EFFECT OF SOIL AND FOLIAR APPLICATION OF VERMIWASH ON GROWTH, YIELD AND QUALITY OF TOMATO (*Lycopersicon esculentum* Mill.)

By

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THESIS
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1999

Dedicated to

MY BELOVED PARENTS

DECLARATION

I hereby declare that this thesis entitled "**Effect of soil and foliar application of vermiwash on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.)**" is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,

07-05-1999

RANI JASMIN

CERTIFICATE

Certified that this thesis entitled **"Effect of soil and foliar application of vermiwash on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.)"** is a record of research work done independently by Ms. Rani Jasmin under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

INTRODUCTION

1. INTRODUCTION

Organic farming is a very important component in sustainable agriculture. After years of using mainly chemical fertilizers, Asian farmers are now turning to organic fertilizers due to several reasons. Organic farming is defined as a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides and growth regulators. Organically produced food is recognized to be healthy as it is free from chemicals and have good quality also.

Organic manures improve the physical, chemical and biological properties of soil. Organic fertilizers help to control soil borne diseases, improve soil properties and help to maintain soil moisture content. Because they contain a wide variety of micro nutrients, they also help to adjust and improve the nutrient balance in soil which often deteriorates after repeated application of chemical fertilizers. But chemical fertilizers are needed for meeting the immediate requirement of the crop. So a judicious application of both organic and inorganic fertilizers are needed for sustaining the productivity of agricultural lands.

Vermitech, ie., introducing earthworms into soil or vermicomposting is the most natural, ancient and perhaps the best among all sustainable agricultural practices. Vermicomposting, the bioconversion of organic waste materials into nutritious compost by earthworm activity, is an important component of organic farming packages. Recycling of materials is an important aspects in solving the garbage problem. Garbage is the waste generally thrown out of our homes, parks, shops and other commercial establishment. Disposal of garbage is a serious problem today and needs much attention. Vermicomposting is an effective method of converting this garbage into nutritious vermicompost by the action of earthworm. Vermicompost is rich in plant nutrients compared to FYM or other organic manures. It can improve the physical, chemical and biological properties of soil. They are rich in microbes beneficial to plant growth. Vermicompost is valued for its content of humus and organic chemicals which have plant growth stimulatory properties, particularly that of roots.

Vermiwash, a liquid organic manure is an aqueous extract of a column of freshly formed vermicompost and surface washings of earthworms which contain beneficial microorganisms and water soluble fractions of substances present in both vermicompost and body surface of the earthworms. The nutrients present in vermiwash are in water soluble form and the immediate requirement of a number of components can be met from a single source. Vermiwash is highly alkaline in nature which suggests its potential for liming. Experiments have shown that soil application results in better availability of nutrients to plants in acid soil. No authentic research work has been reported till date. Vermiwash was very effective for foliar application of nurseries, lawns, and orchids (Ismail, 1995). The preliminary trials conducted in the Department of Soil Science and Agrl. Chemistry, College of Agriculture, Vellayani using different concentrations of vermiwash for foliar application in bhindi and cowpea showed encouraging results and the dilution required for both the crops are found to vary. At this point the present study was undertaken to find out the effect of vermiwash on tomato, an important vegetable of tropics and sub-tropics.

Tomato (*Lycopersicon esculentum* Mill.) known alternately as 'Poorman's orange' is one of the most important and choicest vegetable crops cultivated all over the world. It forms an important source of vitamins and minerals. It is consumed as salad, processed foods like ketch-up, jam and soup. Tomato responds well to the application of fertilizers and manures. The present study is undertaken with the following objectives.

1. To study the physico-chemical and biological properties of vermiwash and its effect on availability of plant nutrients;
2. To find out the effective concentration of vermiwash for maximum growth, yield and quality of tomato;
3. To evaluate the efficacy of soil and foliar application of vermiwash; and
4. To find out whether it is possible to minimise the input of inorganic fertilizers.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

In sustainable agriculture, the role of earthworms is well established. Vermicompost is a very important component of organic farming package. It is very easy to prepare and contains readily available nutrients, growth promoting substances and beneficial micro-organisms. Crops respond well to the application of vermicompost. Vermiwash is an aqueous extract of a column of freshly formed vermicompost and surface washings of the earthworms, containing beneficial micro-organisms and water soluble fractions of substances present in both vermicompost and body surface of the earthworms used for composting. Preliminary trials conducted in the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Vellayani using different concentrations of vermiwash as foliar application in bhindi and cowpea have given promising results. As this is a new area of research, no detailed research reports are available and hence studies related to vermiculture and impact of application of vermicompost in different crops are reviewed here under.

2.1 Effect of vermiculture / vermicompost on the growth and yield of crops

Increasing the use of organic sources of nutrients is important in organic farming and sustainable agriculture. It is well known that earthworms influence physical and chemical properties of soil (Georghengam and Brain, 1948). Their role in improving the soil fertility has been advocated by several early workers

(Barley and Jennings, 1959 ; Dash and Patra, 1979). Nitrogen excretion is an essential contribution of earthworms to soil fertility (Edwards and Lofty, 1980). Earthworm casts have been reported to contain more exchangeable cation (Lal and Akinene, 1983).

Tomati *et al.* (1983) reported the beneficial influence of worm casts due to the biological factors like gibberllins, cytokinins and auxins released by the metabolic activity of the microbes harboured in the cast.

Application of worm worked compost resulted in higher yield of paddy crop to the tune of 95 per cent increase in the grain and 128 per cent in straw and root production (Senapati *et al.*, 1985).

The importance of earthworm in the soil nitrogen cycle apparently lies on the fact that they increase either directly or indirectly the proportion of mineral nitrogen available for plants at any given time. This effect was proved in coniferous forests where the soil was commonly low in nutrients (James and Seastedt, 1986).

Sacirage and Dzelilovic (1986) obtained higher drymatter yield for teak growing in vermicompost. They also found that by the application of 4, 6 and 8 kg m^{-2} of vermicompost, the cabbage drymatter yield increased from 1 to 66 per cent. In watermelon, vigorous growth and increased number of flowers and fruits were observed when treated with vermicompost (Ismail *et al.*, 1991). In another study, Shuxin *et al.* (1991) obtained 30-50 per cent increase in plant growth and 10 per cent increase in height and effective tillering and diameter of sugarcane.

They also reported 20-25 per cent increase in height and 50 per cent increase in weight of soybean plants when vermicompost was applied.

Gunjal and Nikam (1992) reported earthworm inoculation in combination with heavy mulching of agricultural wastes all the year round as a successful practice for grape production without the application of chemical fertilizers.

Barve (1993) reported an increase in the yield and improved quality both in taste and attractive luster of grapes on application of vermicompost. Reduction in cost of cultivation is also indicated.

Phule (1993) obtained more sugarcane yield from vermiculture treated plots and also the juice had 3-4 more brix and lesser salts than chemical fertilizers applied. Ismail *et al.* (1993) studied the influence of vermicompost on the relative appearance, height of plants number of flowers and branches of Zinnea and reported that vermicompost treated plants showed more number of brighter coloured flowers and more number of branches per plant compared to FYM treated plants.

Vadiraj *et al.* (1993) reported that use of vermicompost as a component of potting mixture in cardamom nursery helped better seedling growth and drymatter production in a shorter period of time. Organic compost and chemical control resulted in similar yields, but with vermicomposting an additional yield 3.4 t ha^{-1} was obtained in lettuce (Santos *et al.*, 1993).

Sheshadri *et al.* (1993) conducted an experiment to study the comparative effect of vermicompost, farmyard manure and fertilizers on the yield of chilli. The results showed that yield of dry chillies obtained from vermicompost applied plot was higher than the control and FYM applied plot and lower than the fertilizer treated plot. But the yield of fresh chillies was maximum in the vermicompost treated plots compared to other treatments. Tomato grown after chilli gave yields similar to that of fertilizer treated plots (Desai, 1993).

Stephens *et al.* (1994) studied the ability of earthworm to increase plant growth and foliar concentrations of elements in wheat in sandy loam soil. They observed a significant increase in the plant yield, root and shoot weight and the foliar concentrations of elements like Ca, Na, Mn, Cu, Fe and Al.

Pushpa (1996) reported a seed yield of 105 per tomato fruit which received full inorganic fertilizer (as per POP recommendation) and 25 t ha^{-1} vermicompost.

The nitrogen levels of vermicompost ranged from 1.40 to 2.17 per cent and carbon levels from 23.6 to 30.0 per cent. The nitrogen and potassium levels of vermicompost were significantly higher than that of FYM and cattle dung (Bano and Suseela Devi, 1996). Sagaya Alfred and Gunthilagaraj (1996) obtained higher yield in amaranthus with the incorporation of earthworms into seedbed.

In vanilla, total root length, sprout length, number of leaves and leaf area per vine were found to be higher when vermicompost was used as the rooting medium (Siddagangaiah *et al.*, 1996)

Sarawad *et al.* (1996) reported that application of one tonne of vermicompost could substitute 25 to 50 per cent recommended dose of fertilizers. The study also revealed that physical properties of vertisol was improved with vermicompost application. Organic carbon and available phosphorus were also increased by the vermicompost application.

In cotton var. NH-44, yield was high in plots that received vermicompost compared to 100 per cent of the recommended dose of NPK through inorganic fertilizers (Jambhekar, 1996).

Ushakumari *et al.* (1996) conducted an experiment to study the seasonal response of bhindi to vermicompost. The results showed that when cattle manure was substituted by vermicompost in POP recommendation of Kerala Agricultural University for bhindi, the yield of green vegetables obtained was 105 per cent more.

Phebe (1998) reported that substitution of vermicompost for chemical fertilizers showed highest ascorbic acid content and lowest level of acidity in snakegourd.

2.2 Effect of organic manure other than vermicompost on the growth and yield of tomato

Application of filter press cake at about 10 tonnes / acre was found to increase the yield of marketable tomatoes by 6.76 t (Azzam and Samuel, 1964). Use of commercial as well as prepared starter solutions along with filter press cake led to further yield increase.

Graifenberg and Linardakis (1983) reported a significantly higher yield of tomato cv. Etna, when the plants were grown in pumice as compared to a 1 : 1 pumice peatmoss medium.

Araki *et al.* (1985) studied the effect of long-term application of sawdust, bark and peatmoss at the rate of 60 kg m^{-2} on continuous tomato cropping in a greenhouse. Average yield over 10 years, using a base index of 100 for rice straw plot were assumed as 107, 99 and 110 for sawdust, bark and peatmoss respectively.

The efficiency of solid and liquid fractions obtained from lignite as an organic fertilizer for tomato was studied by Salas *et al.* (1986) and reported that smaller addition of lignite produced similar yield to manure.

Hilman and Suwandi (1989) reported that sheep manure at 30 t ha^{-1} gave the highest yield (1.05 kg) of class one fruits in tomato cultivar Gondol.

Eilliot and Singer (1989) studied the effect of water treated sludge on growth and elemental composition of tomato in a greenhouse and concluded that sludge at 2-10 per cent dry weight raised the pH of silt loam from 5.3 to 8.0 which enhanced the growth.

Murillo *et al.* (1989) were of the opinion that successive application of city waste compost to tomato in a greenhouse experiment, resulted in an increase in yield.

Montegu and Gosh (1990) found that fruit colour of tomato was increased significantly on application of blood meal and bone meal.

Ahmed (1993) reported that incorporation of coirpith along with FYM (5-20 t ha^{-1}) into the soil one day prior to transplanting gave the highest fruit yield (19 t ha^{-1}) followed by 20 t ha^{-1} coir pith alone (16 t ha^{-1}) and lowest in control (11 t ha^{-1}) which were treated with neither FYM nor coir pith.

2.3 Effect of soil and foliar application of NPK on growth and yield of solanaceous crops

Khan and Suryanarayana (1977) reported the beneficial effect of P in increasing the girth of pods in chillies. In a fertilizer trial using N at 0, 60 and 120 kg ha^{-1} in all combinations on Ponderosa var. of tomato, Barooah and Zaman Ahmed (1983) found that application of N brought a permanent increase in yield. Beyond 60 kg ha^{-1} yield diminished. Plants receiving higher doses of P grew much faster. K application did not increase yield, but increased vitamin C content.

Kooner and Randhwa (1983) reported that plant growth, fruit and seed yield of tomato increased with increasing N rates. N at 50-200 kg ha^{-1} was tried.

The positive influence of N and P application on the seed yield of chilli was reported by Singh *et al.* (1991).

In a fertilizer trial, maximum yield of tomato was obtained at 40 kg ha^{-1} N as basal and 10 kg ha^{-1} as top dressing by foliar application (Anonymous, 1988).

Ram *et al.* (1988) reported that foliar spraying of Ti on tomato significantly increased drymatter production and the uptake of Mg, Ti, Al and V from the soil compared with control. Foliar spraying of 1 ppm was the most effective in increasing the drymatter yield over control by 0.442 g kg^{-1} pot containing 5 plants.

Biswas and Mallick (1989) reported that from sowing to first flowering, a minimum of 66 days was necessary, for another variety 82.67 days and for yet another 74.33 days.

Das and Singh (1989) in an experiment with tomato crop, reported that N was applied as basal dressing (40 kg ha^{-1}) and foliar spray (10, 20 or 30 kg ha^{-1}) alone or in various combination. Significant increase in total number of fruits per plot were obtained with N applied as basal dressing (40 kg ha^{-1}) and foliar spray (30 kg ha^{-1}) compared with other treatments.

Shanmughavelu (1989) reported that application of a combination of inorganic fertilizer and FYM was the best for firmness, storage life and keeping quality of tomatoes for a long time.

Subbarama *et al.* (1990) reported that shelf life of tomato was significantly improved by advancing the stage of harvest before red-ripe stage, extended shelf-life of 4.5-12.5 days. Acidity was low in mature green stage. The lycopene and carotenoids contents showed a progressive improvement from mature green stage to red ripe stage.

There was an increase in yield when Zn was applied compared to control. The increase ranged from 5.3 per cent to 94.5 per cent for 0.5 per cent foliar spray with 10 kg $ZnSO_4$ / feddom applied pre-sowing. Plant K, Ca, Fe and Zn concentration were increased, but Na and Mn concentrations were decreased. Mixing the $ZnSO_4$ with soil as pre-sowing was the most effective application method and that foliar application would be used as an emergency treatment if and when Zn deficiency is noted in a crop (El-Shereif *et al.*, 1990).

Singh and Verma (1991) reported that application of K at 120 kg ha^{-1} , Zn at 10 kg ha^{-1} and B at 2 kg ha^{-1} alone or in combination resulted in better plant growth and highest yield and income ha^{-1} of tomato. The positive influence of N and P application on the seed yield of chillies was reported by Singh *et al.* (1993).

2.4 Effect of combined application of organic and inorganic fertilizers on growth and yield of solanaceous crops

In an experiment with inorganic fertilizers and organic manures like FYM and groundnut cake, Chinnaswamy (1967) reported that the mixture of organic and inorganic fertilizers gave better results than organic manure given alone.

Hodos (1968) studied the effects of green manuring on tomato Green manure along with mineral fertilizer gave approximately 20 per cent higher yield than fertilizer alone.

Morelock and Hall (1980) compared the effects of broiler litter applied at different rates (0-8 t per acre) with a preplanting application of commercial fertilizer ($N_{10}P_{20}K_{10}$) at 250-750 lb per acre on field grown tomato plants Marketable fruit yield was found to increase with broiler application.

Subbiah *et al.* (1983) reported that the yield of brinjal fruit was significantly influenced by the level of farmyard manure, but not by the levels of fertilizer or by the interaction between FYM and inorganic fertilizer.

Yoshida *et al.* (1984) found that fertilization with bone and rape seed meals produced firm fruits with most cohesiveness, chewingness and uniform firmness at top and bottom of fruits.

Khavari and Nejad (1986) observed that fertilized compost treated tomato plants produced bigger sized fruits than those treated with Hewitt culture solution.

Zhang *et al.* (1988) reported that in comparison with the application of nitrogen alone, the combined use of nitrogen with soybean meal resulted in better growth, higher yield and better fruit quality.

Shanmughavelu (1989) pointed out that the application of a combination of FYM and inorganic mixture was the best for firmness, storage life and keeping quality of tomatoes for a long-term.

Almazov and Kholuyako (1990) reported that application of optimum dose of NPK along with peat increased drymatter production and yield of tomato crop compared to application of NPK alone. They also found an increase in sugar content.

Nair and Peter (1990) reported highest yield in chilli with FYM and NPK in three seasons compared to FYM alone or inorganic fertilizer alone.

An increase in fruit yield of grape to the tune of 40 per cent and 36 per cent due to the application of chemical fertilizers and vermicompost respectively over the control of nutrient application was reported by Gunjal and Nikam (1992).

2.5 Effect of organic and inorganic fertilizers on the quality of vegetables

Fritz and Habben (1972) reported that potassium fertilization increased vitamin C content in vegetables. Studies conducted by Krynska *et al.* (1976) with N at 80, 160 and 240 kg ha^{-1} and K at 120 , 240 and 360 kg ha^{-1} in cucumber revealed that vitamin C content of fruits increased with increasing N doses along with increase in yield of fruits but nitrogen rates had adverse effect in fruit quality.

Khan and Suryanarayana (1977) found that ascorbic acid content in fruits was increased to a maximum of 54.5 mg 100 g^{-1} by nitrogen application.

Kansal *et al.* (1981) opined that application of 20 t ha^{-1} farmyard manure increased the ascorbic acid content in spinach leaves.

Joseph (1982) observed that incremental doses of nitrogen and phosphorus significantly increased the ascorbic acid content of fruits. But K has no significant effect on ascorbic acid content. Dod *et al.* (1983) reported profound effect of nitrogen fertilization on ascorbic acid content.

Yoshida *et al.* (1984) found that fertilization with bone and rape seed meals produced firm fruits with most cohesiveness, chewingness and uniform firmness at top and bottom of fruits.

Low irrigation and high N level (120 kg ha^{-1}) gave fruits which kept best (Bhatnagar *et al.*, 1985). Application of 87.5 kg ha^{-1} N recorded maximum ascorbic acid content in chillies (Amarithalingam, 1988).

Studies conducted by Meire-ploeger and Lehri (1989) revealed that plants grown with compost produced tomato fruits with higher vitamin C content. Shanmughavelu (1989) pointed out that the application of a combination of FYM and inorganic mixture was the best for firmness, storage life and keeping quality of tomatoes for a long time.

Almazov and Kholuyako (1990) found increased sugar content in tomatoes due to the application of NPK along with peat compared to the application of NPK alone.

Pushpa (1995) reported an increased protein content in tomato fruits in plots receiving 100 t ha^{-1} of vermicompost.

Phebe Joseph (1998) reported that when vermicompost was used as the source of nutrients in snakegourd field, it produced fruits with more shelf-life, phosphorus and potassium content over FYM and poultry manure.

2.6 Effect of organic manure on the availability and uptake of nutrients

Havanagi and Mann (1970) reported that FYM application increased available P_2O_5 content of the soil, but not the total nitrogen in a long-term fertilizer experiment under dry farming conditions in Delhi. Incubation studies conducted by Debnath and Hajra (1972) observed that available K content increased up to 16^{th} day, decreased on 30^{th} day followed by an increase and then stabilised when FYM and daincha were added.

In wheat-maize rotation available N and P_2O_5 content of the soil increased with continuous use of FYM (Prasad and Singh, 1980).

Khan *et al.* (1981) reported that city compost raised the zinc and iron content of plants from deficiency to sufficiency level.

Available K increased slightly with the addition of FYM for a long time (Sharma *et al.*, 1984). Ahmed *et al.* (1984) reported that organic matter promoted grain P uptake which was greater with flooding.

Ganguly (1988) reported the beneficial effect of FYM on the uptake of all nutrients in maize. An increase in available N content of soil up to 20 days after FYM application and a decrease thereafter was noticed in a long-term field experiment with wheat (Gupta *et al.*, 1988).

Sharma and Sharma (1988) compared the effect of FYM and green manure and inferred that there was a build up of available K which was maximum with the use of FYM than green manure. Available phosphorus content of soil was significantly increased with incorporation of FYM.

Dhillon and Dhillon (1991) obtained increased N, P and K uptake in wheat due to incorporation of ground nut residue.

Dhanorkar *et al.* (1994) reported that continuous use of FYM raised the available K by 1.3 to 5.4 folds over control. Minhas and Sood (1994) opined that FYM application was beneficial in enhancing the uptake of all three major nutrients by potato and maize.

Pushpa (1996) reported an increased uptake of plant nutrients by tomato when vermicompost was used as a source of organic manure than FYM.

Phebe Joseph (1998) reported an increased cation exchange capacity of soils from plots applied with vermicompost compared to FYM and poultry manure.

2.7 Effect of organic liquid sprays on crop growth and soil properties

Varshney and Gaur (1974) in a microplot experiment on the sandy loam alluvial soils of Delhi inoculated soybean and subsequent tomato crop were sprayed four times with 125 ml per plot of solution of sodium humate extracted from FYM. Sodium humate at 10 and 50 ppm increased the seed yield of soybean by 24 and 14.5 per cent respectively and also increased nitrogen uptake. Corresponding increase in tomato yield were 109 and 104 per cent.

Kadhum *et al.* (1980) reported that of the seven fertilizer treatments evaluated, yield were highest and the root and shoot growth were best in plants receiving 6 lm^{-2} of a liquid organic fertilizer containing 60 g NPK (18 : 18 : 5).

Featumby and Staden (1983) reported that a commercial sea weed concentrate applied at a dilution of 1 : 500 to the foliage and the soil improved the growth of tomato plants with reduction in root knot nematode. Root growth was significantly improved.

Sarr and Ganry (1985) used rice husk compost + effluent (liquid produced during composting) at 7.5 t ha^{-1} gave tomato yields of 71.96 t ha^{-1} compared with 59.2 t ha^{-1} for control. He reported that any compost + effluent gave better yield than compost with out effluent.

Liquid fraction of lignite used as an organic fertilizer increased fruit yield and induced early fruiting in tomato (Salas *et al.*, 1986). Watery extracts from composted organic material greatly reduced disease development under lab condition in tomato leaves. Extracts from three different composts had similar effect (Weltzein *et al.*, 1987).

David *et al.* (1994) reported that addition of 1280 mg Humic acid / litre produced significant increase in accumulation of N, Cu, Fe and Zn in tomato seedlings. Fresh and dry weights were increased.

Humus preparation applied to the soil increased yield and advanced fruit ripeness by 4 to 5 days (Gonet and Cerny, 1996).

2.8 Microorganism in association with earthworms and vermicompost

Many scientists have reported the presence of microorganisms in the gut of earthworms (Citernesi *et al.*, 1977 ; Contreras, 1980 ; Hutchinson and Kamel, 1956 ; Khambata and Bhat, 1957 ; Parle, 1963a and b ; Sacheu, 1987 ; Satchell, 1967). Stockli (1928) found that there was increased number of bacteria and actinomycetes in the earthworm gut, compared to those in the soil. The number increased exponentially from anterior to posterior portions of the gut.

Ponomareva (1953) found an increase in the number of actinomycetes, pigmented bacteria and other bacteria of *Bacillus cereus* group, after passage through the earthworm intestine. The number of bacteria in the earthworm faeces was observed to be 13 times higher than in the surrounding soil (Ponomareva, 1962).

Atlavinyte and Lugauskas (1971) observed that earthworm increased the number of microorganism in soil as much as 5 times. They concluded that earthworms are important in inoculating the soil with microorganisms harboured in their casts.

Svenson *et al.* (1987) observed about 16 per cent higher carbondioxide evolution in the casts of *Lumbricus terrestris* than in the surrounding soil. Many other workers reported that microflora of cast soil was larger than that of the surrounding soil.

Kale *et al.* (1988) reported high metabolic rate and microbial load in worm worked soil. Cellulolytic organisms were more which led to high degradation of cellulose. The microbial load of the gut of the earthworms showed intense colonization in the anterior part of the intestine than in the other regions. The earthworm *Eudrillus eugeniae* stimulated microbial respiration by 15 to 18 per cent whereas, *Dendrobaena octaedra* stimulated it only slightly. The worms also raised the pH of leaching water and the humus (Haimi and Huhta, 1990).

Kale *et al.* (1992) observed that vermicompost application enhanced the activity of beneficial microbes like nitrogen fixers and mycorrhizal fungi. It played a significant role in nitrogen fixation and phosphate mobilization, leading to higher nutrient uptake by plants. Presence of VAM fungi in the casts of *Lumbricus terrestris* was demonstrated by the successful inoculation of sterile grown onion plants (Harinikumar and Bagyaraj, 1994).

Earthworm gut constitute a micro habitat, enriched in microbe capable of anaerobic growth and activity. Karsten and Druke (1995) found that the ratio of microbes capable of growing under obligate anaerobic conditions to those capable of growing under aerobic conditions was higher in the worm intestine than in the soil. Earthworm encourage mutualism and biodiversity in soil. Mobilisation of nutrients and organic resources through mutualism with soil microflora was encouraged by earthworm (Lavelle *et al.*, 1995).

Indira *et al.* (1996) reported that population of beneficial organisms like phosphorus solubilising bacteria, nitrogen fixing organisms and entomophagous fungi was in the range of 10^5 and 10^6 in vermicompost. Among the P solubilising organisms like *Bacillus* and *Aspergillus*, and nitrogen fixing organisms like *Azotobacter* and *Azospirillum* were prominent among the species.

Jiji (1997) reported that vermicompost produced with *Eudrillus eugeniae* was significantly superior over control with respect to the count of fungi and bacteria.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The study entitled, "Effect of soil and foliar application of vermiwash on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill.)" was carried out as two experiments at the College of Agriculture, Vellayani during 1995-97. The first experiment was a pot culture study and the second one a field trial based on the results of the pot culture experiment.

3.1 **Pot culture experiment**

The pot culture experiment was conducted during May-August 1996 to assess the optimum concentration of vermiwash to produce maximum yield in a test crop of tomato.

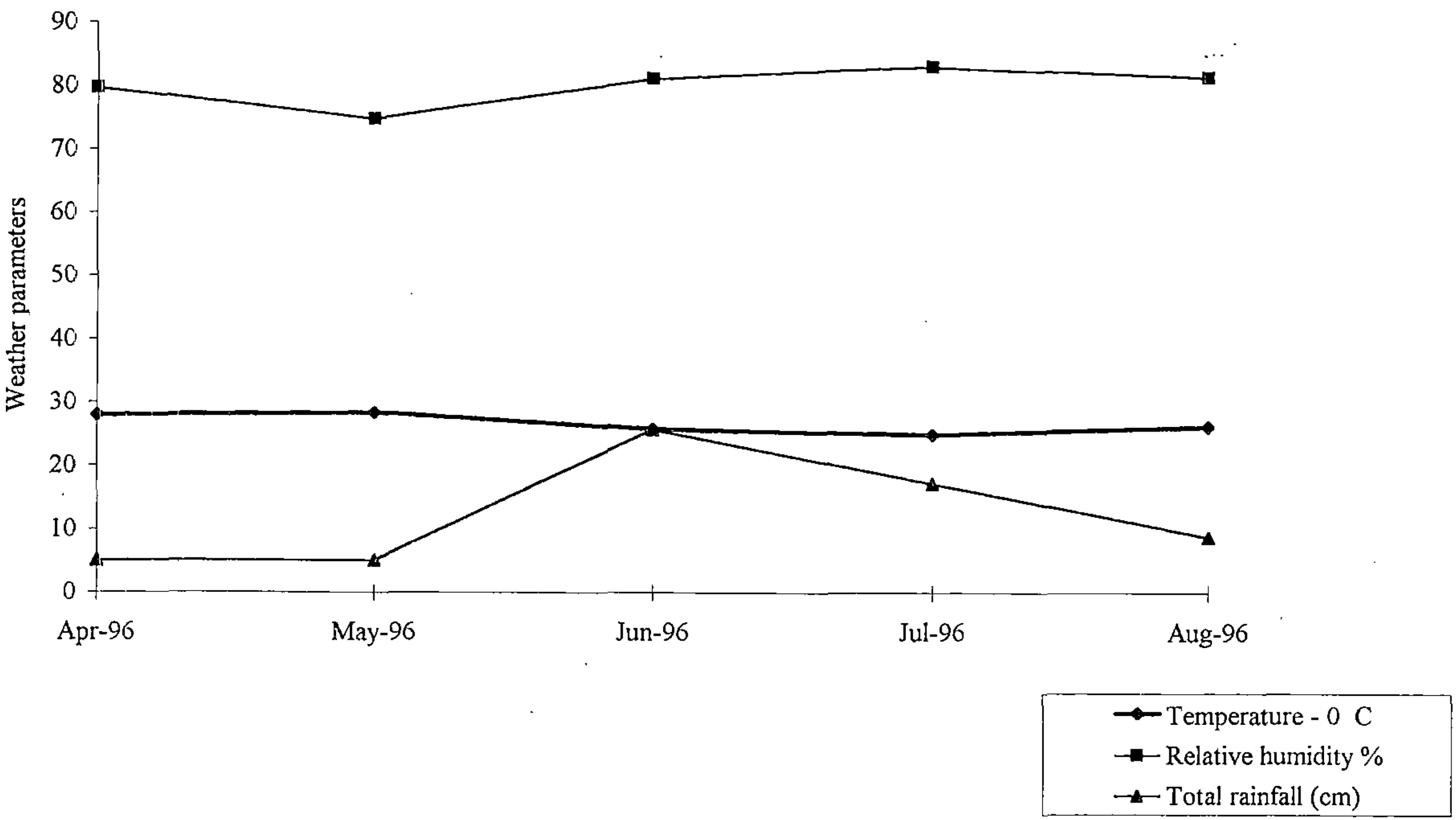
3.1.1 **Meteorological parameters**

The experiment is carried out at the College of Agriculture, Vellayani which is located at 8^0 30' N latitude and 76^0 54' E longitude. The data on various weather parameters like rainfall, maximum temperature, minimum temperature and relative humidity during the two cropping periods are given in Appendix I and graphically presented in Fig (1) and (4).

3.1.2 **Layout and design**

Layout plan of the pot culture experiment is given in Fig. (2). The details of the experiment are given below.

Fig. 1 Weather parameters during the pot culture experiment



Design : Factorial CRD

No. of treatments : 26 (3 x 4 x 2 + 2)

Replication : 2

Crop : Tomato

Variety : Sakthi

Treatment details

A. Method of application of vermiwash

m_1 - Foliar application

m_2 - Soil application

B. Levels of vermiwash

v_o - Water spray (Control)

v_1 - Vermiwash 100 %

v_2 - Vermiwash 50 % (diluted with water)

v_3 - Vermiwash 25 % (diluted with water)

v_4 - Vermiwash 12.5 % (diluted with water)

C. Levels of fertilizers

f_1 - Full NPK @ 75 - 40 - 25 kg ha^{-1} NPK as per Package of Practice Recommendations of Kerala Agricultural University, 1996 for tomato.

f_2 - 1/2 NPK

f_3 - 0 NPK

Fig. 2 Lay-out of pot culture experiment

R_1 (Foliar spraying)	R_2 (Foliar spraying)	R_1 (Soil application)	R_2 (Soil application)
T_8	T_2	T_2	T_3
T_4	T_6	T_9	T_5
T_6	T_{12}	T_3	T_8
T_2	T_3	T_{10}	T_9
T_9	T_5	T_4	T_2
T_3	T_{11}	T_{12}	T_{11}
T_{13}	T_{10}	T_{11}	T_{13}
T_5	T_4	T_7	T_{10}
T_{10}	T_8	T_8	T_4
T_{12}	T_9	T_{13}	T_7
T_7	T_7	T_5	T_{12}
T_{11}	T_{13}	T_6	T_6
T_1	T_1	T_1	T_1

Treatment combinations

Foliar (m_1)	Soil (m_2)
T_1 - v_0f_1 (Control)	v_0f_1 (Control)
T_2 - v_1f_1	v_1f_1
T_3 - v_1f_2	v_1f_2
T_4 - v_1f_3	v_1f_3
T_5 - v_2f_1	v_2f_1
T_6 - v_2f_2	v_2f_2
T_7 - v_2f_3	v_2f_3
T_8 - v_3f_1	v_3f_1
T_9 - v_3f_2	v_3f_2
T_{10} - v_3f_3	v_3f_3
T_{11} - v_4f_1	v_4f_1
T_{12} - v_4f_2	v_4f_2
T_{13} - v_4f_3	v_4f_3

3.1.3 **Vermiwash**

Vermiwash is the aqueous extract of a column of freshly formed vermicompost along with the surface washings of the earth worm, *Eudrillus eugineae* used for making the compost. It contains several beneficial organisms and nutrient elements in a water soluble form (Tables 1 and 2). Vermiwash is odourless. It does not undergo any decomposition and does not develop any unpleasant odour on storage.

3.1.3.1 **Preparation of vermiwash**

A cement tank of size 80 cm^3 was constructed for the collection of vermiwash as is given in plate (1) and Fig. (3). A layer of small brick pieces or gravels was placed at the bottom of the tank. Above it a layer of coconut

FIG: 3 TANK FOR PREPARATION OF VERMIWASH

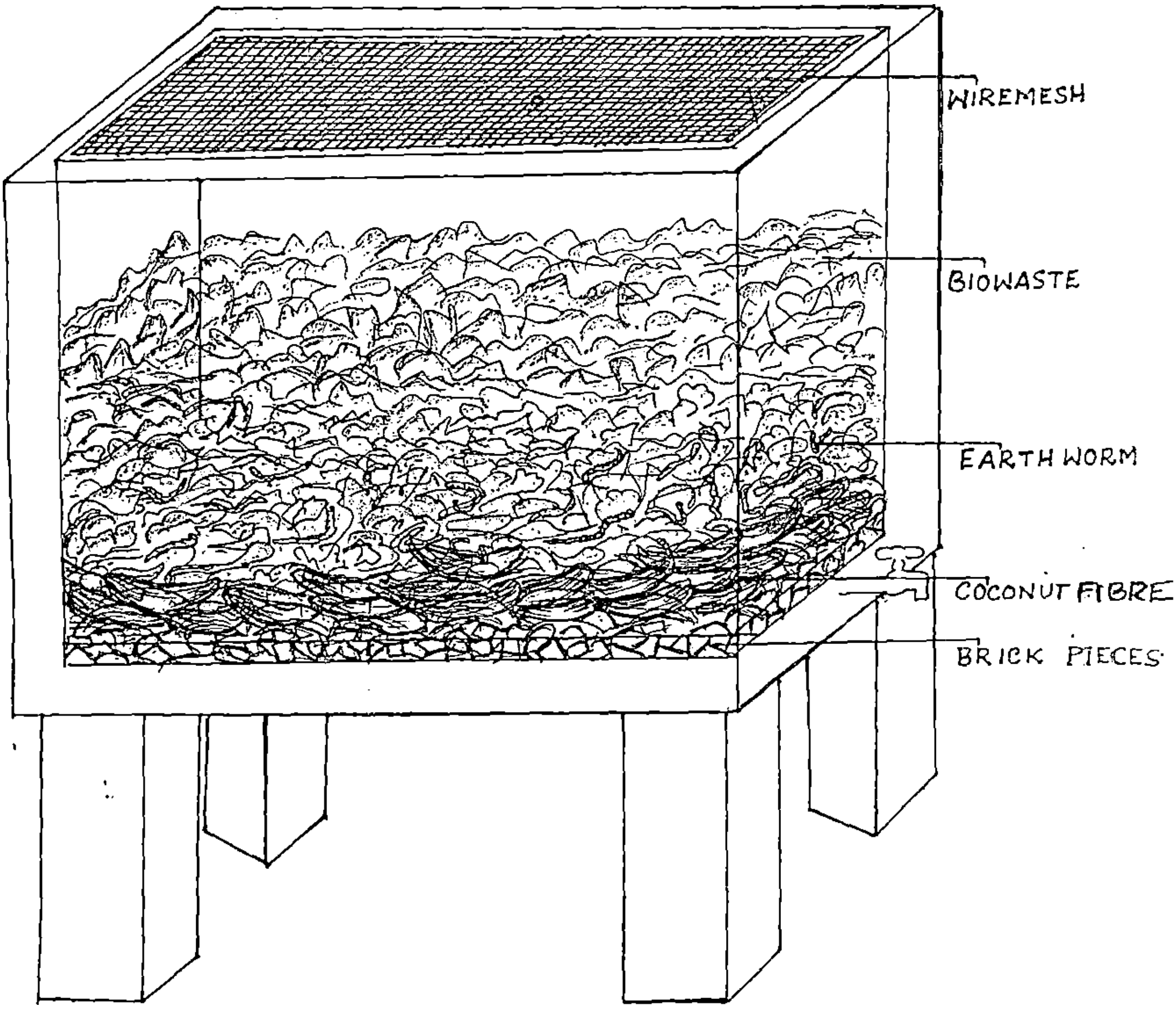


PLATE 1. STRUCTURE FOR PREPARATION OF VERMIWASH.

fibre of 3-4 cm thickness was placed. A definite quantity of biowaste (4 kg) was added to the system along with 2 kg of earthworms. After two weeks the entire mass of the biowaste turned into brownish black compost. Then 2 litre of water was added to the tank containing freshly formed compost and earthworms. Vermiwash was collected through the side tap after 24 hrs. Again biowaste was added to the system and the process was repeated till the entire quantity of vermiwash required for the experiment was collected.

3.1.3.2 **Application of vermiwash**

Vermiwash was sprayed to the crop two weeks after transplanting and at weekly intervals. Spraying was done with Knapsac sprayer and soil application (50 ml.) by pouring the prescribed concentration to the base of each plant. Application was stopped one week before the last harvest.

Table 1 **Physico-chemical properties of vermiwash**

Parameter	Quantity
Odour	Odourless
Colour	Honey brown
pH	8.7
EC	8.2 dSm^{-1}
Organic carbon	0.048 %
N	500 ppm
P	390 ppm
K	460 ppm
Ca	640 ppm
Mg	540 ppm
Fe	110 ppm
Mn	273 ppm
Zn	180 ppm
Cu	21 ppm

3.1.3.3 **Microbial analysis of vermiwash**

Microbial load in vermiwash was determined by culturing vermiwash on specific media purified in autoclave and is given in Table 2.

Table 2 Microbial count in vermiwash

Micro organism	Count / ml
Bacteria	3.5×10^6
Fungi	1.5×10^5
Actinomycetes	1×10^7
N fixing organism	1×10^3

The composition of different media is given in Appendix II.

3.1.4 **Nursery and planting**

Tomato seeds were sown in pots filled with potting mixture. The pots were drenched with phytolan (copper oxychloride) two days prior to sowing. After sowing the pots were irrigated twice daily.

Earthen pots of uniform size having 45 cm diameter were filled with 9 kg potting mixture (sand, soil and cowdung in the ratio of 1 : 1 : 1). One month old seedlings of uniform size were transplanted to the pots and shade was given till they were established.

3.1.5 **Fertilizer application**

Control pots were fertilized as per the Package of Practice recommendations of Kerala Agricultural University (75 - 40 - 25 kg ha^{-1} NPK) and other pots as per the treatments. Nitrogen as urea (46 % nitrogen) is given in three splits, Mussorie rock phosphate (20 % P_2O_5) as basal dose and MOP (60 % K_2O) in two splits were used as the sources of N, P and K respectively.

3.1.6 **Maintenance of the crop**

The crop was irrigated daily. No irrigation was given on the day of spraying. Weeds were removed as and when they appeared. The plants were stacked one month after transplanting.

3.1.7 **Pests and diseases**

Occurrence of epilachna beetle was found even in the early stage which could be effectively controlled by spraying Malathion (0.03 %). Fungal leaf spot also occured for which phytolan was effective. Fruit rot appeared during the fruit maturity stage. Indofil M 45 (0.02 %) spraying reduced the intensity to a great extent. A few fruits showed blossom end rot in the early maturity stage.

3.1.8 **Harvesting**

The fruits were picked when a slight yellow colour appeared. Harvesting was continued for one month. Fruit yield per plant was recorded.

3.1.9 **Statistical analysis**

Yield data were analysed statistically for selecting the best treatments.

3.2 **Field experiment**

A field experiment was carried out in the IV^{th} block of Instructional Farm, College of Agriculture, Vellayani during September - January 1996-97.

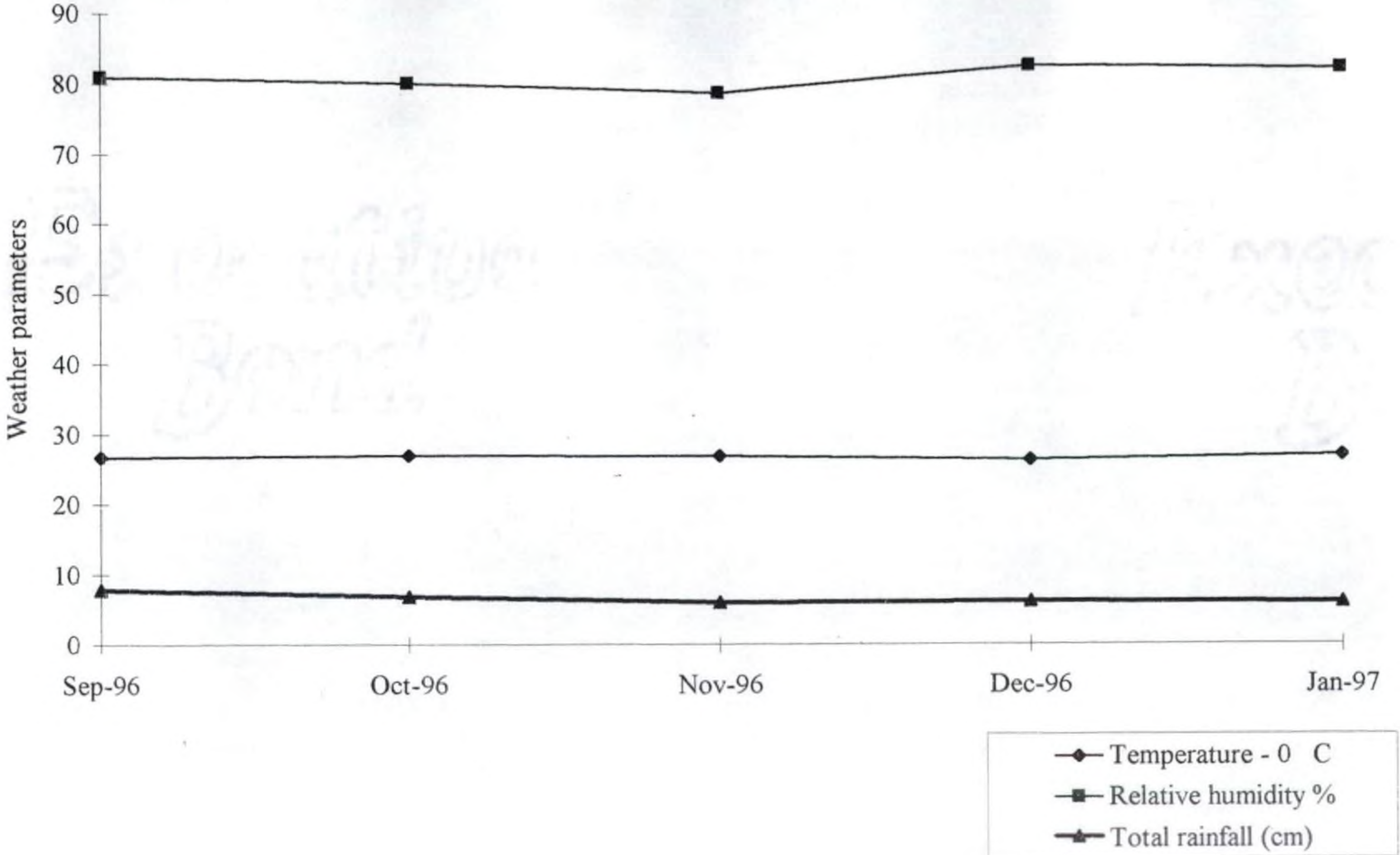
3.2.1 **Soil**

The soil of the experimental site was red loam coming under the order Oxisol belonging to the family of fine loamy, kaolinitic, isohyperthermic, Rhodic Haplustox. The physcio-chemical properties of the soil where the field experiment was conducted were given in Table 3.

Table 3 **Physico-chemical properties of soil of the experimental site**

Parameters	Quantity
Coarse sand	20.8 per cent
Fine sand	28.0 per cent
Silt	26.1 per cent
Clay	25.1 per cent
Texture	Sandy clay loam
Organic C	0.7 per cent (medium)
pH	5.3
EC	< 0.05 dS m^{-1}
CEC	1.2 $cmol^{(+)}$ kg^{-1}
Available N	305.8 kg ha^{-1} (medium)
Available P_2O_5	39.7 kg ha^{-1} (high)
Available K_2O	119.3 kg ha^{-1} (medium)

Fig. 4 Weather parameters during the field experiment



3.2.2 **Layout and design**

Layout plan of the experiment is given in fig. (5). The details of the experiment were given below.

Design	: Factorial RBD
Number of treatments	: 24 (2 x 4 x 3)
Replication	: 2
Plot size	: 2 x 2 m
Spacing	: 45 x 60 cm
Crop	: Tomato
Variety	: Sakthi

Treatment combinations

A. Method of application

m_1 - foilar application

m_2 - soil application

B. Levels of vermiwash

v_o - Water spray (Control)

v_1 - vermiwash 50 % (diluted with water)

v_2 - vermiwash 25 % (diluted with water)

v_3 - vermiwash12.5 % (diluted with water)

C. Levels of fertilizers

f_1 - full NPK (as per POP of Kerala Agricultural University, 75-40-25 kg ha^{-1} NPK)

f_2 - 1/2 NPK

f_3 - 0 NPK

Fig. 5 Lay-out of field experiment

R_1	R_2	R_1	R_2
(Foliar spraying)		(Soil application)	
T_3	T_8	T_{12}	T_1
T_9	T_3	T_5	T_8
T_6	T_{11}	T_9	T_{12}
T_1	T_6	T_{11}	T_2
T_4	T_5	T_2	T_4
T_{11}	T_{10}	T_7	T_6
T_{12}	T_2	T_{10}	T_{10}
T_2	T_4	T_1	T_3
T_8	T_9	T_4	T_7
T_5	T_{12}	T_6	T_{11}
T_{10}	T_7	T_8	T_9
T_7	T_1	T_3	T_5

Treatment combinations

	Foliar (m_1)	Soil (m_2)
T_1 -	v_0f_1	v_0f_1
T_2 -	v_0f_2	v_0f_2
T_3 -	v_0f_3	v_0f_3
T_4 -	v_1f_1	v_1f_1
T_5 -	v_1f_2	v_1f_2
T_6 -	v_1f_3	v_1f_3
T_7 -	v_2f_1	v_2f_1
T_8 -	v_2f_2	v_2f_2
T_9 -	v_2f_3	v_2f_3
T_{10} -	v_3f_1	v_3f_1
T_{11} -	v_3f_2	v_3f_2
T_{12} -	v_3f_3	v_3f_3

3.2.3 Manures and fertilizers

FYM @ 20 t ha^{-1} was applied at the time of preparatory cultivation. The fertilizers applied were urea (46 % N), Mussoorie rock phosphate (20 % P_2O_5) and MOP (60 % K_2O).

3.2.4 Details of cultivation

3.2.4.1 Nursery

Raised beds of 1 x 1 m size was prepared for raising seedlings. The bed was drenched with phytolan (@ 3 g/l) two days before sowing to check the occurrence of damping off. Seeds of variety Sakthi which had shown good germination percentage were sown and irrigated twice in a day.

3.2.4.2 Land preparation

The main field was dug twice and plots of size 2 x 2 m were taken with bunds of width 60 cm all around. Individual plots were again dug, properly levelled and drenched with phytolan. Small ridges were taken 45 cm apart. One month old seedlings were transplanted in ridges at 60 cm spacing. the seedlings were given uniform irrigation and shade was also provided till they were established.

3.2.4.3 Application of vermiwash

Vermiwash was applied at weekly intervals. Foliar spraying was done in the early morning using Knapsac sprayer. For soil application, it was applied at the base of each plant (50 ml / plant).

3.2.4.4 Application of fertilizers

Fertilizers were applied as per the schedule of treatments. The entire dose of P, half of N and K were applied as basal dressing one week after transplanting. One fourth of N and half of potash were applied I MAT and the remaining quantity of N at 2 MAT.

3.2.4.5 Maintenance of the crop

During the initial stages, irrigation was given twice daily. Gap filling was done on fifth day after transplanting. After the establishment of the crop, irrigation was given once in two days. The plants were stacked 1 MAT. Weeds were removed as and when necessary.

3.2.4.6 Incidence of pests and diseases

3.2.4.6.1 Pests

Attack of epilachna beetle was a problem during the initial stages. It could be effectively controlled by spraying malathion (0.03 %). Sporadic incidence of fruit borer was also there for which 0.05 % Ekalux 25 EC was used. Phorate 10 G at the rate of 1 g $plant^{-1}$ was applied at the base of the plant as a prophylatic measure against root knot nematode.

3.2.4.6.2 Diseases

Spraying and drenching with phytolan to prevent the occurrence of damping off and other fungal diseases. Some fruits showed blossom end rot at the maturity stage. Dithane M - 45 (mancozeb) 0.3 % was used for the control of fruit rot.

3.2.5 Observations recorded

Four plants in the centre of each plot were marked for observations.

3.2.5.1 Flowering date

Flowering date of the observational plants was recorded as the number of days from the day of sowing to the day of first flower bud appearance. Flowering in the entire area was completed within one month.

3.2.5.2 Leaf area

Total leaf area of a plant was determined at the maximum flowering stage using Leaf Area Meter (L1 - COR Model 3100 Area Meter).

3.2.5.3 Harvest and fruit yield

The crop was ready for first harvest 2 MAT and subsequent harvests were made at an interval of 3-4 days. Harvesting was carried out for nearly one month. Total weight of the fruits from the observational plants were recorded.

3.2.5.4 Average fruit size

Four fruits were selected from each plant and diameter at the middle portion was recorded.

3.2.5.5 Average seeds per fruit

When the fruits were fully ripe, seeds were removed and counted. From each plant, four fruits were selected and the average was taken.

3.2.5.6 Biomass production

Observational plants were carefully removed alongwith roots, washed free of adhering soil particles, dried between folds of blotting paper, air dried and then oven dried to constant weight at 65^0C. The oven dry weight of the plant was taken as the total dry matter or biomass produced.

3.2.5.7 Root shoot ratio

Roots and shoots were separated oven dried at 65^0C and weight was recorded separately. Root shoot ratio for the oven dried sample was calculated.

3.2.6 Quality parameters of fruits

3.2.6.1 Shelf life at room temperature

The number of days taken from the period of harvest to the stage when rotting appeared was taken as the shelf-life or storage life at room temperature.

3.2.6.2 Vitamin C

Ascorbic acid content of ripe fruits was determined by titrimetric method (Ramganna, 1977) and expressed in mg/100 g of fruit.

3.2.6.3 Lycopene

Fruits which had attained the maximum red colour were used for the estimation. A known weight of the fruit was extracted with acetone and then taken in a separating funnel containing petroleum ether. Lycopene which is dissolved in petroleum ether formed a separate layer above the acetone. The ether extract containing the carotenoids was poured into a brown bottle containing one gram anhydrous Na_2SO_4. After keeping it for 30 minutes transferred to a volumetric flask and the colour intensity was measured using PE as blank in Klett-Summerosn Photoelectric Colorimeter (Sadasivam and Manickam, 1992).

3.2.6.4 Crude fibre

Crude fibre of the ripe fruit was determined by the methodology suggested by Sadasivam and Manickam (1992).

3.2.6.5 Viability of seeds

The number of seeds which germinated when kept for a period of two weeks under moist condition was taken as the germination count or viability and expressed in percentage.

3.2.7 Nutrient status of soil and plant

3.2.7.1 Soil analysis

Soil samples were collected from each plot at the maximum flowering stage and after harvest. Samples were taken from a depth of 0-15 cm from four locations in the plot. Composite samples prepared from this was air dried under shade, gently ground and sieved through 2 mm sieve and used for analysis.

3.2.7.2 Plant analysis

One plant out of the four observational plants was uprooted after the harvest and root was removed. The plant was washed with water to remove adhering soil particles, chopped, air dried and then dried at 65^0 C in a hot air oven. The dried samples were powdered in a Wileymill and used for analysis.

3.2.7.3 Fruit analysis

Mature fruits were collected from the plant during the second and third harvest. They were sliced, air dried and then oven dried at 65^0C. They were powdered and used for analysis.

3.2.7 Chemical analysis

Soil, plant and fruit samples collected for chemical analysis were analysed using the following methods given below

Sl. No	Parameter	Method	Reference
I	Soil analysis		
	Mechanical analysis	International Pipette method	Piper (1966)
	pH	pH meter with glass electrode	Jackson (1973)
	Available C	Walkley - Black method	Jackson (1973)
	Available N	Alkaline Permanganate method	Subbiah and Asija (1956)
	Available P_2O_5	Bray No. 1 extract and Klett-Summerson Photoelectric colorimeter making use of chlorostannus reduced phosphoric blue colour.	Jackson (1973)
	Avaliable K_2O	Neutral normal ammonium acetate extract and Flame Photometer	Stanford and English (1949)

II Plant and fruit analysis

N	Modified Kjeldahl's method	Jackson (1973)
P	Vanadate molybdate yellow colour method and Klett-Summerson Photoelectric Colorimeter	Jackson (1973)
K	Flame photometry	Stanford and English (1949)
Ca, Mg, Mn, Zn, Cu	Atomic Absorption Spectrophotometry	Piper (1966)

3.2.7.5 Uptake of nutrients

Uptake of N, P, K, Mg, Mn, Zn and Cu was calculated from their contents in the plant parts multiplied by their respective dry weight.

3.2.8 Statistical analysis

The data collected from the study was subjected to statistical methods of analysis such as analysis of variance and correlation to find out the relationship between variables and to draw definite conclusions (Snedecor and Cochran, 1975).

RESULTS

4. RESULTS

Results based on statistically analysed data pertaining to pot culture experiment and field experiment conducted during the course of investigation are presented in this chapter.

4.1 Pot culture experiment

Pot culture experiment was conducted as a preliminary trial to assess the best concentration of vermiwash when applied as foliar or soil applications along with graded doses of NPK on tomato, the test crop. Treatment effects were evaluated on fruit yield basis.

4.1.1 Fruit yield

Data on the effect of different treatments on fruit yield of tomato are presented in the Table 4.

There was significant difference on the fruit yield of tomato by the application of vermiwash. But no significant difference was observed on the method of application of vermiwash. Among all the treatments, T_5, showed the highest yield (1045.37g pl^{-1}) and significantly superior over the control (T_1). Treatments with lower concentrations (50, 25 and 12.5 %) were on par and but significantly superior over T_1. Treatments with highest concentration of

Table 4. Effect of treatments on fruit yield of tomato (g $plant^{-1}$)

Treatments	Fruit Yield g pl^{-1}		
	Foliar (m_1)	Soil (m_2)	Mean
T_1	485.4	490.8	488.11
T_2	611.2	781.6	693.43
T_3	768.3	876.3	822.31
T_4	622.5	494.5	558.50
T_5	1075.1	1015.6	1045.37
T_6	899.0	901.1	900.09
T_7	507.9	1142.8	825.36
T_8	1009.7	649.4	829.57
T_9	982.0	1144.9	1036.47
T_{10}	861.5	1001.5	931.54
T_{11}	1045.3	980.4	1012.81
T_{12}	968.1	994.3	981.19
T_{13}	529.9	1168.0	848.90
Mean	797.38	895.41	

CD for (m) - NS
CD for (T x m) - NS
CD for (T) - 311.07 (106.98)

CD values are given wherever f values are significant and SE values are given in bracket

vermiwash (100 %) showed lower values, compared to treatments receiving lower concentration.

4.2 Field experiment

Based on the results of the pot culture experiment, vermiwash concentrationof 50, 25 and 12.5 per cent were selected for conducting field experiment using the same test crop, tomato. The data on growth, yield, plant characters and important soil properties are given below. The physico-chemical and biological properties of vermiwash used for the experiment are given in Tables 1 and 2 respectively. The physico-chemical properties of the soil of the experimental site is given in Table 3.

4.2.1 Number of days taken to flower

The data on the number of days taken to flower is presented in Table 5. The treatments did not produce any significant difference on the number of days taken to flower. But in general treatments receiving vermiwash took only lesser number of days to flower compared to control treatments (T_1, T_2 and T_3).

4.2.2 Leaf area at 50 per cent flowering

The data on the leaf area of tomato is presented in Table 5. The different concentrations of vermiwash did not produce any significant difference on the leaf area of tomato. But between foliar and soil application, foliar application was

Table 5. Effect of treatments on the leaf area and number of days taken to flower

Treatments	Leaf area ($cm2\ pl^{-1}$)			Number of days to flower		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	1940.49	1970.52	1955.00	63.5	71.0	67.3
T_2	1733.86	1055.95	1394.90	75.5	74.0	74.8
T_3	1219.41	974.89	1097.15	71.0	69.5	70.3
T_4	1783.25	1690.84	1737.04	63.5	62.0	62.8
T_5	1776.45	1724.11	1750.28	76.0	62.5	63.0
T_6	1245.27	1213.99	1229.63	65.0	69.0	72.5
T_7	1741.85	934.39	1338.12	68.5	65.5	65.3
T_8	1207.92	968.90	1097.41	64.5	68.0	68.0
T_9	923.33	952.41	937.87	62.0	69.0	66.8
T_{10}	2328.52	771.03	1549.77	68.0	70.5	66.3
T_{11}	543.69	1356.28	949.98	78.0	64.5	66.0
T_{12}	1302.49	907.50	1104.99	68.0	69.0	73.5
Mean	1478.87	1211.57		68.35	67.8	

CD for (m)	- 183. 84	(m)	- NS
CD for (T x m)	- NS	(T x m)	- NS
CD for (T)	- NS	(T)	- NS

CD values are given wherever f values are significant and SE values are given in bracket

found to be significantly superior over soil application. In foliar application, T_{10} showed the highest value which is significantly superior over all other treatments. T_{11} produced the lowest value. In soil application, T_1 produced the highest value (full NPK) followed by T_4.

4.2.3 Fruit size

Table 6 shows data on the effect of different treatments on the fruit size of tomato. It may be seen that the treatments did not produce any significant difference on the fruit size of tomato.

4.2.4 Fruit yield

Significant difference in the fruit yield of tomato is observed (Table 6) due to the different treatments. Highest yield (18.33 t ha^{-1}) was recorded by the treatment T_{10} in which 12.5 per cent vermiwash was given as soil application along with full NPK and was significantly superior over all other treatments. T_1, T_2 and T_3 of soil and foliar applications were on par. There was a decreasing trend in yield with decreasing levels of inorganic fertilizers. At the lowest concentration (12.5 per cent) of vermiwash, soil application was found to be better than foliar application. But at 50 per cent and 25 pre cent concentration of vermiwash, in general foliar application was found to be superior over soil application. When vermiwash was given along with full NPK (POP of KAU) a marked increase in fruit yield was obtained. In foliar application of vermiwash, T_4 recorded the highest yield (16.44 t ha^{-1}) followed by T_7

Table 6. Effect of treatments on fruit size, fruit yield and number of seeds per fruit

Treatment	Fruit size (cm)			Fruit yield (tha^{-1})			Number of seeds per fruit		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	11.13	10.47	10.80	11.13	12.05	11.59	114.0	94.0	104.0
T_2	12.00	11.32	11.66	7.93	9.34	8.63	88.5	83.5	86.0
T_3	12.20	13.40	12.80	6.83	6.87	6.85	88.5	89.5	89.0
T_4	12.47	12.63	12.55	16.44	12.99	14.71	104.5	84.0	94.3
T_5	11.77	12.63	12.20	11.01	9.13	10.07	92.0	82.0	87.0
T_6	11.59	11.67	11.63	7.56	9.89	8.73	98.5	84.0	91.3
T_7	12.60	11.63	12.12	15.68	11.47	13.57	101.5	74.5	88.0
T_8	12.05	11.49	11.17	10.25	8.78	9.52	98.0	71.0	84.3
T_9	11.27	11.54	11.40	8.43	7.38	7.90	99.0	62.5	80.7
T_{10}	11.92	11.58	11.90	12.19	18.33	15.26	87.0	69.5	78.3
T_{11}	12.24	12.57	12.40	5.70	11.08	8.39	102.5	87.5	95.0
T_{12}	12.45	10.83	11.64	2.61	9.25	5.39	85.5	82.5	84.0
Mean	11.97	11.84		9.60	10.55		96.63	80.38	

Fruit size	Fruit yield	Number of seeds per fruit
CD for (m) - NS	(m) - 0.44 (0.15)	(m) - 3.93 (1.34)
CD for (T x m) - NS	(T x m) - 1.53 (0.52)	(T x m) - NS
CD for (T) - NS	(T) - 1.08 (0.37)	(T) - 9.62 (3.29)

CD values are given wherever f values are significant and SE values are given in bracket

(15.68 t ha^{-1}) both of which differ significantly from rest of the treatments in foliar application. T_5 (50 per cent vermiwash + ½ NPK), T_8 (25 per cent vermiwash + half NPK) and T_{10} (12.5 per cent vermiwash + full NPK) of foliar spray produced the same effect as T_1 (POP of KAU - Control).

4.2.5 Seeds per fruit

The data on the number of seeds per fruit is given in Table 6. The treatments produced significant difference on the number of seeds per fruit. Foliar spraying was found to be significantly superior over soil application in the seed production. Among the different treatments T_1 in foliar spraying produced the highest value which was on par with T_4 and significantly superior over all other. T_9 in soil application showed the lowest value for the number of seeds per fruit.

4.2.6 Total dry weight of the plant

Dry matter yield of the plant at harvest of the crop is presented on Table 7. It may be noted that treatments produced no significant difference on the dry weight of the plants.

4.2.7 Root - shoot ratio

Effect of treatments on root - shoot ratio is presented in Table 7. There was no significant variation in root - shoot ratio of the plants by the application of

Table 7. Dry weight and root - shoot ratio influenced by the different treatments

Treatment	Dry weight (kg ha^{-1})			Root - shoot ratio		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	747.2	1245.2	996.2	0.22	0.18	0.20
T_2	1086.0	1113.8	1099.2	0.26	0.19	0.22
T_3	850.6	1091.7	971.2	0.14	0.28	0.21
T_4	1141.6	712.7	927.2	0.17	0.20	0.19
T_5	938.0	1404.55	1174.3	0.31	0.22	0.26
T_6	961.3	945.6	978.5	0.24	0.20	0.22
T_7	1014.4	1093.9	1054.2	0.23	0.19	0.21
T_8	1930.4	990.0	1460.2	0.18	0.15	0.17
T_9	957.2	1071.5	1014.4	0.17	0.19	0.18
T_{10}	871.5	738.9	805.2	0.21	0.24	0.23
T_{11}	1039.2	1171.1	1105.2	0.26	0.25	0.25
T_{12}	838.7	981.3	910.0	0.17	0.16	0.17
Mean	961.6	1046.7		0.21	0.20	

CD for (m) - NS (m) - NS

CD for (T x m) - NS (T x m) - NS

CD for (T) - NS (T) - NS

CD values are given wherever f values are significant and SE values are given in bracket

vermiwash. The highest value was recorded (0.31) by the foliar application of vermiwash at 50 per cent concentration level along with half NPK fertilizers (T_5).

4.2.8 Shelf life of fruits

The data on the effect of the different treatments on the shelf - life of fruits is given in Table 9. The different concentrations of vermiwash and the method of application produced significant difference. Soil application of vermiwash produced fruits with better shelf - life compared to foliar spraying. Among the treatment T_1, showed the highest value (15.5 days) which was on par with T_3, T_4, T_7, T_8 and T_{10}. In foliar application, lowest concentration was found to be better for longer shelf - life whereas in soil application, higher concentration resulted in better shelf - life.

4.2.9 Vitamin C content of fruits

No significant difference was observed on the vitamin C content of tomato fruits by the application of different concentration of vermiwash (Table 8). But significant difference was observed between soil and foliar application. In foliar application, T_4 showed the highest value which is significantly superior over all other treatments and T_3 produced the lowest value. In soil application, T_5 was found to be significantly superior cover all other treatments and T_3 showed the lowest value for vitamin C content.

Table 8 Effect of treatments on the quality of fruits

Treatments	Vitamin C (mg. $100g^{-1}$)			Lycopene (mg. $100g^{-1}$)			Crude fibre (%)		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	25.65	19.96	22.80	2.66	4.22	3.44	0.20	0.26	0.23
T_2	17.84	16.58	17.21	2.83	2.35	2.59	0.21	0.20	0.21
T_3	16.15	11.40	13.77	2.65	2.44	2.54	0.17	0.20	0.18
T_4	30.06	25.77	27.92	2.94	3.57	3.26	0.28	0.21	0.24
T_5	20.83	29.20	25.01	2.12	2.40	2.57	0.23	0.19	0.21
T_6	18.91	21.22	20.06	2.12	2.75	2.43	0.21	0.20	0.20
T_7	27.20	23.42	25.31	2.40	3.11	2.75	0.25	0.26	0.25
T_8	18.93	11.60	15.27	2.94	2.97	2.95	0.21	0.23	0.22
T_9	18.84	15.78	17.31	4.17	2.34	3.25	0.21	0.18	0.19
T_{10}	21.76	22.08	21.92	3.03	4.83	3.93	0.20	0.28	0.24
T_{11}	21.50	12.42	16.96	2.40	1.95	2.17	0.23	0.25	0.24
T_{12}	18.70	13.04	15.87	1.84	2.04	1.96	0.19	0.20	0.19
Mean	21.36	18.54		2.68	2.96		0.22	0.22	

CD for (m) - 2.39 (0.82)	(m) - NS	(m) - NS
CD for (T x m) - NS	(T x m) - NS	(T x m) - NS
CD for (T) - NS	(T) - 1.02 (0.35)	(T) - NS

CD values are given wherever f values are significant, SE values are given in bracket

Table 9 Shelf - life of fruits and fermination percentage of seeds as affected by the different treatments

Treatments	Shelf life (days)			Germination (%)		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	15.5	15.5	15.5	95	97	96.0
T_2	10.5	11.0	10.8	85	81	83.0
T_3	11.0	14.0	12.5	73	70	71.5
T_4	11.5	18.0	14.8	97	93	95.0
T_5	9.0	10.0	9.5	86	83	84.5
T_6	10.0	10.0	10.0	75	66	70.5
T_7	12.5	15.5	14.0	94	91	92.5
T_8	10.5	14.0	12.3	86	79	82.5
T_9	11.5	10.0	10.8	76	63	69.5
T_{10}	15.5	12.5	14.0	93	89	91.0
T_{11}	13.0	11.0	12.0	83	75	79.0
T_{12}	10.5	12.5	11.5	64	61	62.5
Mean	11.75	12.83		83.00	79.00	

CD for (m)	- 0.87 (0.30)	(m)	- 2.01 (0.69)
CD for (T x m)	- 3.03 (1.03)	(T x m)	- NS
CD for (T)	- NS	(T)	- NS

CD values are given wherever f values are significant and SE values are given in bracket

4.2.10 Lycopene content of fruits

The data on the effect of different treatments on the lycopene content of fruits are presented in Table 8. No significant difference on the lycopene content is noticed between foliar and soil applications. But significant difference was observed among the different treatments. T_{10} showed the highest value (3.93 mg 100 g^{-1} fruit) among all the treatments.

4.2.11 Crude fibre

Table 8 shows data on the effect of treatments on the crude fibre content of fruits. It is notified that no significant difference was observed in the crude fibre content of fruits by the application of different concentrations of vermiwash.

4.2.12 Germination percentage of seeds

The data on the Table 9 shows that the treatments did not produce any significant difference on the germination percentage of seeds. However, foliar application produced seeds with more germination capacity over soil application.

4.2.13 Available soil NPK at flowering stage of the crop

The data presented in the Table 10 reveals that the application of vermiwash produced significant difference in the available soil N at flowering stage of the crop. But no significant difference on the method of application of

Table 10 The available N, P and K content in the soil influenced by the treatments at the time of flowering

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	478.67	439.28	458.98	46.06	53.45	49.75	125.74	163.62	144.68
T_2	387.98	415.17	401.58	41.70	36.80	39.25	98.91	110.23	104.52
T_3	331.29	405.41	368.35	42.20	22.50	32.38	104.71	36.96	70.52
T_4	441.37	417.83	429.60	60.75	44.10	52.43	118.72	128.13	122.92
T_5	366.90	353.48	360.19	45.05	23.80	34.43	173.20	104.16	138.68
T_6	342.03	388.58	340.30	29.55	18.40	23.97	141.20	33.60	87.36
T_7	343.04	400.46	371.75	48.15	56.10	52.13	189.48	126.53	158.01
T_8	334.27	374.22	354.25	43.20	36.35	39.77	145.20	72.13	108.67
T_9	411.22	386.35	398.78	24.30	25.10	24.70	88.48	36.48	62.48
T_{10}	314.82	320.76	317.79	46.55	54.90	50.72	182.16	126.10	154.13
T_{11}	372.12	313.20	342.60	38.10	39.04	38.57	170.96	113.12	142.04
T_{12}	366.52	299.97	333.24	25.30	22.65	23.98	108.64	110.88	109.76
Mean	374.19	372.06		40.91	36.10		137.22	96.74	

CD for (m) - NS
CD for (T x m) - NS
CD for (T) - 60.19 (20.57)

(m) - 3.41 (1.16)
(T x m) - NS
(T) - NS

(m) - 20.26 (6.93)
(T x m) - NS
(T) - NS

CD values are given wherever f values are significant and SE values are given in bracket

vermiwash. Among the different treatments. T_1 showed the highest value which is on par with T_4.

The different concentrations of vermiwash produced no significant difference on the available soil P at flowering stage. But the method of application produced significant difference. Foliar spraying of vermiwash was found to be significantly superior cover soil application. In foliar application, T_4 showed the highest value of 60.75 kg ha^{-1} which was significantly superior over all other treatments. In soil application, T_7 showed the highest value (56.10 kg ha^{-1}) which was on par with T_1 and T_{10} and the lowest value was shown by T_6 (18.40 kg ha^{-1}).

The treatments showed the same effect on the available K as that on the available P. Only the method of application produced significant difference. Here also foliar spraying was found to be significantly superior over soil application. In foliar spraying, T_7 showed the highest value (189.48 kg ha_{-1}) which was on par with T_5, T_{10} and T_{11}. In soil application, T_1 showed the highest value which was significantly superior over all other treatments.

4.2.14 Available soil NPK after harvest of the crop

The data on the available soil NPK after harvest of the crop are presented in the Table 11. The treatments did not produce any significant difference on the available soil N after harvest of the crop.

Table 11 Effect of treatments on the available soi N, P and K after harvest of the crop

Treatments	Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	363.73	281.92	322.83	34.60	36.15	35.38	117.74	136.32	127.19
T_2	304.63	304.35	304.63	35.20	28.25	31.72	90.40	101.41	96.15
T_3	222.39	317.91	270.15	30.45	19.85	25.15	95.49	33.32	64.40
T_4	341.74	268.98	305.36	46.95	33.10	40.02	114.10	115.92	114.95
T_5	254.17	246.60	250.38	33.15	15.40	24.28	123.45	88.57	106.01
T_6	199.39	223.20	211.29	27.30	16.95	22.13	114.09	33.67	73.83
T_7	237.92	264.33	251.12	43.20	43.20	43.20	150.67	102.52	126.59
T_8	273.94	328.43	301.18	35.10	25.95	30.53	123.62	61.66	92.64
T_9	282.41	282.20	284.30	15.25	17.55	16.43	77.66	34.47	56.07
T_{10}	237.11	177.43	207.64	25.30	37.90	31.60	119.41	115.32	117.36
T_{11}	273.90	223.39	248.64	25.55	27.10	26.33	132.31	79.81	106.06
T_{12}	237.53	142.28	189.90	23.45	18.90	21.18	96.31	95.49	95.90
Mean	269.07	255.42		31.29	26.69		112.93	83.26	

CD for (m) - NS
CD for (T x m) - NS
CD for (T) - NS

(m) - 2.84 (0.97)
(T x m) - NS
(T) - 3.57 (2.38)

(m) - 11.22 (3.83)
(T x m) - 38.57 (13.28)
(T) - NS

CD values are given wherever f values are significant and SE values are given in bracket

The method of application and the different concentrations of vermiwash produced significant difference on the available soil P. Between foliar and soil applications, foliar application was found to be significantly superior over soil application. Among the treatments T_4 in foliar application produced the highest value (46.95 kg ha^{-1}) which was on par with T_7 in both soil foliar applications.

Available soil K after harvest of the crop was significantly influenced by the different concentrations of the vermiwash and the method of application. Foliar spraying was found to be significantly superior over soil application. Among all the treatments, T_7 in foliar spraying showed the highest value (150.07 kg ha^{-1}). In soil application, T_1 showed the highest value (136.32 kg ha^{-1}) which was on par with T_4, T_{10}, T_2 and T_7.

4.2.15 Total NPK content of fruits

The different concentrations of vermiwash and the method of application did not produce any significant difference on the total N and K content in fruits (Table 12).

Between foliar and soil applications, foliar spraying was found to be significantly superior over soil application in the case of P content in fruits. The different concentrations of vermiwash produced no significant difference. In foliar spraying, T_7 showed the highest value (0.62 %) which was on par with T_4 (0.61 %).

Table 12 Effect of treatments on the total NPK content of furits

Treatments	Total N (%)			Total P (%)			Total K (%)		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	3.64	4.24	3.94	0.52	0.54	0.53	5.75	6.30	6.03
T_2	3.46	3.89	3.68	0.53	0.51	0.50	5.85	5.55	5.70
T_3	3.61	3.45	3.53	0.50	0.49	0.50	5.40	5.25	5.33
T_4	4.11	4.97	4.54	0.61	0.42	0.52	6.15	5.65	5.90
T_5	4.10	4.71	4.40	0.49	0.40	0.44	6.15	5.20	5.67
T_6	3.41	3.78	3.60	0.53	0.48	0.50	5.80	5.10	5.45
T_7	4.24	3.60	3.92	0.62	0.46	0.53	6.15	5.80	5.98
T_8	3.71	3.93	3.82	0.48	0.52	0.50	5.45	4.85	5.15
T_9	3.68	3.31	3.49	0.56	0.49	0.53	5.65	5.20	5.43
T_{10}	4.34	4.30	4.32	0.58	0.43	0.51	5.95	5.85	5.90
T_{11}	3.89	3.53	3.71	0.43	0.39	0.41	5.35	5.30	5.33
T_{12}	4.03	3.39	3.71	0.52	0.56	0.53	5.50	6.00	5.75
Mean	3.85	3.92		0.53	0.47		5.76	5.50	

Total N	Total P	Total K
CD for (m) - NS	(m) - 0.03 (0.01)	(m) - NS
CD for (T x m) - NS	(T x m) - NS	(T x m) - NS
CD for (T) - NS	(T) - NS	(T) - NS

CD values are given wherever f values are significant and SE values are given in bracket

4.2.16 Ca and Mg content of fruits

The data on Ca and Mg content of fruits are presented in Table 13. It was observed that there was no significant difference on the Ca and Mg content of fruits due to the different concentration of vermiwash. As far as the method of application of vermiwash was concerned, soil application was found to be significantly superior over foliar spraying. In both foliar and soil application, the treatments T_4 showed the highest value for Ca and Mg content compared to the rest of the treatments.

4.2.17 Micronutrient content of fruits

The data on the Mn, Zn and Cu content of fruits were given in Table 14. The different concentrations of vermiwash and the method of application did not produce any significant difference on the Mn and Zn content of fruits. Application of vermiwash along with graded doses of organic fertilizers recorded comparatively higher values than T_1, T_2 and T_3 which received inorganic fertilizers without vermiwash.

With respect to the Cu content of fruits, foliar spraying was found to be significantly superior over soil application. The different concentrations of vermiwash did not produce any significant difference on the Cu content in fruits.

Table 13 Ca and Mg content of fruits as influenced by the different treatments

Treatments	Ca content (%)			Mg content (%)		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	0.27	0.30	0.28	0.31	0.47	0.39
T_2	0.22	0.22	0.22	0.22	0.39	0.31
T_3	0.19	0.19	0.19	0.19	0.29	0.24
T_4	0.50	0.50	0.50	0.39	0.49	0.44
T_5	0.39	0.46	0.43	0.33	0.34	0.36
T_6	0.33	0.35	0.34	0.27	0.41	0.34
T_7	0.42	0.50	0.46	0.39	0.11	0.41
T_8	0.38	0.47	0.42	0.35	0.39	0.37
T_9	0.31	0.41	0.36	0.30	0.37	0.33
T_{10}	0.45	0.39	0.42	0.37	0.41	0.39
T_{11}	0.31	0.32	0.31	0.34	0.32	0.33
T_{12}	0.27	0.29	0.25	0.29	0.35	0.32
Mean	0.34	0.36		0.31	0.39	

CD for (m)	- 0.02 (0.01)	(m)	- 0.02 (0.01)
CD for (T x m)	- NS	(T x m)	- NS
CD for (T)	- NS	(T)	- NS

CD values are given wherever f values are significant and SE values are given in bracket

Table 14 Effect of treatments on the Mn, Zn and Cu content of fruits

Treatments	Mn (ppm)			Zn (ppm)			Ci (ppm)		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	0.85	0.70	0.77	39.0	32.5	35.75	0.54	0.49	0.54
T_2	0.75	0.55	0.65	22.5	32.0	27.25	0.44	0.48	0.46
T_3	0.40	0.45	0.43	22.0	23.0	22.50	0.28	0.18	0.23
T_4	1.25	1.55	1.40	55.0	54.5	54.75	0.71	0.72	0.71
T_5	0.95	1.20	1.08	43.0	44.5	43.75	0.64	0.65	0.66
T_6	0.75	1.10	0.93	39.5	41.5	40.50	0.49	0.45	0.47
T_7	1.65	1.45	1.55	47.5	46.5	47.00	0.69	0.64	0.66
T_8	1.35	1.05	1.20	34.0	36.0	35.00	0.64	0.58	0.61
T_9	0.85	0.95	0.90	26.0	28.0	27.00	0.50	0.31	0.40
T_{10}	1.30	1.35	1.45	43.0	38.0	40.50	0.59	0.61	0.60
T_{11}	1.10	0.85	1.08	37.5	34.0	35.75	0.50	0.48	0.49
T_{12}	1.10	0.70	0.90	29.5	29.5	29.50	0.32	0.33	0.33
Mean	1.06	0.99		36.54	36.67		0.53	0.49	

CD for (m) - NS
CD for (T x m) - NS
CD for (T) - NS

(m) - NS
(T x m) - NS
(T) - NS

(m) - 0.03 (0.01)
(T x m) - NS
(T) - NS

CD values are given wherever f values are significant and SE values are given in bracket

4.2.18 Total N, P and K content of plants

The application of different concentration vermiwash produced significant difference on the total N content of plants (Table 15). But the method of application of vermiwash did not produce any significant difference on the total N content of plants. Among the different treatments, T_1, T_4 and T_7 are on par and significantly superior over all other treatments. T_{12} showed the lowest value.

The application of different concentration of vermiwash did not produce any significant difference on the total phosphorus content of plants. Between foliar and soil application of vermiwash, foliar spraying was found to the superior over soil application. In foliar spraying, T_4 and T_{10} are on par and significantly superior over all other treatments. In soil application also, T_4 produced the highest value which is on par with T_1 and significantly superior over all other treatments. The different concentration of vermiwash and the method of application of vermiwash produced significant difference on the total K content of plants. Among the treatments, T_4 in soil application showed the highest value which is on par with T_1 in soil application and T_4, T_5 and T_7 in foliar application are significantly superior over all other treatments. Between foliar and soil application, soil application was found to the superior over foliar application.

4.2.19 Ca and Mg content of plants

No significant difference was observed on the Ca and Mg content of plants by the different concentrations and the method of application of vermiwash (Table 16).

Table 15 Effect of different concentrations and the method of application of vermiwash on the plant NPK content

Treatments	N (%)			P (%)			K (%)		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	1.79	1.83	1.81	0.55	0.56	0.56	2.20	2.31	2.25
T_2	1.10	1.42	1.26	0.55	0.40	0.47	1.99	2.12	2.06
T_3	0.95	1.05	1.00	0.34	0.28	0.31	1.38	1.42	1.40
T_4	1.92	1.46	1.60	0.64	0.58	0.61	2.52	2.60	2.56
T_5	1.26	1.09	1.18	0.54	0.53	0.53	2.33	1.67	2.00
T_6	1.12	0.89	1.00	0.30	0.29	0.30	2.03	1.27	1.65
T_7	1.56	1.66	1.61	0.50	0.43	0.47	2.41	2.18	2.30
T_8	1.56	1.39	1.45	0.48	0.21	0.34	1.75	1.71	1.73
T_9	1.03	1.09	1.06	0.39	0.28	0.33	1.28	1.26	1.27
T_{10}	1.38	1.34	1.36	0.61	0.50	0.56	2.30	1.69	2.00
T_{11}	1.38	1.11	1.25	0.42	0.41	0.42	2.06	1.14	1.60
T_{12}	6.85	0.75	0.80	0.21	0.33	0.26	1.29	1.02	1.15
Mean	1.32	1.26		0.46	0.40		1.96	1.70	

CD for (m) - NS
CD for (T x m) - NS
CD for (T) - 6.20 (0.07)

(m) - 0.04 (0.02)
(T x m) - NS
(T) - NS

(m) - 0.11 (0.04)
(T x m) - 0.37 (0.13)
(T) - NS

CD values are given wherever f values are significant and SE values are given in bracket

Table 16 Ca and Mg content of plants as influenced by the treatments

Treatments	Ca (%)			Mg (%)		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	1.50	2.26	1.88	1.55	2.34	1.95
T_2	1.96	1.67	1.81	1.86	1.52	1.69
T_3	0.87	1.19	1.03	0.91	1.15	1.63
T_4	2.72	1.86	2.29	4.21	2.78	3.50
T_5	1.94	3.00	2.47	2.64	4.06	3.35
T_6	1.38	1.10	1.24	1.19	1.21	1.20
T_7	2.06	2.32	2.19	3.31	3.98	3.64
T_8	1.69	1.46	1.57	1.91	2.16	2.03
T_9	1.02	1.12	1.07	1.38	1.45	1.42
T_{10}	1.76	1.52	1.64	3.36	2.12	2.74
T_{11}	1.62	2.07	1.84	1.83	2.53	2.18
T_{12}	0.89	0.85	0.87	1.06	1.32	1.19
Mean	1.61	1.70		2.10	2.22	

CD for (m)	- NS	(m)	- NS
CD for (T x m)	- NS	(T x m)	- NS
CD for (T)	- NS	(T)	- NS

CD values are given wherever f values are significant and SE values are given in bracket

Table 17 Mn, Zn and Cu content of plants as influenced by the treatments

Treatments	Mn (ppm)			Zn (ppm)			Cu (ppm)		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	71.98	67.00	69.49	30.00	25.00	27.50	94.00	85.00	89.50
T_2	52.00	51.00	51.50	17.49	15.00	16.25	74.45	63.50	68.98
T_3	32.00	36.00	84.00	4.94	5.00	6.72	30.00	27.00	28.50
T_4	99.75	113.00	106.38	59.00	62.00	60.50	119.50	128.00	123.75
T_5	69.55	74.49	72.02	24.52	27.50	26.01	67.00	79.50	73.25
T_6	42.00	52.00	47.00	12.50	10.00	11.25	30.50	28.50	29.50
T_7	81.49	80.95	81.22	40.50	50.00	45.25	104.50	114.95	104.73
T_8	52.00	45.24	48.62	29.00	22.00	25.80	58.47	74.00	66.24
T_9	36.50	33.00	34.75	11.50	6.00	8.75	31.00	31.08	31.04
T_{10}	73.98	64.50	69.24	33.50	29.00	31.25	84.99	97.49	91.24
T_{11}	41.50	43.50	42.50	20.49	15.00	17.74	40.50	66.50	53.50
T_{12}	26.50	21.00	23.75	9.85	8.50	9.18	29.50	23.00	26.25
Mean	56.60	56.81		24.69	22.96		63.70	68.21	

CD for (m) - NS
CD for (T x m) - NS
CD for (T) - 9.08 (3.11)

(m) - 0.45 (0.33)
(T x m) - 3.30 (1.13)
(T) - 2.30 (0.79)

(m) - 2.32 (0.79)
(T x m) - 8.02 (2.74)
(T) - 5.67 (1.94)

CD values are given wherever f values are significant and SE values are given in bracket

4.2.20 Micronutrient content of plants

Mn content of plants was influenced by the application of different concentrations of vermiwash and not by the method of application. Among the different treatments, T_4 showed the highest value which is significantly superior over all other treatments and the lowest value was for the T_{12} (Table 17).

In the case of Zn, both the method of application and the different concentration of vermiwash influenced significantly. Foliar spraying was found to be significantly superior over soil application. Among all the treatments, T_4 in both soil and foliar application showed the highest value and significantly superior over all other treatments. The lowest value for T_9 is soil application.

Both the method of application and the different concentrations of vermiwash influenced positively on the Cu content of plants. Soil application was found to be significantly superior over foliar application. Among the treatments T_4 showed the highest value which is significantly superior over all other treatments.

4.2.21 Plant uptake of N, P and K

Table 18 shows data on plant uptake of N, P and K. The different concentration of vermiwash produced significant difference on the plant uptake of N, but foliar and soil application produced similar values. Among the treatments, T_4 in foliar application produced the highest value (60.1 kg ha^{-1}) which was on par with T_7 in foliar spraying and T_1 and T_4 in soil application.

Table 18 Effect of different concentraitons and method of application of vermiwash on the plant uptake of NPK

Treatments	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	30.9	48.6	39.85	5.9	10.3	8.1	37.0	71.6	54.3
T_2	27.3	36.5	31.9	8.3	7.1	7.7	45.0	53.2	49.2
T_3	26.3	24.1	25.2	6.0	5.1	5.6	45.9	36.6	41.3
T_4	60.1	46.9	52.5	13.0	7.1	10.1	86.0	60.2	73.1
T_5	37.3	40.4	38.9	8.0	9.7	8.9	60.3	50.9	55.6
T_6	25.4	30.7	28.1	5.1	5.6	5.4	44.3	42.2	43.3
T_7	53.3	43.8	48.6	10.5	7.8	9.2	79.3	56.0	67.7
T_8	34.9	31.2	33.1	7.4	4.7	6.1	47.8	43.5	45.7
T_9	28.0	25.6	26.9	6.5	6.3	6.4	39.5	39.7	39.6
T_{10}	40.5	44.5	42.5	9.2	7.1	8.2	56.3	56.3	56.3
T_{11}	26.7	35.5	31.1	4.7	7.1	5.9	33.6	46.8	40.3
T_{12}	12.9	25.1	19.0	2.5	6.1	4.3	18.7	41.3	30.1
Mean	33.7	36.1		7.28	7.01		49.5	49.9	

CD for (m) - NS
CD for (T x m) - 15.2 (5.2)
CD for (T) - 9.08 (3.11)

(m) - NS
(T x m) - 2.37 (0.81)
(T) - NS

(m) - NS
(T x m) - 16.87 (5.76)
(T) - NS

CD values are given wherever f values are significant and SE values are given in bracket

Significant difference was observed on the plant uptake of P by the application of different concentration of vermiwash, but no significant difference on the method of application. Among the treatments, T_4 in foliar spraying showed the highest value which was significantly superior over all other treatments and T_{12} showed the lowest for P uptake by plants.

The different concentration of vermiwash produced significant difference on the plant uptake of K, but the method of application failed to produce any significant change. Among the treatments, T_4 in foliar spraying showed the highest value which was on par with T_7 in foliar spraying and T_1 in soil application. T_5 (Vermiwash 50 % + ½ NPK) registered similar effect as T_1 (POP of KAU).

4.2.22 Ca and Mg uptake by plants

The data on the Ca and Mg uptake are presented in Table 19. The different concentrations of vermiwash did not show any significant difference, but the method of application was found to be significant in case of Mg. Here soil application was found to be significantly superior over foliar application T_4.

4.2.23 Uptake of Mn, Zn and Cu

Table 20 shows data on the effect of treatments on the uptake of Mn, Zn and Cu. The different concentration of vermiwash and its method of application did not produce any significant difference on the plant uptake of Mn, Zn and Cu.

Table 19 Effect of treatments on the Ca and Mg uptake by plants

Treatments	Ca (kg ha^{-1})			Mg (kg ha^{-1})		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	2.46	4.23	3.34	2.65	4.98	3.81
T_2	3.16	2.84	3.00	2.86	3.62	3.24
T_3	5.91	3.38	4.65	2.15	2.28	2.21
T_4	6.70	5.68	6.19	7.82	6.40	7.11
T_5	4.40	5.36	4.89	4.70	6.07	5.39
T_6	2.79	3.54	3.16	2.32	3.55	2.94
T_7	5.73	5.15	5.44	6.69	6.91	6.80
T_8	3.85	3.56	3.71	3.95	4.09	4.02
T_9	2.45	2.83	2.64	2.80	3.97	3.39
T_{10}	4.69	4.40	4.55	5.77	5.30	5.54
T_{11}	2.14	4.09	3.11	2.93	4.40	3.67
T_{12}	1.29	2.20	1.74	1.49	2.87	2.18
Mean	3.80	3.94		3.84	4.54	

CD for (m)	- NS	(m)	- 0.529 (0.181)
Dd for (T x m)	- NS	(T x m)	- NS
Cd for (T)	- NS	(T)	- NS

CD values are given wherever f values are significant and SE values are given in bracket

Table 20 Effect of treatments on the Mn, Zn and Cu uptake by plants

Treatments	Mn (kg ha^{-1})			Zn (kg ha^{-1})			Cu (kg ha^{-1})		
	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean	Foliar (m_1)	Soil (m_2)	Mean
T_1	0.05	0.08	0.07	0.07	0.11	0.09	0.02	0.03	0.03
T_2	0.05	0.05	0.05	0.08	0.08	0.08	0.02	0.02	0.02
T_3	0.03	0.03	0.03	0.03	0.02	0.03	0.01	0.01	0.01
T_4	0.11	0.08	0.09	0.13	0.09	0.11	0.04	0.04	0.04
T_5	0.07	0.11	0.09	0.06	0.11	0.08	0.02	0.04	.003
T_6	0.05	0.05	0.05	0.03	0.03	0.03	0.01	0.05	0.03
T_7	0.08	0.09	0.08	0.11	0.13	0.12	0.04	0.05	0.05
T_8	0.05	0.05	0.05	0.06	0.08	0.07	0.02	0.02	0.02
T_9	0.02	0.19	0.18	0.03	0.04	0.03	0.01	0.01	0.01
T_{10}	0.08	0.05	0.06	0.07	0.08	0.07	0.03	0.02	0.03
T_{11}	0.05	0.05	0.05	0.05	0.07	0.05	0.02	0.02	0.02
T_{12}	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Mean	0.07	0.07		0.06	0.07		0.02	0.03	

CD for (m) - NS
CD for (T x m) - NS
CD for (T) - NS

(m) - NS
(T x m) - NS
(T) - NS

(m) - NS
(T x m) - NS
(T) - NS

CD values are given wherever f values are significant and SE values are given in bracket

Table 21 Coefficient of correlation between yield and soil and plant characters

Characters	r values
Leaf area x yield	0.4674**
Dry weight x yield	0.7136**
Number of days to flower x yield	-0.1439
Root-shoot ratio x yield	0.2983**
Number of seeds per fruits x yield	-0.0365
Uptake of N x yield	0.2826**
Uptake of P_2O_5 x yield	0.3468**
Uptake of K_2O x yield	0.2607*
Uptake of Mn x yield	0.4447**
Uptake of Zn x yield	0.5383**
Uptake of Cu x yield	0.5236**
Available N x yield	0.0686
Available P_2O_5 x yield	0.3431**
Available K_2O x yield	0.2623*
Plant N x yield	0.5369**
Plant P x yield	0.5579**
Plant K x yield	0.5160**

4.2.24 Correlation studies

Yield was significantly and positively correlated with leaf area, dry weight and root-shoot ratio of the plants. Nutrient uptake by plants was positively and significantly correlated with yield. From the value of correlation it could be observed that among the major nutrients, phosphorus uptake showed the highest correlation followed by nitrogen and potassium.

Soil available P_2O_5 and K_2O showed positive and significant correlation with yield. Available P_2O_5 in the soil showed the highest value for correlation compared to N and K_2O. Plant N, P and K content also showed significant correlation with yield. Phosphorus showed the highest value.

Negative correlation was observed for the number of days taken to flower ($r = -0.1439$) and number of seeds per fruit ($r = -0.0365$) which were not significant.

DISCUSSION

5. DISCUSSION

One pot culture experiment and a field experiment were carried out at the Instructional Farm, College of Agriculture, Vellayani to find out the effect of vermiwash applied as foliar spray or soil application along with graded doses of fertilizers on growth, yield and quality of tomato. The important results obtained from the investigation are discussed in this chapter.

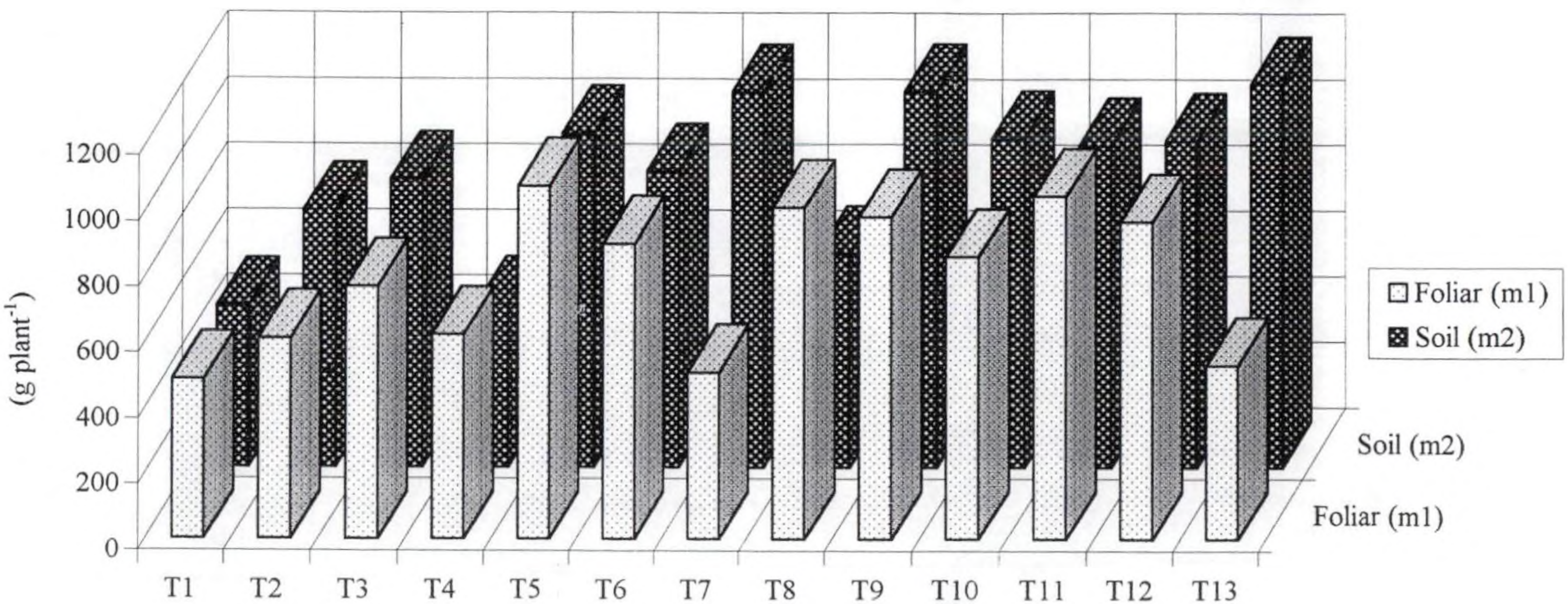
5.1 Pot culture experiment

Results from the pot culture experiment to select the ideal level of vermiwash showed a significant difference on the fruit yield of tomato with respect to the different concentrations of vermiwsh. Fruit yield was significantly different between levels of vermiwash and control. Among the various concentrations, the highest concentration (100 %) of vermiwash produced lower yield compared to other concentrations. Therefore the highest concentration (100 %) was eliminated and the next three levels (50 %, 25 % and 12.5 %) were selected for conducting the field experiment to study the effect of vermiwash on growth, yield and quality of tomato.

5.2 Field experiment

Field experiment was carried out with three levels of vermiwash (50 %, 25 % and 12.5 %) in two modes of application (foliar, m_1 and soil application, m_2)

Fig. 6 Effect of treatments on fruit yield of tomato (pot culture experiment)



along with three levels of fertilizers (full NPK, ½ NPK and 0 NPK). The significant results obtained from the field experiment are discussed in this chapter.

5.2.1 Growth characters

5.2.1.1 Number of days taken to flower

The application of different concentration of vermiwash and its method of application did not produce any significant difference on the number of days taken to flower.

5.2.1.2 Leaf area at 50 per cent flowering

The different concentration of vermiwash did not produce any significant difference on the leaf area of tomato. But the method of application showed significant difference on the leaf area. Between foliar and soil application, foliar spraying was found to be superior in producing more leaf area. It may be seen from Table 1 that vermiwash has a high content of readily available forms of major and micronutrients required for plant growth. Foliar application of vermiwash might have resulted in a comparatively higher uptake of these nutrients elements directly through foliage and has resulted in a better growth giving a larger leaf area. The addition of fertilizers also may naturally lead to a higher uptake of nutrients along with the nutrients received through the foliar application of vermiwash. This might have resulted in an increased growth of leaves. A higher level of N resulting in a higher leaf area has been reported by Russel

(1973). Increase in leaf area through N application in solanaceous vegetables has been reported by Ramachandran and Subbiah (1982). Muchow (1990) reported an increased leaf area with increasing doses of N.

5.2.2 Yield and yield attributes

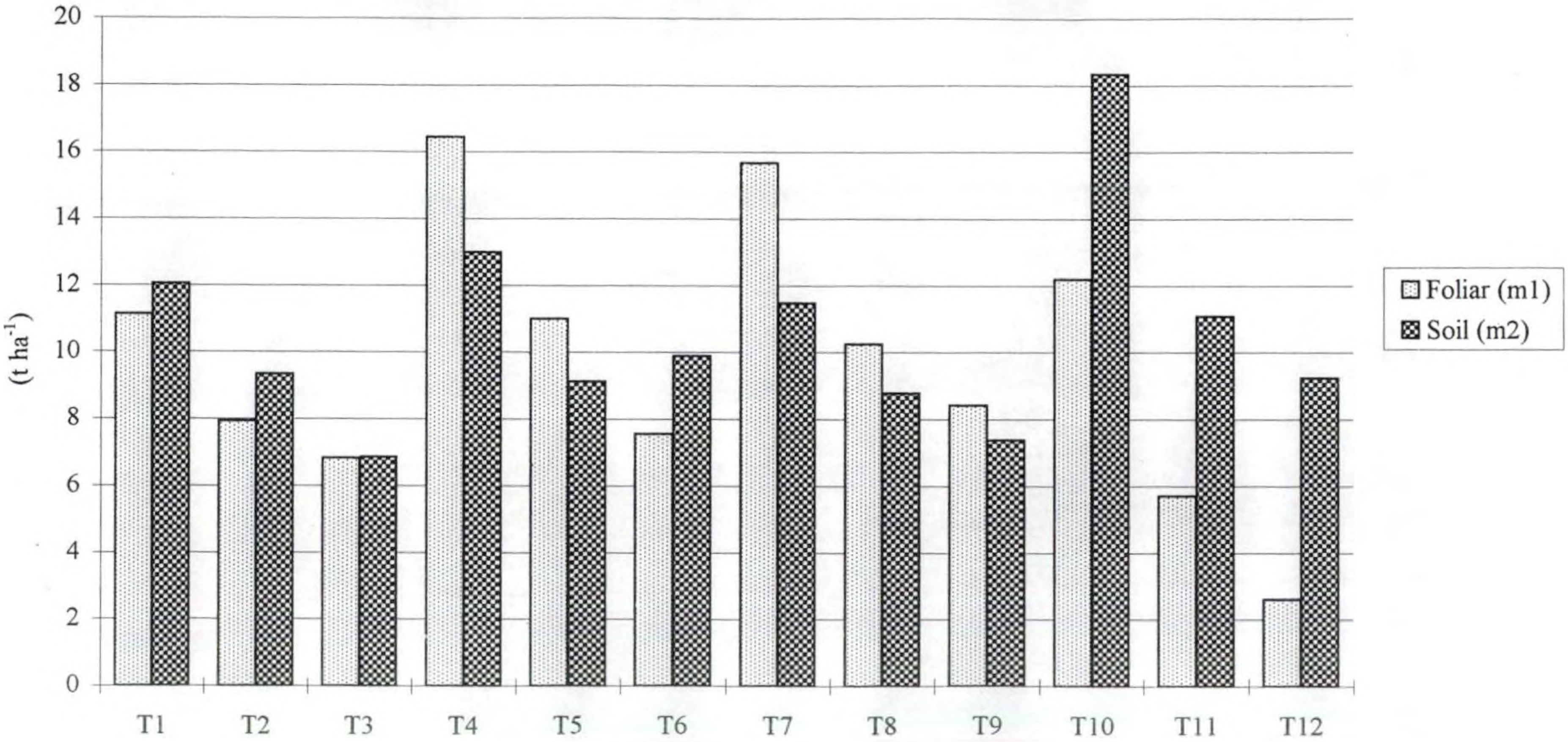
5.2.2.1 Fruit size

The different concentrations of vermiwash and the method of application did not produce an significant difference on the fruit size of tomato.

5.2.2.2 Fruit yield

The application of different concentrations and the method of application of vermiwash produced significant difference on the fruit yield of tomato. Highest yield was recorded by the treatment T_{10} in which 12.5 per cent vermiwash was given as soil application along with full NPK. It was also significantly superior over all other treatments. T_1, T_2 and T_3 of soil and foliar applications were on par. At lowest level of concentration of vermiwash (12.5 %) soil application was found to be better than foliar spraying. But at 50 per cent and 25 per cent levels of vermiwash, in general foliar spraying was found to be superior over soil application. When vermiwash was given along with full NPK (POP of KAU) a marked increase in fruit yield was obtained. The result clearly indicates that vermiwash application has contributed to an increase in yield when applied along

Fig. 7 Effect of treatments on fruit yield of tomato (Field experiment)



with inorganic fertilizers. It reveals that a higher yield in tomato can be obtained by the soil application of vermiwash along with the recommended levels of NPK for tomato. The increase in yield compared to the control which comes to more than 50 per cent may be attributed to the beneficial effect of vermiwash. It is possible that in addition to the high nutrient status in vermiwash, its alkaline nature (pH 8.7) might have ameliorated the soil reaction of the experimental field which had a pH of 5.3 and resulted in a better uptake of all plant nutrients. Moreover, the growth hormones and other growth promoting substances present in vermiwash also might have stimulated better plant growth leading to a better yield. Nielson (1965) reported that earthworms produced plant growth substances in the alimentary canal and excreted it along with earthworm cast. Since vermiwash is a derived product from freshly formed compost containing live earthworm, vermiwash may also contain growth promoting substances, group B vitamins, mucus deposit of epidermal cells and coelomic fluid produced by worms which contain plant hormones and chemical exudates as reported by Grappelli *et al.* (1987) and Tomati *et al.* (1983). These organic substances present in vermiwash might have produced a positive effect on fruit set which in turn has reflected in a higher fruit yield.

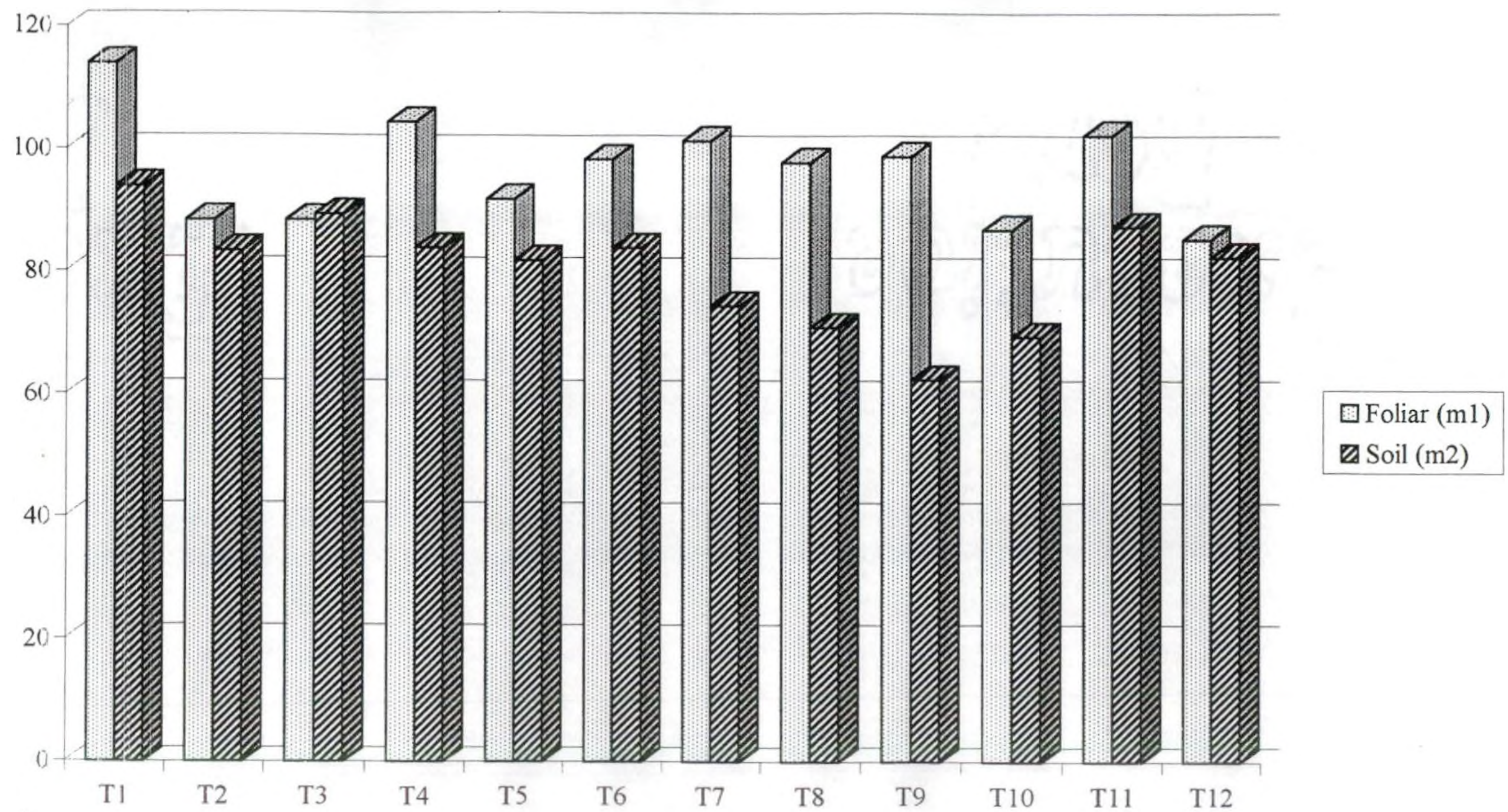
At higher concentration, foliar application was found to be better than soil application whereas at lower concentration soil application appeared to be better. The integrated application of vermiwash with fertilizers has shown a complementary effect. At 50 per cent and 25 per cent concentrations of vermiwash, there was no yield reduction when the inorganic fertilizer was reduced to half of POP of KAU. The result clearly indicated that the use of chemical fertilizers can be reduced to half when 50 per cent or 25 per cent vermiwash was used as an organic source. Jiji *et al.* (1996) and Ushakumari *et al.* (1996) have made similar observation when vermicompost was used as an organic source along with inorganic fertilizers for various crops.

5.2.2.3 Seeds per fruit

The different concentration of vermiwash and the method of application of vermiwash produced significant difference on the number of seeds per fruit. Foliar spraying was found to be significantly superior over soil application. Similar result of superiority of foliar application of N over soil application was reported by Randhawa *et al.* (1992). So for the purpose of seed production in tomato, it is better to apply vermiwash as foliar spray rather than as soil application. The highest number of seeds were produced by the control plants (with full NPK of POP). Pushpa (1996) reported an increase of 105 seeds per fruit in treatments receiving 25 t vermicompost and full NPK.

Under situations where tomato with less seeds are preferred (such as in the case of salads) soil application of vermiwash can be resorted to along with the recommended fertilizer level.

Fig. 8 Effect of treatments on the number of seeds per fruit



5.2.3 Quality parameters of fruits

5.2.3.1 Shelf - life at room temperature

The treatments produced significant difference on the shelf - life of fruits. Soil application of vermiwash produced fruits with better shelf - life compared to foliar spraying. Among the treatments, T_1 showed the highest value (15.5 days) which was on par with T_4, T_8, T_7 and T_{10}. T_1 received full NPK (as per POP of KAU). T_7 in soil application also produced fruits with the same shelf-life. Bhatnagar *et al.* (1985) reported that high N level gave fruits which are kept best. Fritz and Haben (1972) reported K fertilizers increase the durability of fruits by lowering the activities of enzymes which breakdown carbohydrate.

At higher concentrations of vermiwash, foliar spraying produced fruits with lower shelf-life compared to soil applications. This indicates that foliar spraying of vermiwash may deteriorate the keeping quality of fruits. So from the results, it is observed that in order to get fruits with better shelf-life, soil application of vermiwash may be preferred to foliar spraying.

5.2.3.2 Vitamin C and lycopene content of fruits

The different concentrations of vermiwash produced significant difference on the lycopene content of tomato fruits, but no effect on the ascorbic acid content. T_{10} showed the highest value among all the treatments (3.93 mg 100 g^{-1}) compared to T_1 (3.44 mg 100 g^{-1}). So the application of vermiwash has got some effect in bringing colour to tomato fruits. N is the main component required for

Fig. 9. Shelf life of fruits as affected by the different treatments

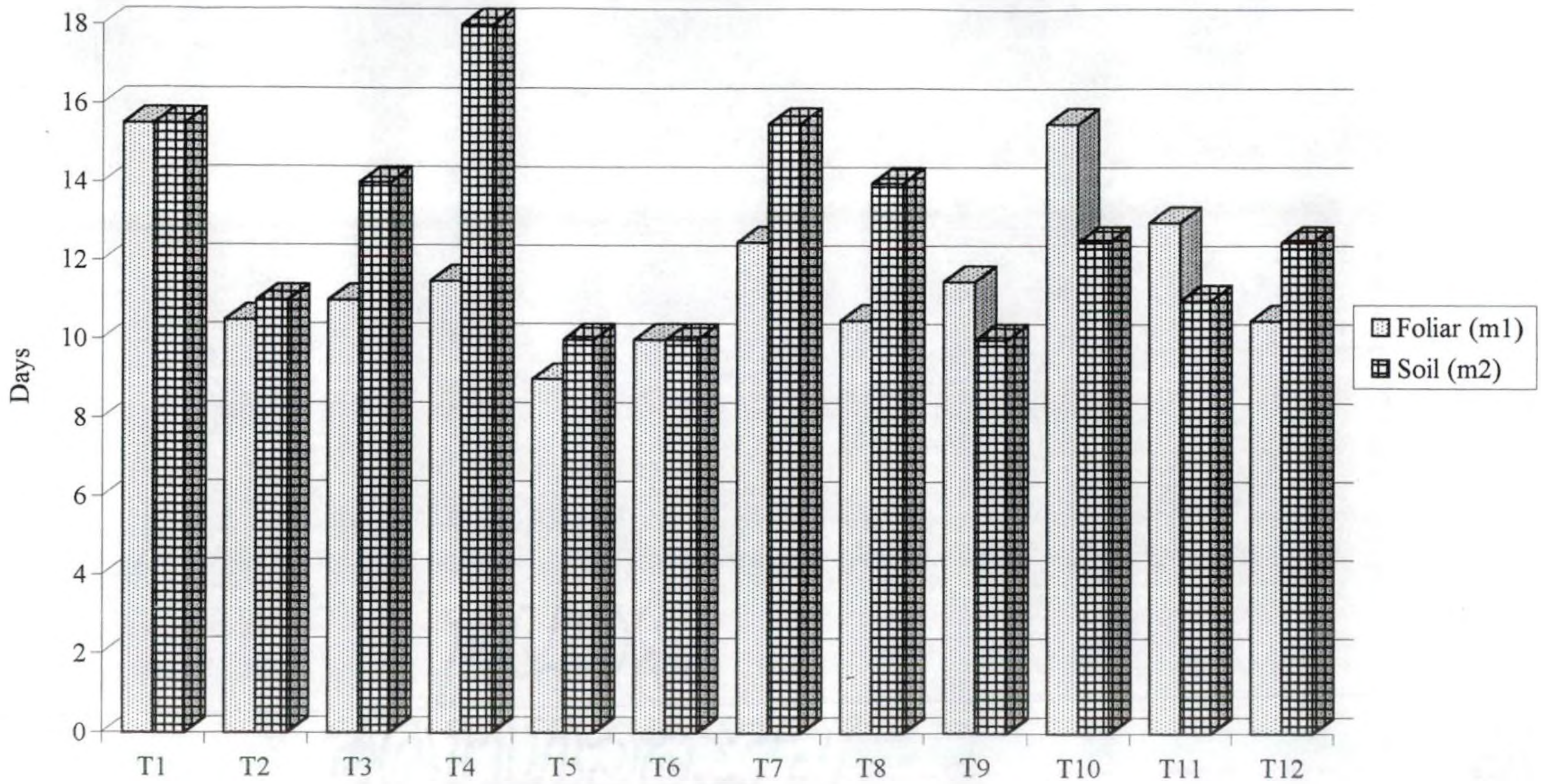
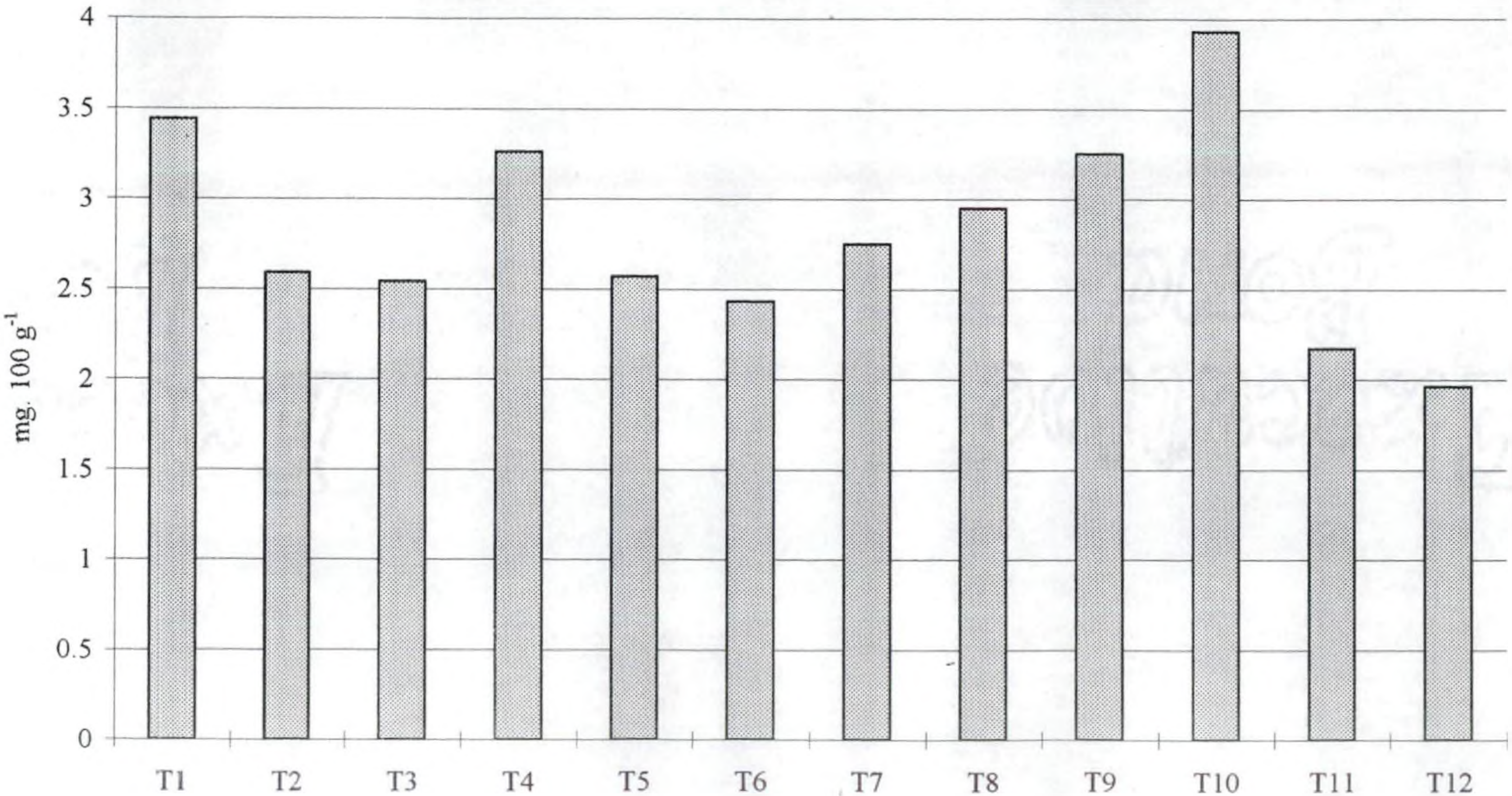


Fig. 10. Lycopene content of fruits as influenced by the different treatments



the synthesis of lycopene (Adams, 1986) along with some micronutrients. The application of vermiwash along with inorganic fertilizers can supply the nutrients required for the synthesis of lycopene which might have resulted in a higher content in fruits.

5.2.4 Nutrient status of soil and fruits

5.2.4.1 Available soil NPK at flowering stage of the crop

The different treatments produced significant difference on the available N content in the soil at the time of flowering. But the two methods of application produced no significant difference. Of all the treatments T_1 showed the highest value which was on par with T_4. The application of different concentration of vermiwash produced no significant difference on the P and K content of soil at the time of flowering, but foliar spraying was found to be superior over soil application. The result shows that no desirable change has been produced in the soil at the time of flowering by the application of different concentration of vermiwash. Since the nutrients present in vermiwash was in a readily available form and plants can utilize it directly through leaves by which the plant requirement can be met. So foliar spraying was found to be better than soil application till the flowering stage of the crop in maintaining a higher status of available N, P and K in the soil.

5.2.4.2 Soil available NPK at harvest of the crop

The different treatments and the method of application of vermiwash produced no significant difference on the available soil N at harvest of the crop, but the treatments produced significant difference on the P and K content in soil. Foliar spraying was found to be significantly superior over soil application. T_4 showed the highest value for P which was on par with T_7. T_7 showed the highest value for K. The results indicates that highest value for P and K is produced by the treatments receiving inorganic fertilizers and vermiwash. The alkaline nature of vermiwash might have ameliorated the acidity of the soil of the experimental field and thereby increased the content of available P in the soil at harvest of the crop. Vermiwash contain K in a soluble and highly available form.

5.2.4.3 Total NPK content of fruits

Total NPK content of fruits showed no significant variation over the application of different concentrations of vermiwash. The method of application of vermiwash also produced no significant difference in case of N and K. Foliar spraying was found to be significantly superior over soil application in case of P. P and K which are present in vermiwash in a highly soluble form may be absorbed more through the foliage than through the soil and might have resulted in their higher content in the plant.

5.2.4.4 Ca and Mg content of fruits

The different concentrations of vermiwash produced no significant difference on the Ca and Mg content of the fruits. But between foliar and soil application, soil application was found to be significantly superior and T_4 showed the highest value. Vermiwash contain Ca and Mg in a readily available form. So the application in the soil might have resulted in a higher content in fruits. Kale and Krishnamoorthy (1980) reported that considerable amount of Ca in casting was due to the selective feeding of Ca rich materials by the norms. The calciferous glands in earthworms contain carbonic unhydrase which catalyse the fixation of CO_2 as Ca Co_3, thereby increasing the Ca availability (Shuxin *et al.*, 1991). According to Pierce (1972) species with active calciferous glands absorb excess Ca from their diet and thereby transfer it to calciferous glands from which it is excreted through the digestive system. The high content of Ca and Mg in the vermiwash arising through the reasons said above has naturally contributed to their higher uptake by the plants also.

5.2.4.4.5 Micronutrient content of fruits

The different concentrations of vermiwash and the method of application of vermiwash did not produce any significant difference on the Mn and Zn content of fruits. Foliar spraying was found to be significantly superior over soil application in case of Cu, but no significant variation produced by the different concentration of vermiwash.

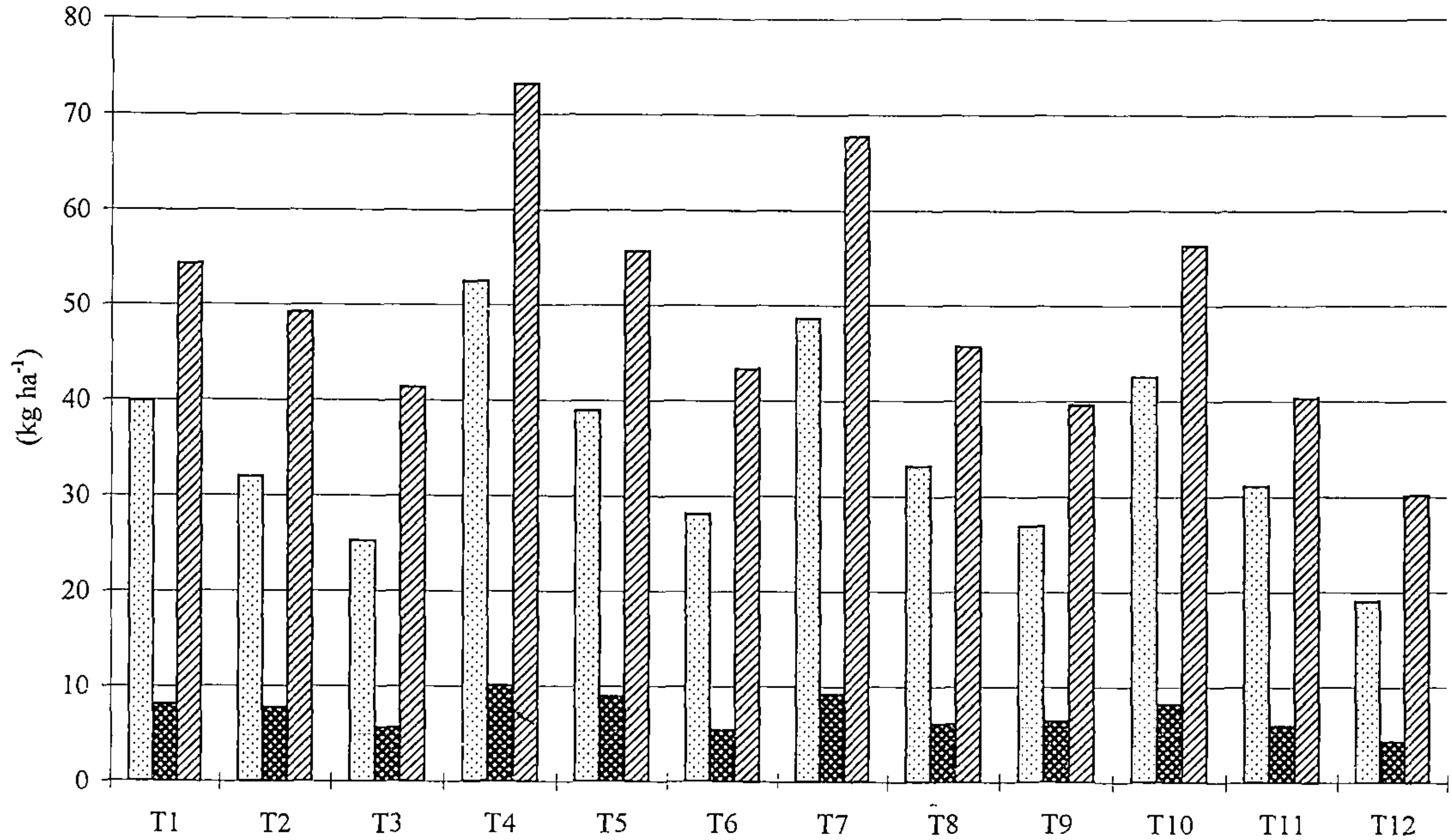
5.2.5 Total content of nutrients and uptake by the plants

5.2.5.1 NPK

The application of different concentration of vermiwash produced significant difference on the plant N content and uptake. Among the different treatments T_4, T_1 and T_7 were on par and significantly superior over all other treatments in the N content of plants. Considering plant uptake, T_4 in foliar spraying produced the highest value which was on par with T_7, T_4 and T_1. Though T_4, T_7 and T_1 were on par, T_4 and T_7 showed higher values compared to T_1. T_4 and T_7 received vermiwash along with inorganic fertilizers compared to the control which received the fertilizers. N content and plant uptake of N by the application of vermiwash has thus increased in their plant uptake. It may be due to the alkaline nature and nutrient content of vermiwash. Vermiwash also contain N fixing organisms as seen from the results given in Table 2 which can supplement soil available N by their metabolic reactions. It can cause an increase in the uptake of N. James *et al.* (1967) reported that a higher rate of metabolic activity with rapid cell division brought out by vermicompost application can resulted in a high uptake of nutrients and this might have resulted in increased utilization of N.

The application of vermiwash produced significant difference on the plant uptake of P. T_4 in foliar spraying showed the highest value. Application of 50 per cent vermiwash along with inorganic fertilizers produced the highest value for P uptake. The increased P availability by the solubility of P brought out by higher

Fig. 11. Effect of different treatments on the plant uptake of NPK



phosphatase activity by vermicompost application was reported by Syres and Springett (1984). The higher content of P in vermiwash as well as an increased mineralisation of soil P as a result of production of organic acids during decomposition of vermicompost may be the reason for increased P uptake by the plants. The solubilisation of P by these micro-organisms present in vermiwash may be attributed to excretion of organic acids like citric acid, glutamic acid, succinic acid, lactic acid, oxalic acid etc. as proposed by Gaur (1988) and Subba Rao (1988).

K uptake and the content in plants varied significantly over the different concentrations of vermiwash. Here also, 50 per cent concentration of vermiwash with full inorganic fertilizers produced the highest value for K content and uptake. Vermiwash contain K in a highly soluble form. Zachariah (1995) reported the superiority of vermicompost application in the uptake of K by chilli. The same effect may be prevalent with the use of vermiwash also.

5.2.5.2 Ca and Mg

Ca and Mg uptake as well as the content did not vary significantly over the different concentrations of vermiwash. Soil application was found to be significantly superior cover foliar spraying in case of Mg.

5.2.5.3 Mn, Zn and Cu

Mn, Zn and Cu content of plants showed significant difference over the different concentration of vermiwash. For all the three nutrient elements, the treatment T_4 (50 % vermiwash + full NPK) showed the highest value. Vermiwash contain the micronutrients in an appreciable amount (Table 1). So the application along with fertilizers might have resulted in a higher content in the plants.

SUMMARY

SUMMARY

The study entitled "Effect of soil and foliar application of vermiwash on growth, yield and quality of tomato (*Lycopersicon esculentum* Mill) was carried out at the Instructional Farm attached to the College of Agriculture, Vellayani. The study was conducted in two experiments. One was a pot culture trial followed by a field experiment using selected treatments based on fruit yield from the pot culture experiment.

Pot culture experiment was laid out in completely randomised design. Based on fruit yield, treatments were selected and field experiment was carried out in randomised block design. The treatment factors were method of application, (m_1 - foliar spraying and m_2 - soil application) different concentration of vermiwash (V_0 - 0 %, V_1 - 50 %, V_2 - 25 % and V_3 - 12.5 %) and different levels of NPK (f_1 - full NPK, f_2 - ½ NPK and f_3 0 NPK). The results of the experiment are listed below.

1. It was revealed from the pot culture experiment that the highest concentration of vermiwash produced comparatively lower yield. Soil and foliar applications produced similar results. So the lower concentrations (50 %, 25 % and 12.5 %) in two methods of applications along with graded doses of inorganic fertilizers were selected to find out the effect in the field level.

2. The different concentrations of vermiwash and the method of application did not produce any significant difference on the number of days taken to flower and fruit size. The method of application produced significant difference on the leaf area of tomato. Foliar spraying produced higher leaf area over soil application.
3. Significant difference in the fruit yield of tomato was obtained. Application of vermiwash along with inorganic fertilizers produced marked increase in fruit yield. At higher concentration (50 % and 25 %) of vermiwash. Inorganic fertilizers could be reduced to half of the recommended dose without any yield deduction. It was also observed that at higher concentrations, foliar spraying was found to be better whereas at lower concentration soil application was more effective.
4. As far as the seed production was concerned, in general vermiwash along with full NPK resulted in higher yield of seed. Foliar application was found to be superior over soil application.
5. The dry weight of the plant and the root - shoot ratio did not produce any significant difference over the different treatments.
6. Tomato fruits with better shelf - life was produced by soil application of vermiwash T_1, T_3, T_4, T_7, T_8 and T_{10} were on par which shows that no difference in the shelf - life of fruits of control plots and vermiwash applied plots.
7. The treatments produced significant difference on the lycopene content of fruits. T_{10} showed the highest value for lycopene content of fruits. But the

treatments did not produce any significant difference on the vitamin C and crude fibre content of fruits.

8. Soil application of vermiwash produced seeds with higher germination capacity compared to foliar application.
9. The application of different concentrations of vermiwash did not produce any significant difference on the available NPK at flowering stage of the crop. T_1 (Control) showed the highest value for N. Foliar spraying was superior over soil application for P and K.
10. No significant difference was observed on the available N content of soil at harvest of the crop. Foliar spraying produced higher values over soil application for P and K. T_4 and T_7 showed the highest values for P and K respectively.
11. The different concentrations of vermiwash did not produce significant difference on the total NPK content of fruits. The same effect was produced in case of Ca, Mg, Mn, Zn and Cu. Soil application was superior over foliar spraying in case of Ca and Mg.
12. The different treatments produced significant difference on the plant N and K content. T_4, T_7 and T_1 were significantly superior for N and K. The different concentration and the method of application did not produce significant difference on the plant P. The treatments cannot influence significantly on the Ca and Mg content of plants. With regard to the Mn, Zn and Cu content of plants, T_4 showed the highest value.

13. Considering the plant uptake of nutrients, T_4 in foliar spraying showed the highest value for N, P and K. The different concentrations of vemiwash did not show any significant difference on the Ca, Mg, Mn, Zn and Cu uptake.

It can be concluded that vermiwash application along with inorganic fertilizers could increase the yield of tomato crop. At higher concentration of vermiwash, inorganic fertilizers could be reduced to half of the recommended dose without any yield reduction. It was observed that at higher concentrations, foliar spraying was found to be better whereas at lower concentration, soil application was more effective. Soil application is preferred to get fruits with more shelf - life. Plant uptake of nutrients increased when vermiwash was applied along with inorganic fertilizers rather than inorganic fertilizers alone.

APPENDIX - I

Weather paremeters during the cropping period

Period	Temperature - 0^0C	Relative humidity %	Total rainfall (cm)
I Pot culture experiment			
April 1996	28.0	79.7	5.1
May 1996	28.5	74.9	5.1
June 1996	25.9	81.2	25.8
July 1996	25.05	83.2	17.3
August 1996	26.3	81.5	8.9
II Field experiment			
September 1996	26.7	81.0	7.8
October 1996	27.0	80.0	6.9
November 1996	26.9	78.6	6.0
December 1996	26.3	82.5	6.2
January 1997	27.0	82.0	6.0

APPENDIX - II

1. Media for isolation of bacteria (Soil extract agar)

Soil extract (stock)	1000 ml
Tap water	900 ml
Glucose	1 g
K_2HPO_4	0.5 g
Agar	15 g

1 kg of sieved garden soil is mixed with 1 litre of tap water and steamed in an autoclave for 30 min. A small amount of $CaCO_3$ is added and the whole is filtered through a double filter paper. Dissolve the agar in 900 ml of water by steaming it for an hour or more. Add 100 ml of stock soil extract solution. Then add glucose and pH adjusted to 6.8 using 1 N NaOH.

(Allen, 1957)

2. Media for isolaiton of fungi

Dextrose	10 g
Peptone	5 g
K_2HPO_4	1 g
$MgSO_4$	0.5 g
Rosebengal	trace
Streptomycin	30 mg
Distilled water	1000 ml

(Martin, 1950)

3. Media for isoation of actinomycetes (Kenknight's medium)

Glucose	1 g
K_2HPO_4	0.1 g
$MgSO_4$	0.1 g
KCl	0.5 g
$FeSO_4 . 2H_2O$	0.01 g
Distilled water	1000 ml

pH adjusted to 6.8 - 7.0 uisng 1 N NaOH.

(Subba Rao, 1986)

4. Media for phosphate solubilising microorganisms (Pikovsky's medium)

Glucose	10 g
$Ca_3 (PO_4)_2$	5 g
$(NH_4)_2 SO_4$	0.5 g
KCl	0.2 g
$MgSO_4 . 7 H_2O$	0.1 g
$MnSO_4$, $FeSO_4$	trace
Yeast extract	.05 g
Distilled water	1000 ml

(Sundara Rao and Sinha, 1963)

5. Media for nitrogen fixing microorganisms

Sucrose	20 g
K_2HPO_4	1 g
$MgSO_4 . 7 H_2O$	0.5 g
NaCl	0.5 g
$FeSO_4$	0.1 g
$Na_2 MnO_4$	0.005 g
$CaCO_3$	2 g
Agar	15 g
Distilled water	1000 ml

(Jensen, 1942)

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EFFECT OF SOIL AND FOLIAR APPLICATION OF VERMIWASH ON GROWTH, YIELD AND QUALITY OF TOMATO (*Lycopersicon esculentum* Mill.)

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ABSTRACT OF THE THESIS
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ABSTRACT

An investigation was carried out at the Instructional Farm attached to the College of Agriculture, Vellayani in two experiments to find out the effect of soil and foliar application of vermiwash on growth, yield and quality of tomato. First one was a pot culture experiment in completely randomised design to find out the best concentration among the different treatments. Based on fruit yield, treatments were selected and field experiment was carried out in factorial RBD. The treatment factors were two methods of application (m_1 and m_2), four concentrations of vermiwash (V_0, V_1, V_2 and V_3) and three levels of inorganic fertilizers (f_1, f_2 and f_3).

The fruit yield of pot culture experiment revealed that the highest concentration of vermiwash (100 %) produced the lowest yield among the different concentrations of vermiwash. Soil and foliar application produced similar results.

Field experiment was carried out without the highest concentration (100 %) of vermiwash. The results revealed that significant difference in the fruit yield of tomato was obtained. Application of vermiwash along with inorganic fertilizers produced marked increase in fruit yield. At higher concentrations (50 and 25 %) of vermiwash, inorganic fertilizers could be reduced to half of the recommended dose without any yield reduction. It was also observed that at higher concentration, foliar spraying was found to be better whereas at lower concentration soil application was more effective. But

vermiwash application did not produce any influence on the number of days to flower, fruit - size, dry weight and root - shoot ratio. Vermiwash application through the foliage along with inorganic fertilizers resulted in a higher seed yield. Soil application of vermiwash produced fruits with more shelf - life. The different concentration of vermiwash produced positive influence on the lycopene content of tomato, but no influence on the ascorbic acid and crude fibre content. Nutrient content of plant and fruits were influenced by the vermiwash application. Plant uptake of major and micronutrients was maximum for the highest concentration of vermiwash applied through foliage along with full inorganic fertilizers.

The present study revealed that vermiwash application in conjunction with inorganic fertilizers could increase the yield and the quality parameters of fruits of tomato.