
14.	Fertigation Installation		18,500/-
15.	Mulching		10,000/-
16.	Staking	5000 poles/ha (5/pole)	8,333/-
17.	Jute thread	200 kg/ha (40/kg)	4,000/-
18.	Training	27 male labour	4,000/-
19.	Plant protection		10,500/-
20.	Harvesting	8 harvest/6 female labour	9,600/-
21.	Transport and marketing		10,000/-
	Total		**1,57,409/-**

ANNEXURE –III

Weather data during crop growth period (June 2008 to May 2009)

Sl. No.	Months	Temperature °C		Relative humidity (%)		Rainfall (mm)	No. of rainy days	Sunshine (hrs)	Evaporation (mm)	Solar radiation (cal/cm^2/day)	Wind Speed (km/hr)
		Max.	Min.	Morn.	Eve.						
1	June 2008	32.1	23.6	77	51	21.4	2	4.4	6.6	344.3	11.5
2	July	31.3	23.1	82	54	27.8	3	5.8	5.8	355.2	9.7
3	August	31.8	22.7	88	54	66.3	4	5.0	5.4	334.6	7.8
4	September	31.5	21.7	84	52	26.3	4	7.1	5.5	383.0	7.0
5	October	28.2	22.0	91	62	312.9	14	5.5	3.8	321.1	4.0
6	November	30.2	20.8	91	55	43.6	5	5.6	3.3	356.8	3.8
7	December	28.6	19.2	90	51	11.1	1	6.4	3.3	373.4	4.7
8	January 2009	30.0	18.7	90	39	-	-	8.9	4.9	452.1	5.8
9	February	33.5	19.2	82	28	-	-	10.0	6.3	476.9	5.2
10	March	34.6	21.4	83	34	101.8	3	8.2	5.9	418.8	4.5
11	April	35.6	24	83	38	-	-	7.3	6.0	387.4	10
12	May	34.8	23.8	87	47	104.6	5	7.5	6.0	379.5	5.5