PRODUCTION AND EFFECTIVE UTILIZATION OF BIOGAS FROM FRUIT WASTE

By

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(2013-11-146)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Agriculture

(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

Faculty of Agriculture

Kerala Agricultural University, Thrissur

Department of Soil Science and Agricultural Chemistry

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2015

DECLARATION

I hereby declare that the thesis entitled **"PRODUCTION AND EFFECTIVE UTILIZATION OF BIOGAS FROM FRUIT WASTE"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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Certified that the thesis entitled **"PRODUCTION AND EFFECTIVE UTILIZATION OF BIOGAS FROM FRUIT WASTE"** is a record of research work done independently by **Ms. Aswathy Gopinadhan** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the advisory committee of **Ms. Aswathy Gopinadhan (2013-11-146)**, a candidate for the degree of **Master of Science in Agriculture**, with major field in **Soil Science and Agricultural Chemistry**, agree that the thesis entitled **"Production and effective utilization of biogas from fruit waste"** may be submitted by **Ms. Aswathy Gopinadhan**, in partial fulfilment of the requirement for the degree.

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ACKNOWLEDGEMENT

First and foremost I bow my head before my ***All God*** *who enabled me to successfully complete the thesis work in time.*

It is with great respect and devotion, I place on record my deep sense of gratitude and indebtedness to my major advisor ***Dr. P.K. Sushama*** *Professor & Head, Department of Soil Science and Agricultural Chemistry and chairperson of my Advisory Committee for her sustained and valuable guidance, ever willing help, constructive ideas, unfailing patience, constant encouragement, friendly approach, and above all the understanding enthusiasm during the whole period of investigation and preparation of the thesis. Always looking for perfection, she corrected me several times. I gratefully remember her knowledge and wisdom, which nurtured this research project in the right direction without which fulfillment of this endeavour would not have been possible.*

I would like to express my extreme indebtedness and deep obligation to ***Dr. Radha T.,*** *Professor and Head, Department of Pomology and Floriculture , College of Horticulture and member of my Advisory Committee for her meticulous help, unwavering encouragement, forbearance, affectionate advice and well timed support and I owe a deep sense of gratitude to her.*

With profound respect and esteem I express my deep sense of gratitude and never ending indebtness to ***Dr. K.B. Sheela*** *Professor and Head, Department of Processing Technology, College of Horticulture, Vellanikkara and member of my Advisory Committee for his expert guidance, valuable suggestions, constant encouragement and sustained interest and for being kind enough to be available for guidance in spite of his busy works.*

I think it is my privilege to express my heartfelt thanks to ***Dr. Beena V.I,*** *Assistant professor (SS & AC), College of Horticulture, Vellanikkara and member of my Advisory Committee for his constant encouragement, sincere help, valuable suggestions, enthusiastic approach, constructive criticism, unreserved help and kind concern during the conduct of this research work and preparation of the thesis.*

I express my heartful gratitude to ***Visveswaran sir,*** *Assistant professor, Department of Soil Sciencce & Agricultural Chemistry for his valuable and positive advice and instructions were always informative and helpful to me throughout the course of investigation and research work.*

I extend my sincere respect and gratitude to ***Dr. Betty Bastin, Dr. Jayasree Sankar, Dr. Durga Devi K.M., Dr. A. K. Sreelatha, Dr. Suersh Kumar, Dr. Prema, Dr. George Thomas*** *who have always given encouragement and support and their personal involvement was highly valuable whenever I needed.*

I would like to acknowledge in depth to ***Dr. S. Krishnan and Dr Laly C. John*** *who helped me a lot for statistical analysis of data and correction of results & discussion part of my thesis.*

I would like to record my sincere gratitude to all teaching and non-teaching staff members of College of Horticulture, Vellanikkara for their wholehearted co-operation and assistance during the programme.

No words can truly portray my indebtness to ***Maya chechi, Arya chechi, Divya chechi, Vyshakhi chechi, Anu chechi, Chris chechi, Irene chechi, Indu Chechi, Anooja chechi, Sreenathettan, Baby chechy, Prsadhettan, Sindhu chechi, Devi chichi, Arun chettan, Surya, Ramanan, Vijithra chechi*** *and research*

associates of Department of Soil Science and Agricultural Chemistry for their timely help, and assistance always accorded to me during the course of investigation.

My loving and wholehearted thanks to my classmates ***Bhavya Sree, Nithya Jose and Samsheer*** *and my juniors* ***Amrudha, Beena, Aneesa, Adithya, Rincy , Neeraja, Reshma and Neenu,*** *for their help, good company, moral support throughout my P.G programme.*

My loving and whilehearted thanks to my friends ***Reshma N.T., Sreedhu,, Nithya, Asha, Ammu, Shafna and Greeshma*** *with a deep regret on the impossibility of repayment of their support, help, love and affection showed on me througout the period of this study.*

Words cannot be expressed to the support that I relished from ***my father, mother, Anju and Rajeshettan*** *their unflagging love, enormous patience and kind support rendered throughout the study period.*

I wish to acknowledge with gratitude the award of fellowship by the Kerala Agricultural University during the tenure of the M. Sc. (Ag.) programme.

A word of apology to those I have not mentioned in person and a note of thanks to one and all who worked for the successful completion of this endeavour.

Aswathy Gopinadhan

Dedicated to

My Family

&

My Teachers

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Introduction

1. INTRODUCTION

The annual production of fruits in India is estimated to be over 60 x 10^6 tons (Banu, *et al.,* 2007). During their transport from the harvesting place to the marketing centers, a sizable portion is lost due to poor and inadequate transport, storage facilities and marketing practices. Besides loss of fresh fruits, waste is also generated during the processing stage. There are over 18550 food-processing industries in India, emanating large quantities of solid wastes (Nand and Viswanath, 1989). Fruits and vegetable processing industries generate waste up to the extent of 25-40 % of raw materials used. These wastes are either uneconomically utilized or disposed of as they are, thereby causing serious pollution problems.

Mango and pineapple are the fruits which are increasingly being processed for finished products, juices, candy, slices and to some extent pulp. Since demand for processed food is increasing day by day, in future more such wastes will be generated. Utilization of these commodities results in 33 and 35% of waste generation, respectively (Inthapanya *et al.,* 2013). In India the annual production of pineapple is 0.7 million tones, amounting to 0.23 tons of solid waste (FAO, 2009). Biological conversion of biomass to methane has received increased attention during recent years. Fruit-processing wastes are highly biodegradable as they are rich in organic matter and have high moisture content. Since they have above 50% of moisture content, it is found that bio-conversion processes are more suitable than thermo-conversion processes. Biomethanation of fruit wastes is the best suited treatment as the process not only adds energy in the form of methane, but also results in a highly stabilized effluent which is almost neutral in pH and is odourless. Biogas is a clean energy source which can be used as fuel and for electrical purpose. Besides, biogas slurry is a good source of nutrients for plant growth, since the manurial value of dung is enhanced due to digestion.

Cattle manure which is used as fuel in rural areas can be used for biogas and slurry production which provides both fuel and high quality manure. Co-digestion of fruit waste with cow dung resulted in increased biogas yield and methane (Narayani and Priya, 2012). The use of co-substrates usually improves the biogas yields from anaerobic digester due to positive synergisms established in the digestion medium and the supply of missing nutrients by the co-substrates. A biogas (cow dung alone) plant of size 2.85 m^3 has heat equivalent of 1.7 litre of diesel oil for running of bio fuel based engines or 1.06 kg of LPG or 1.5 litre of Kerosene oil.

However the production of biogas is sensitive to temperature, pH, dilution, reaction period and nature of substrate. The optimum temperature for methane producing microorganisms is 30-35 ^{0}C. These microorganisms thrive best in neutral to slightly alkaline media and become inactive below pH of 6.0. The carbon: nitrogen (C: N) ratio ranging from 20-30:1 is considered as optimum for digestion.

Mango (*Mangifera indica* L.), the King of fruits occupies an important place among the fruit crops grown in India. Mango is a highly cross pollinated crop and as a result there is enormous variation in the seedlings raised from the seeds of single tree. Rootstocks are always seedling origin irrespective of zygotic/nucellar nature. For using as rootstocks, mango seedlings are required in large numbers. Usually mango stones are sown in large nursery beds immediately after extraction. On an average, the germination % of mango stones ranges from 60 to 80, though there exists variation among varieties. The time taken for germination is 15 to 25 days and the seedling vigour also differs from variety to variety. Improvement of germination capacity and enhancement of seedling vigour will be useful for obtaining good and sizable rootstocks for the production of quality planting materials of mango.

Thus the proposed programme envisages the standardization of biogas production from fruit waste and the effect of biogas slurry on the germination of mango stones. The results will enable the agro-entrepreneurs to effectively utilize the fruit waste from processing factories.

The objectives of the study are

1. Standardization of optimum combination of cow dung and fruit waste for maximum biogas production
2. Effect of biogas slurry on the germination of mango stones

Review of Literature

2. REVIEW OF LITERATURE

The literature on aspects pertaining to the study on "Production and Effective Utilization of Biogas from Fruit waste" is reviewed here under.

2.1 BIOGAS

Biogas, the gas generated from organic digestion under anaerobic conditions by mixed population of microorganisms, was reported as an alternative energy source which had been utilized both in rural and industrial areas at least since 1958 (Coelho *et al.*, 2006). Biogas, a clean and renewable form of energy, could very well be a substitute for conventional sources of energy which were causing ecological and environmental problems and at the same time depleting at a faster rate (Santosh *et al.*, 2004).

The biogas in general composed of methane (55–65%), carbon dioxide (35-45%), nitrogen (0–3%), hydrogen (0–1%), and hydrogen sulfide (0–1%) (Milono, 1981). Natural gas is about 90–95% methane, but biogas is about 55–65% methane. Biogas was regarded as low grade natural gas (House, 2007). Biogas was found to be 20 percent lighter than air and has an ignition temperature in the range of 650 to 750 °C. Viji (2011) reported that the odourless and colourless biogas burned with clear blue flame similar to that of LPG gas with calorific value 20 Mega Joules (MJ) per m^3 and had about 60 % efficiency in a conventional biogas stove.

2.1.1 Historical background

The appearance of flickering lights emerging from below the surface of swamps was noted by Plinius and Van Helmont who recorded the emanation of an inflammable gas from decaying organic matter in 1630. Shirley discovered marsh gas

(methane) in 1667. Alessandro Volta concluded in 1776 that there was a direct correlation between the amount of decaying organic matter and the amount of flammable gas produced (Adnan, 2010). Humphrey Davy in the early 1800's conducted the first laboratory experiment to produce methane by anaerobic fermentation of wastes. In earlier period anaerobic fermentation was carried out mainly as a municipal waste treatment process and energy recovery was not the primary concern. In 1806 William Henery showed that Volta's gas was identical with methane gas. In 1895, biogas from a waste treatment plant at Exter in England, was collected and used to light nearby streets, while gas from human waste in the Matinga Leper Asylum in Mumbai, India, was used for lighting in 1897 (Mital, 1996). During the World War II, crude oil shortages led to the rediscovery of biogas as an alternate fuel. However, the efforts were short-lived with the end of the War. The period from 1950 to 1970 saw the proliferation of small-scale biogas plants in India and China. With the passage of time, anaerobic digestion was increasingly recognized as an inexpensive technology to stabilize organic waste. In India, the Gramalakshmi plant was developed in 1951, which was later modified in 1954. This model was adopted by the Khadi and Village Industries Commission (KVIC) during 1960s and 1970s. Janata type fixed dome biogas plant was developed in 1977, by Gobar gas research station at Etawah, Uttar Pradesh (Khoiyangbam *et al.*, 2011).

2.1.2 Method of biogas production

Using biogas digester is simple; the digester is initially filled with water until it overflows which creates an air lock with water in lower two third of the tank and air in the top one third. Once in the chamber the bacteria starts decomposition of the organic matter as the matter flowed through the tank, biogas accumulated in the upper part of the digester (Dhanalakshmi and Ramanujam., 2012).

2.1.3 Substrate for biogas

Biogas production had usually been applied for waste treatment, mainly sewage sludge, agricultural waste (manure), and industrial organic waste streams (Hartmann and Ahring, 2005). The primary source, which delivered the necessary microorganisms for biomass biodegradation as well as one of the largest single sources of biomass from the food/feed industry, was manure from animals, mainly from cows and pig farms (Balat, 2007). Anaerobic digestion of Organic Fraction Municipal Solid Waste (OFMSW) had been studied to develop a technology that offered waste stabilization with resources recovery (Nguyen *et al.*, 2007).

Biogas production was mainly based on the anaerobic digestion of single energy crops. Maize, sunflower, grass, and sudan grass were reported as most commonly used energy crops. Biogas production increased on a wide range of energy crops that were grown in versatile, sustainable crop rotations (Bauer *et al.*, 2007). Filipkowska and Agopsowicz (2004) reported landfills as specific source of biogas. In a typical landfill, the continuous deposition of solid waste resulted in high densities and the organic content of the solid waste had undergone microbial decomposition to release biogas.

2.1.4 Suitability of fruit waste as substrate for biogas production

Biomethanation of fruit waste was the best suited treatment as the process not only adds energy in the form of methane, but also resulted in a highly stabilized effluent which was almost neutral in pH and was odourless (Bardiya *et al.*, 1996). Cuzin *et al.*, (1992) studied methanogenic fermentation of cassava peel and recorded 0.217 m^3 biogas production/kg fresh cassava peel, with a mean methane content of 57%. A mixture of fruit and vegetable wastes subjected to anaerobic digestion produced 0.12 m^3 biogas/kg Total Solids (TS) added at an Hydraulic Retention Time

(HRT) of 16 days (Viswanath, *et al.,* 1992). Kalia *et al.,* (1992) observed a gas production of 0.27 m^3/kg TS added in the case of apple pomace. Anaerobic digestion of mango peel resulted in biogas production of 0.33 m^3/kg TS added with 53% methane content at an HRT of 15 days (Somayaji, 1992). Mata-Alvarez *et al.,* (1992) had shown that biomethanation of food-market waste resulted in a production of 0.64 m^3 biogas/kg TS added.

The lowest possible HRT for banana peel was 25 days, resulting in a maximum rate of gas production of 0.76 vol/day with 36% substrate utilization, while pineapple processing digesters could be operated at 10 days HRT, with a maximum rate of gas production of 0.93 vol/day with 58% substrate utilization (Bardiya *et al.*, 1996). Pilot scale batch biodigesters were used to measure gas production and methane concentration from fresh samples (150 g) of banana skin, orange rind, papaya peel and cow manure incubated at 30 days in a water bath at 35^{0}C. Gas production over 30 days incubation period was found to be the highest with cow manure followed by orange rind, with the lowest value for papaya peel and banana skins (Inthapanya *et al.,* 2013).

2.1.5 Co-digestion of substrate

The co-fermentation of plant mass with liquid manure enabled the stabilized process of biogas production due to the high buffering capacity of manure in the substrate and it limited dysfunctions caused by the higher ammonia contents (Mclnerny and Bryant, 1981). Co-digestion generally resulted in improved biogas and methane yields compared to separate digestion (Schnurer *et al.,* 1999; West erhom *et al.,* 2012). Livestock waste had a major disadvantage of low organic content coupled with low biodegradability (Vedrenne *et al.,* 2008). The use of manure was

relatively rare and co-substrates were often added to increase biogas production (Mata-Alvarez, 2000)

Co-digestion generally resulted in improved ultimate biogas and methane yield compared to separate digestion and methane production was further more significantly higher at intial (0-7) days of digestion and to some extent also at later stages (above 20 days) of digestion during co - digestion process (Callaghan *et al.,* 2002). For single substrate the bio-methane potential assay showed that kitchen waste had the highest methane content yield of 352 L- CH_4 /kg volatile solids added, which was 92% more than dairy manure (Ye *et al.,* 2015).

2.2 Biogas production process

2.2.1 Anaerobic digestion

According to Adeleken and Bamgboye, (2009) anaerobic digestion was a process through which organic materials were decomposed by bacteria in the absence of air to produce biogas. Biogas was used as energy to replace fossil fuels and thereby to reduce carbon dioxide emissions. Wilkie (2000) reported anaerobic digestion a natural process that converted biomass to energy. Biomass could be any organic material from plants, animals or their wastes. During anaerobic digestion, very little heat was generated in contrast to aerobic decomposition in presence of oxygen. The energy which is chemically bounded in the substrate remained as produced biogas, in the form of methane (Seadi *et al.*, 2008).

According to Rajendran *et al.*, (2012) methane formation in anaerobic digestion involved four different steps including hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Different bacterial communities worked in a syntrophic relationship with each other to form methane. In the last phase, methanogens converted the

intermediates produced into methane and carbon dioxide. Almost one-third of methane formation was due to reduction of carbon dioxide by hydrogen.

Mclnerny and Bryant (1981) reported that biogas process could be divided into three steps namely hydrolysis, acidification and methane formation. The first step involved the enzyme- mediated transformation of insoluble organic material and higher molecular mass compounds such as lipids, polysaccharides, proteins, fats, nucleic acids, etc. into soluble organic materials and was carried out by strict anaerobes such as *Streptococci.* The rate of hydrolysis depended on the pH, temperature, composition and concentration of intermediate compounds. At acetogenesis stage the monomers were further degraded by fermenting and acetogenetic bacteria to hydrogen gas, carbon dioxide, alcohols, organic acids (including acetate), ammonia (NH_3) and hydrogen sulphide (H_2S) (Khandeiwal, and Mahdi, 1986). In third step, the acetic acid, hydrogen and carbon dioxide were converted into a mixture of methane and carbon dioxide by the methanogenic bacteria (acetate utilizers like *Methanosarcina* Spp. and *Methanothrix* Spp. and hydrogen utilizers like *Methanobacterium* and *Methanococcus*) (Mclnerny and Bryant, 1981).

In the complex process of anaerobic digestion, hydrolysis/acidification and methanogenesis were considered as rate-limiting steps (Juanga *et al.,* 2005; Nguyen *et al.,* 2007). The biogas produced in anaerobic digesters could contain methane concentrations of 80% in volume, and its quality would depend on its origin, drain, anaerobic digestion of residual waters, or treatment of residuals (Benito *et al.,* 2007).

2.2.2 Anaerobic digesters

Anaerobic digesters are small man-made ecosystems enclosed in a chamber in which the parameters of anaerobic fermentation are optimized to yield a steady and predictable supply of usable gas. A simple apparatus or plant is enough to produce biogas. Desired capacity and life of a plant affects cost and complexity of a biogas system. A simple digester required an oxygen free container, relatively constant temperature, means for collecting gas and some mixing device (Mital, 1996). According to Singh *et al.*, (1997), main types of anaerobic digesters were floating drum type, fixed dome (Chinese or hydraulic) type, plug flow digesters and flexi type. The fixed dome type digesters are built underground. Floating drum type biogas plants are made up of two integral units, one a gas holder and the second a digester with inlet and outlet pipes. Plug flow digesters or tubular digesters are portable models built over the ground.

Flexi type digesters mainly consisted of two parts, a lower digester part and an upper gas holder part. This plant is completely made up of neoprene rubber reinforced with nylon. Popular anaerobic digesters in India included floating gas holder type plants such as KVIC model and ASTRA model, and fixed dome type plants such as Janata and Deenbandhu models. Other major models in India are Pragati model (a combination of KVIC and Deenbandhu designs), Manipal model (a combination of Indian and Chinese designs). Flexi model and Jwala model (gas holder made up of polythene sheet). Bag type digester (Taiwan), Solid state fermenters, Biphasic fermenters, Anaeroic baffled reactors (United States) and Upflow anaerobic sludge blankets (Netherlands) are other major types of anaerobic digesters used in various parts of the world (Khoiyangbam *et al.*, 2011).

According to Rajendran *et al.*, (2012), out of all the different digesters developed, the fixed dome model developed by China and the floating drum model

developed by India had continued to perform until today. Divya *et al.*, (2014) reported that floating drum biogas plants had more gas production when compared to traditionally use fixed dome biogas plants.

2.3 Factors affecting anaerobic digestion

The performance of biogas plants can be controlled by studying and monitoring the variation in parameters like pH, temperature, carbon/nitrogen ratio, retention time, etc. Any drastic change in these could adversely affect the biogas production. So these parameters should be varied within a desirable range to operate the biogas plant efficiently (Santosh *et al.*, 2004).

2.3.1 pH

A major variable to be monitored and controlled is pH. The range of acceptable pH in digestion theoretically ranged from 5.5 to 8.5. However, the most methanogens function only in a pH range between 6.7 and 7.4 (Buekens, 2005). A decrease in pH could point towards acid accumulation and digester instability. Gas production was the only parameter that showed digester instability faster than pH (Ostrem, 2004). Thy (2003) reported that in the initial period of fermentation, the pH inside the digester fell below 5 due to the formation of large amount of organic acids and it inhibited the growth of methanogenic bacteria. According to Yadvika (2004) the pH of the digester should be kept within a desired range of 6.8 to 7.2 by feeding at an optimum loading rate.

Nagaswami and Ramaswamy (1999) reported that, pH of 7.0- 7.2 was optimum for increased biogas yield, though the gas production was satisfactory between pH 6.6- 7.6. The pH of the digester was a function of the concentration of the volatile

fatty acids, bicarbonate alkalinilty and the amount of carbon dioxide produced in the system. The pH was found to be an important parameter affecting the growth of microbes during anaerobic fermentation. Khalid *et al.*, (2011) stated that methanogenesis in an anaerobic digesters occured efficiently at pH 6.5 – 8.2, while hydrolysis and acidogenesis occurred at pH 5.5 and 6.5, respectively.

For an anaerobic fermentation to proceed normally concentration of volatile fatty acids and acetic acid in particular should be below 2000 mg L^{-1}. Jain and Mattiasson (1998) found that, the efficiency of CH_4 production was more than 75% above the pH 5.0. The major problem related to drastic reduction in pH due to rapid acidification of Onion storage waste was overcome by Sharma (2002) by mixing cattle dung in a suitable ratio so that the medium is well buffered to take care of acid accumulation.

2.3.2 Temperature

Maurya *et al.*, (1994) and Desai and Madamwar (1994) reported that the different temperature ranges during which anaerobic fermentation could be carried out varied between psychrophilic (below 30 ^{0}C), mesophilic (30–40 ^{0}C) and thermophilic (50–60 ^{0}C) zones. However, anaerobes were reported to be most active in the mesophilic and thermophilic temperature range. The length of fermentation period is dependent on temperature.

Bacteria had a limited range of temperature in which they were active (Elango *et al.*, 2006). Methane production had been documented under a wide range of temperatures, but bacteria were most productive in either mesophilic conditions at 25 – 40 °C, or in the thermophilic range, 50 – 65 °C. A mesophilic digester must be

maintained between 30 °C and 35 °C for optimal functioning. A thermophilic digester was maintained near 50 °C (Ostrem *et al.*, 2004).

Temperature had significant effects on the microbial community, process kinetics, stability, and methane yield. Lower temperatures during the process decreased microbial growth, substrate utilization rates and biogas production. In contrast, high temperatures lowered biogas yield due to the production of volatile gases such as ammonia which suppressed methanogenic activities (Khalid *et al.*, 2011)

Weiland (2010) stated that temperature changes or fluctuations would affect the biogas production negatively. Mesophilic bacteria tolerated temperature fluctuations of 3 °C without significant reductions in methane production but thermophilic processes were more sensitive to temperature fluctuations and required longer time to adapt to a new temperature. According to Adelekan and Bamgboye (2009), biogas production was greatest when the digester temperature was in the range of 32 to 40°C and also the digestion temperatures for optimum designs occured in the mesophilic range of 32 to 40 °C.

The anaerobic digestion process usually runs at 30–40 ^{0}C (mesophilic) or 50–60^{0}C (thermophilic) temperatures. Mesophilic temperatures were well documented to display good operating performance and to be less sensitive, e.g. to ammonia inhibition (Kim *et al.*, 2002). High temperature resulted in high microbial activity and faster degradation of organic materials, allowing shorter hydraulic retention time and higher Organic Load Rate (OLR). The conventional temperatures used for digestion were mesophilic (35-40^{0}C) and thermophilic (50-65 ^{0} C) (Kim *et al.*, 2002).

Thermophilic digestion gave higher biogas and methane productivity than mesophilic and was able to operate at the higher OLR where mesophilic digestion showed signs of instability. Thermophilic operation allowed higher loadings to be applied without loss of performance, and gave a digestate with superior dewatering characteristics and very little foaming potential. The thermophilic process could operate stably at this OLR and recovered more than 68% of the calorific value as methane (Sushartni *et al.*, 2014).

Temperature inside the digester had a major effect on the biogas production process. The length of fermentation period was dependent on temperature. Angelidaki and Ahring (1994) observed that when the NH_3 load was high, reducing temperature below 55°C resulted in an increase of biogas yield and better process stability, as shown by the reduced Volatile Fatty Acid (VFA) concentration.

Garba (1996) observed that methanogens were very sensitive to sudden thermal changes; therefore any drastic change in temperature should be avoided. Nozhevnikova *et al.*, (1999) proposed a two step anaerobic treatment of cattle dung involving (i) acidogenic fermentation at high temperature (55–82 °C), and (ii) separation of solid and liquid fractions and treating the liquid manure under low temperature conditions (5–20°C).

2.3.3 C : N Ratio

It was necessary to maintain proper composition of the feedstock for efficient plant operation so that the C: N ratio in feed remained within a desired range. It was generally found that during anaerobic digestion microorganism utilized carbon 25–30 times faster than nitrogen (Bardiya and Gaur, 1997; Malik *et al.*, 1987). Thus, to meet

this requirement, microbes needed a 20–30:1 ratio of C to N with the largest percentage of the carbon being readily degradable (Shilpakar and Shilpakar, 2009). A high C: N ratio was an indication of rapid consumption of nitrogen by methanogens and resulted in lower gas production. On the other hand, a lower C: N ratio caused ammonia accumulation and pH values exceeding 8.5, which was toxic to methanogenic bacteria. Optimum C: N ratio of the digester materials could be achieved by mixing materials of high and low C: N ratios, such as organic solid waste mixed with sewage or animal manure (Verma, 2002).

Karki and Dixit (1984) reported that the common substrates used for biogas production were cattle manure (24:1), pig manure (18:1), poultry manure (10:1), human excreta (8:1) and vegetable waste (12-30: 1). Waste material that was low in C could be combined with materials high in N to attain desired C: N ratio of 30:1 (Babatola, 2008; Fry and Merill, 1973).

According to a study conducted by Idnani and Laura (1971) biogas production from 0.5 kg of cow dung almost doubled from 17.2 to 31.5 L by addition of 200 ml of urine. Use of urine soaked waste materials was particularly advantageous during winter months when gas production was otherwise low.

2.3.4 Retention Time

In anaerobic digestion technology, two types of reactors were used: the batch process and the continuous process. In the batch process, the substrate was put in the reactor at the beginning of the degradation period and sealed for the duration of digestion. All the reaction stages occur more or less consecutively and therefore the production of biogas followed a bell shaped curve. Retention time ranged from 30–60

days and only about 1/3 of the tank volume was used for active digestion (Ostrem, 2004).

The retention time was determined by the average time that was taken for organic material to digest completely, as measured by the chemical and biological oxygen demand (COD and BOD) of exiting effluent. Speeding up the process would make it more efficient. Microorganisms that consumed organic material controlled the rate of digestion that determined the time for which the substrate must be remained in the digestion chamber, and therefore the size and cost of the digester (Ostrem, 2004).

According to Tomar (1995), HRT was the time taken by the substrates for maximum gas production *i.e.,* 70-80 percent of the substrate completed their digestion at Hydraulic Retention Time. In Indian conditions, HRT varied from 30-60 days and in Kerala conditions it was around 30 days. Seadi *et al.*, (2008) reported that HRT was the average time interval when the substrate is kept inside the digester tank and it was related to the digester volume and the volume of substrate fed per unit time. Adelekan and Bamgboye (2009) reviewed that at a given organic loading rate, HRT was lower for substrates having higher water content than those having lower water content. Weiland (2009) stated that there was a negative correlation between HRT and operating temperature. A well-functioning thermophilic biodigester could have a lower HRT than a mesophilic one. A shorter retention time would lead to a higher production rate per reactor volume unit, but a lower overall degradation. These two effects have to be balanced in the design of the full-scale reactor. Several practices were generally accepted as aiding in reducing retention time. Two of these were continuous mixing and using low solids (Ostrem, 2004).

Rajendran *et al.*, (2012) opined that HRT should be at least 10 – 15 days and it varied between 20 and 100 days in the case of mesophilic household anaerobic digesters. It was the average time spent by the input slurry inside the digester before it came out. In tropical countries like India, HRT varied from 30–50 days while in countries with colder climate it might go up to 100 days. Shorter retention time was likely to face the risk of washout of active bacterial population

2.3.5 Season of biogas production

According to Hamad *et al.*, (1981), the biogas production was more in summer than in winter. Khoiyangbam *et al.*, (2004) pointed that in North Indian conditions, methane emissions were higher in summer months having high atmospheric temperatures than other seasons. According to Divya *et al.*, (2014) there was a drop in biogas production in winter months due to a decreased atmospheric temperature and was more in summer months. The decrease in gas generation during winter season had been reported which, poses a serious problem in the practical application of this technology. Kalia and Singh (1996) found that biogas production reduced from around 1700 L/day in May–July to around 99 L/day in January–February.

2.3.6 Quantity and quality of substrate

2.3.6.1 Organic Loading Rate (OLR)

Gas production rate was highly dependent on loading rate. Methane yield was found to increase with reduction in loading rate (Vartak *et al.*, 1997). In an another study carried out in Pennsylvania on a 100 m^3 biogas plant operating on manure, when OLR was varied from 346 kg Volatile Solids (VS) /day to 1030 kg VS/day, gas yield increased from 67 to 202 m^3/day. There was an optimum feed rate for a

particular size of plant, which would produce maximum gas and beyond which further increase in the quantity of substrate will not proportionately produce more gas. According to Mohanrao (1974), a daily loading rate of 16 kg VS/m^3 of digester capacity produced 0.04-0.074 m^3 of gas/kg of dung fed. A lab-scale digester operating at different OLRs produced a maximum yield of 0.36 m^3/kg VS at an OLR of 2.91 kg VS/ m^3/day (Sundrarajan *et al.,* 1997). Based on pilot plant studies (1 m^3 capacity), maximum gas yield was observed for a loading rate of 24 kg dung/m^3 digester/day although percent reduction of VS was only 2/3rd of that with low loading rate (Mohanrao, 1974).

2.3.6.2 Solid concentration

The amount of fermentable material in a unit volume of slurry was defined as solid concentration. Ordinarily 7–9% solids concentration was found to be best-suited (Zennaki *et al.,* 1996). The biogas yield increased, reaching 0.46 m^3/day at 37 °C and 0.68 m^3/day at 55 °C, respectively. Baserja (1984) reported that the process was unstable below a total solids level of 7% (of manure) while a level of 10% caused an overloading of the fermenter.

2.3.6.3 Dilution and consistency of inputs

Gurung (1996) reported that fresh cattle dung had to be mixed with water at the ratio of 1:1 on a unit volume basis. The dilution should be made to maintain the total solid content from 7 to 10 %. When the dung was too diluted, the solid particles settled down in the digester and when too thick, gas formed at the lower part of digester was impeded to flow up through the particles. In both cases, gas production was less than the optimum. Iteun *et al.*, (2007) found that the best dilution was with

1:1 ratio of substrate and water for better gas production which ensured 8 % of total solids.

2.3.6.4 Pretreatment

Feedstocks sometimes required pretreatment to increase the methane yield in the anaerobic digestion process. Pretreatment broke down the complex organic structure into simpler molecules which were then more susceptible to microbial degradation. Dar and Tandon (1987) observed an improvement of 31–42% in microbial digestibility and an almost twofold increase in biogas when alkali treated (1% NaOH for 7 days) plant residues were used as a supplement to cattle dung. Predigestion of fresh cattle slurry in a batch system for 1–2 days at 30–35 °C increased acetate production and the use of this slurry as a feed material for anaerobic digesters increased biogas production by 17–19 % and methane content from 68–75% to 75–86%. It also helped in the pretreatment of polymeric constituents and conversion of major components of carbohydrates into volatile fatty acids. It produced 58% more gas as compared to control (Madhukara *et al.,* 1993).

2.3.6.5 Particle size of substrate

The size of the feedstock should not be too large otherwise it would result in the clogging of the digester and also it would be difficult for microbes to carry out its digestion. Smaller particles on the other hand would provide large surface area for adsorbing the substrate that would result in increased microbial activity and hence increased gas production. Madamwar and Mithal (1986) found that out of five particle sizes (0.088, 0.40, 1.0, 6.0 and 30.0 mm), maximum quantity of biogas was produced from raw materials of 0.088 and 0.40 mm particle size. Large particles could be used for succulent materials such as leaves. However, for other materials

such as straws, large particles could decrease the gas production. The results suggested that a physical pretreatment such as grinding could significantly reduce the volume of digester required, without decreasing biogas production (Gollakota and Meher, 1988). Patel *et al.,* (1993) found that thermochemical pretreatment of water hyacinth improved biomethanation and the best results were obtained when water hyacinth was treated at pH 11.0 and at 121 °C. Ultrasonic pretreatment of waste activated sludge for 30 minutes resulted in a 64% increase in methane production (Wang *et al.,* 1999).

2.4 Biogas slurry and properties of soil

According to Rajendran *et al.* (2012), the slurry leftover from the digesters, was found to be rich in nitrogen, phosphorus and potassium, and could be directly used as a fertilizer in farming.

Biogas slurry consisted of 93 % water and 7 % dry matter, of which 4.5 % was organic and 2.5 % was inorganic matter. The percentage of NPK content of slurry on wet basis was 0.25, 0.13 and 0.12 while on dry basis it was 3.6, 1.8 and 3.6 respectively. In addition to the major plant nutrients, it also provided micro-nutrients such as Zn, Fe, Mn and Cu (FAO, 2007). Janotti *et al.*, (1986) and Goldstein (2000) concluded that during fermentation process of manures and other biomaterials, the NH_4^+ content and pH of the biogas slurry was increased, while dry matter content, C/N ratio and smell decreased in comparison to animal manures used as organic sources.

During the anaerobic fermentation process about 25 to 30 percent of the organic matter from the fecal matter was converted into biogas while the rest becomes available as residual manure (Chawla, 1986) which was generally

considered to be rich in major plant nutrients. Nutrients such as zinc, iron, manganese and copper, were generally in short supply in many soils (Tripathi, 1993). Acharya (1961) also reported that on drying the digested cow dung slurry, around 96 percent of the dissolved ammonia escaped into the air. In order to explain this loss a measurement of pH before and after the fermentation was found to be 7.2 and 8.3, respectively. The increased alkalinity was presumed to be due to the accumulation of ammonia in the slurry after digestion. Due to the alkaline pH, almost the whole of the ammonia present was lost by volatilisation during the evaporation and drying of the digested slurry (Acharya, 1961). The dried residue contained only 1.78 percent of nitrogen. If there was no loss of ammoniacal nitrogen, the total nitrogen would have come to around 2.16 percent of the dry matter. Tarn and Thanh (1983) stated that the nitrogen level did not reduce during anaerobic digestion, and the degree of reduction ranges from 3 to 10 percent.

2.4.1 Effect of Biogas slurry on physical properties of soil

Bioslurry, in its different forms was reported to be relatively free from foul smell, weed-seed and phytopathogenic organisms (Tripathi, 1993). It also improves soil porosity and water holding capacity (Tripathi, 1993; Santosh *et al.,* 1993). Slurry had bulk fibre to hold soil manure (Itodu and Awalu, 1999). The slurry produced by a biogas plant is considered to be an effective fertilizer and soil conditioner.

2.4.2 Effect of Biogas slurry on chemical properties of soil

Odlare *et al.,* (2008) showed that soil chemical properties hardly change in short term when the soil was amended with organic wastes, including digestates. However, relative to other treatments, (pig manure, cow manure, compost, inorganic fertilizer), soils treated with liquid digestate from household wastes displayed the

highest microbial biomass, nitrogen mineralization rate and potential ammonia oxidation. An incubation study (Canali *et al.,* 2011) revealed that anaerobic digestates from wine industry mineralized nitrogen at a higher rate than their compost counterparts. Canali *et al.,* (2011) observed that nitrogen mineralization of organic products ranked inversely with respect to their C/N ratio. Since the feedstock inputs lost their C as CO_2 and CH_4 through the anaerobic digestion process, anaerobic digestates generally had a lower C/N ratio than their aerobic compost counterparts. Earlier incubation research work (Loria and Sawyer, 2005) on digested swine manure described the dynamics of N and P in amended soils. Raw and digested swine manure produced similar rates of conversion of NH_4^+ to NO_3^-, net organic N and increase in soil test P.

2.4.3 Biogas slurry on improving biological properties of soil

Slurry provided energy to soil microflora including the N fixing and P solublizing organisms (Lakshmanan, 1993). Xianjun *et al.* (2011) reported that slurry application increased soil microflora and amounts of phosphobacteria, silicate bacteria, ammonifying bacteria, N-fixation bacteria and actinomycetes but the accumulation of fungi was significantly inhibited. Compared with the control treated by chemical fertilizers, the bacteria and fungi ratios of the soils treated with biogas slurry @ 168 kg ha^{-1} and 225 kg ha^{-1} increased by 142.7 % and 202.3 % respectively. At the same level of slurry @ 225 kg ha^{-1}, the activities of soil enzymes *viz.,* invertase, phosphatase and protease also increased by 63.96 %, 137.61 % and 139.66 % respectively.

2.4.4 Effect of biogas slurry on germination of seeds

Seed treatment was a technique of applying needed inputs such as organic, inorganic inputs, biofertilizers and pesticides on the seed themselves in an effort to provide a self-sustaining seed unit with an improved micro-environment for germination and seedling development. Bioslurry contains soluble nutrients and numerous active substances like enzymes and vitamins secreted by microbes which were capable of promoting metabolism of the seedlings and also possesses anti-disease, (Zhicheng, 1991). It was an effective seed coating medium (Lakshmanan *et al.,* 1993). Zhicheng (1991) reported that paddy seed soaked with slurry improved germination rate, developed better plants that were greener and less susceptible to disease.

Kanwar *et al.*, (1993) reported that seeds of bread wheat when treated with biodigested slurry for six hours increased the germination percentage, vigour index, shoot and root length. Seed pelleting with biodigested slurry at 50 % for 5 days gave increased germination % and grain yield of 589 kg ha^{-1} over unpelleted seeds in rice fallow green gram (kuppuswamy *et al.,* 1992).

Soaking of wheat seeds for 6-12 hours in slurry and water before sowing resulted in significant increase in germination percentage at Palampur, Himanchal Pradesh. In addition, mean germination time was reduced and the root length increased. In Karnataka, application of slurry stimulated beneficial microbiological activities in respect to fungi, phosphorous solublizer and nitrogen fixing azotobactor (Singh, *et al.,* 1995).

2.4.5 Biogas slurry and crop response

Dhussa (1985) concluded that the application of biodigested slurry increased the yield of rice, wheat, maize and cotton upto 6.5, 8.9, 15.2, 15.7 % respectively compared to farm yard manure. Application of biodigested slurry alone at (15 t/ ha) for rice recorded maximum yield (5316.56 kg/ha) and it was at par). with the application of FYM I2.5 t/ha with 75% NPK (4873.93 kg/ha) (Kanthaswamy, 1993)

Thus biogas slurry was concluded to be superior manure for raising crops than farm yard manure (Singh *et al.*, 1995). In groundnut, the yield increased at the range of 20 to 33 % pod number per plant ranged from 60 to 70 as compared to 45 to 55 in the control and sunflower showed an incremental yield of 25 % by adding biogas slurry. The plants from the treatment plot were also reported to be healthier and taller than those from the control plots (Kologi, I993). Around 40 percent nitrogen substitution through slurry application was found to be optimum for maize and paddy in sandy loam soil (Singh *et al.*, 1995).

Islam *et al.*, (2009) reported that the application of biogas slurry as nitrogen fertilizer stimulated the growth of maize fodder. Approximately 70 kg of slurry nitrogen was optimum for maize growth. Islam *et al.*, (2009) confirmed that increasing the level of slurry nitrogen presumably increased the availability of soil nitrogen and that of other macro and micro nutrients which might have enhanced meristamatic growth and resulted in higher fodder yield. Application of 50, 75 and 100 % nitrogen through biogas poultry manure resulted in a significant increase in cob and stover yield of maize. The green fodder yields of cow pea which was grown on residual fertility were significantly influenced by poultry manure and biogas poultry manure (Molnar and Bartha, 1989).

Gypsum enriched biogas slurry in combination with 75% recommended NPK registered maximum grain yields in rice-black gram cropping system. Based on these findings it was concluded that the basal application of gypsum enriched biogas slurry was found to be promising as a viable agronomic practice for the realization of higher yields in rice-black gram crop-sequence and the maintenance of soil fertility (Kuppuswamy *et al.*, 1993).

Shen (1985) reported that spraying digested slurry only or with little pesticide could effectively control red spider mite and aphids attacking vegetables, wheat, and cotton. The effect of effluent with 5-20% pesticide on controlling pest was the same as that of pesticides showing the potential for biogas slurry to reduce cost of production and pollution (Kate, 1991). Shen (1985) also showed that basal dose of barley seeds with anaerobically fermented sludge could very effectively control the barley yellow mosaic virus which was one of the most destructive diseases in barley growing areas of India. It was estimated that barley yield could be increased by 20-25% by improving the health of plants. It was achieved because slurry dressing prohibited large amount of pathogens and pests from entering into the seed by creating slurry coat around the seed and by producing volatile substances as methane and ethylene which form a protective layer around the coat. The higher production (than in the control) of Vitamin B_{12} and hormones like auxinns, kinins, and gibberlins in the treated plants also offer resistance to diseases (Kate, 1991). Bhindi seeds pelleted with 20% digested slurry were reported (Lakshmanan *et al.*, 1989) to have given higher pod production in India. Seed pelleting in black gram using effluent slurry at 50% w/w was reported to have increased yield by 35% over control (Kate, 1991).

Coating with digested slurry alone in sorghum seeds gave more yield than the uncoated in both wet and semi-dry conditions. Increased yield in slurry coated seeds

might be due to the supply of readily available ammoniacal nitrogen and micro nutrients from bio-digested slurry (Lakshmanan *et al.*, 1993).

2.6. Pre germination treatment of mango stones

Girija (1998) reported that coating mango stones with wood ash at the rate of 250 g 100 kg^{-1} helped to retain viability for a period of 2 ½ months. Kumar *et al.*, (2008) conducted an experiment to study the effect of different presoaking treatments with organics and chemicals on germination, growth and graft-take in mango. GA_3 at 100 ppm had showed the highest germination index and seedling height which was on par with KNO_3 and water soaking. The significant enhancement of germination in different pre-germination treatments with organics was noticed by Padma and Reddy (1998) and Rao (2002) in Mango. Dawale *et al,* (2011) reported that the stones presoaked with beejamruth recorded significantly higher germination, vigor index (1.74). The increase in seedling height and girth by application of panchagavya and amrit pani was also reported by Yellesh *et al.*, (2008).

Materials and Methods

3. MATERIALS AND METHODS

An investigation entitled "Production and effective utilization of biogas from fruit waste" was conducted at College of Horticulture, Vellanikkara, Thrissur district during the period 2014-2015 with two experiments as detailed below

Experiment 1: Standardization of optimum combination of cow dung and fruit waste for maximum biogas production

Experiment 2: Effect of biogas slurry on the germination of mango stones

3.1.EXPERIMENT I

The experiment was conducted using $0.5m^3$ ordinary floating dome biogas plants to find out the optimum ratio of cow dung and fruit waste to be used for maximum biogas production.

3.1.1 Materials used

Processing waste of pineapple was used as a substrate for co-digestion with cow dung for biogas enhancement. The waste was collected from the processing unit of Pineapple Research Centre, Vellanikkara. The biogas plants installed at the vermicompost unit of College of Horticulture were made use of.

3.1.2 Anaerobic digester

The floating drum biogas plants of 0.5 m^3 (plate 1) capacity was used for anaerobic digestion of substrates. The main body of the biogas plant was the digester which holds substrates. The substrates were added through inlet pipe. The gas produced inside the digester was collected in gas holder and the bottom of gas holder

was dipped into the substrates to create an anaerobic condition. The gas collected in gas holder was used daily through gas outlet. When substrates got completely digested, slurry flowed through slurry outlet.

3.1.3 Experimental details

Design	-	CRD (Completely Randomized Design)
Replications	-	3
Treatments	-	5
Capacity of digester	-	0.5 m^3

Treatment details of biogas production

T_1	Cow dung alone
T_2	Fruit waste alone
T_3	Cow dung + fruit waste (1:0.5)
T_4	Cow dung + fruit waste (1:1)
T_5	Cow dung + fruit waste (1:1.5)
T_6	Cow dung + fruit waste (1:2)

Fig. 1 Layout of experiment I

T_1R_1	T_1R_2	T_3R_1	T_4R_1	T_5R_1	T_6R_1
T_1R_2	T_2R_2	T_2R_2	T_4R_2	T_5R_2	T_6R_2
T_1R_3	T_2R_3	T_3R_3	T_4R_3	T_5R_3	T_6R_3

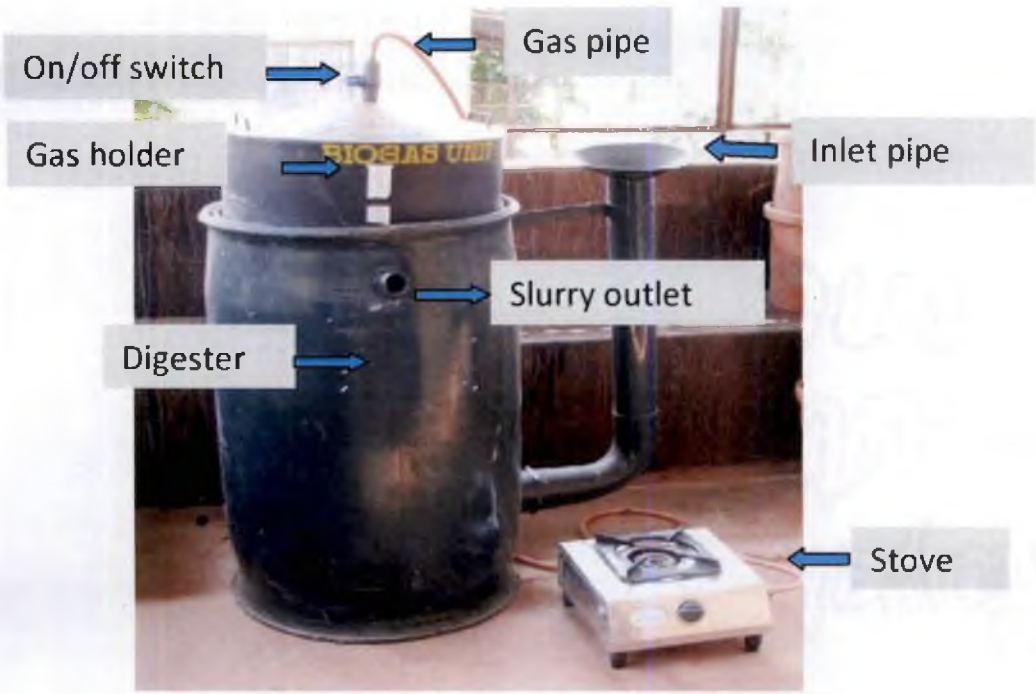


Plate 1. Floating drum biogas unit of 0.5 m^3 capacity

Plate 2.Anaerobic digestion of substrate in biogas plants

3.1.4 Loading of substrates in digester

The biogas plants with a digester capacity of 0.5 m^3 were made use of for all the treatments (plate2). The waste was mixed with cow dung as per the treatment allocation. The solid material was mixed with equal quantities of water in all the treatments. About 150 litres of such slurry for all the treatment were loaded for each plant. Regular feeding had done with the slurry at the rate of 1litre (as per the treatment) per day in all biogas plants.

3.1.5 Analysis of substrate

The substrate analysis was carried out on dry weight basis. The analytical work was undertaken by following the methodology as indicated in table 1

3.1.6 Regular monitoring of biogas plants:

During the anaerobic digestion period, Hydraulic Retention Time (HRT) and daily temperature inside the digester, volume of gas produced and quantity of slurry generated were determined regularly.

Hydraulic Retention Time (HRT) is defined as the time taken by the substrates for maximum gas production. Normally 70- 80 % digestion gets completed within one HRT. The daily temperature of the biogas unit was noted by using digital thermometer for the entire period of study.

The gas volume was recorded everyday in each treatment. The gas produced in each treatment was measured and used for burning the stove. The increase in height of gas holder was recorded daily and volume of gas was calculated with the formula,

$V = \pi r^2 h$, where V denotes volume, r denotes radius of gas holder and h denotes height increased after gas production.

The slurry output from the digester was also measured daily for all the treatments using measuring cylinder.

3.1.7 Analysis of biogas

The gas produced during the first three days was discarded for a stabilized biogas production. Biogas samples were collected after nine days at three days intervals in gas collection bladders (Hans Seamless latex value bladders) (plate3) and analyzed in the gas chromatography (Kalia *et al.,* 1992). The gas chromatograph used for analysis of biogas was "Thermo Scientific Trace GC with packed column injector (poropack-q), Flame ionization detector (FID) and with additional methanizer. By comparing with standard chromatogram the ethylene, carbon dioxide and methane content of sample were found out. Retention time was noted after the initial loading.

3.1.8 Slurry analysis

Quantity of slurry generated after each intake of substrate up to 24 hrs was noted for all the treatments. The entire quantity of slurry under each treatment was pooled to obtain a representative sample for each treatment. The nutrient status of slurry was analysed by standard procedures given in table 2.

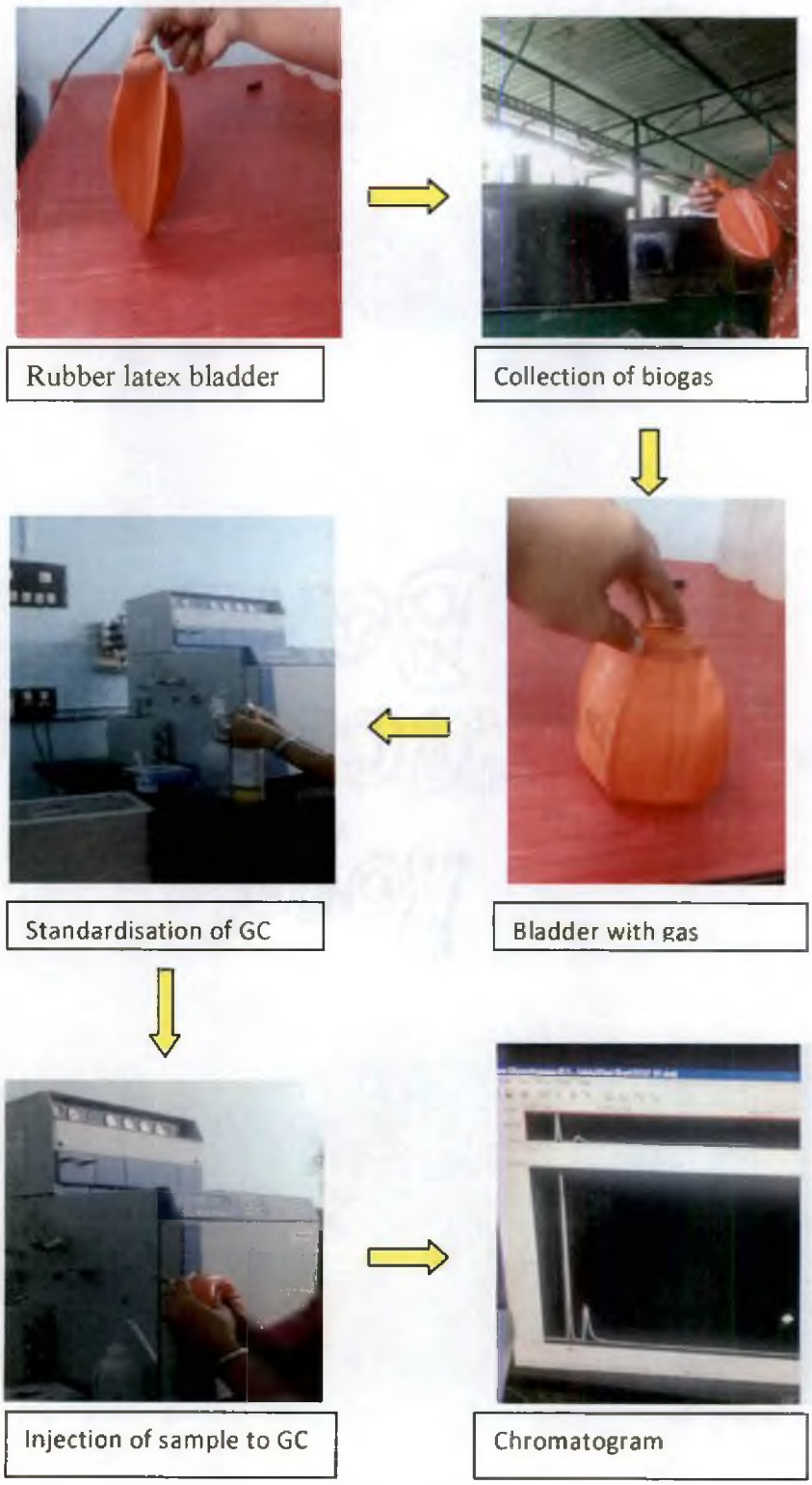


Plate 3. Schematic representation of analysis of biogas

Table 1. Methodology for physico- chemical analysis of substrate

Sl No	Parameter	Method
1	pH	pH meter (substrate and water in 1:2.5 ratio) (FCO,1985)
2	EC	EC meter (substrate and water in 1:2.5 ratio) (FCO,1985)
3	Toatal C and N	Estimated by CHNS analyzer (Model : Elementar's vario EL Cube)
4	Crude protein (N content *6.25)	N content was estimated by CHNS analyzer (Model : Elementar's vario EL Cube)
5	Total Phosphorus	Diacid digestion and estimation by Vanadomolybdate yellow colour method (Piper, 1966)
6	Total Potassium	Diacid digestion and Flame photometric determination (Piper, 1966)
7	Total Sulphur	Estimated by CHNS analyzer (Model : Elementar's vario EL Cube)
8	Total Calcium and magnesium	Diacid digestion and Atomic Absorption Spectrophotometer (Issac and Kerber, 1971)
9	Total Iron, manganese, zinc and copper	Diacid digestion and Atomic Absorption Spectrophotometer (Piper, 1966)
10	Crude fiber	Acid alkali digestion method (Thimmaiah, 1989)

Table 2. Methodology of slurry analysis

SL No	Parameter	Method
1	pH	pH meter (FCO, 1985)
2	EC	EC meter (FCO, 1985)
3	Total N	Modified Kjeldhal digestion and distillation (Jackson 1958)
4	Organic carbon	Ashing method (FCO, 1985)
5	Total Phosphorus	Diacid digestion and estimation by Vanodomolybdate yellow colour method (Piper,1966)
6	Total Potassium	Diacid digestion and Flame photometric determination (Jackson, 1958)
7	Total Calcium and Magnesium	Diacid digestion and determination using Inductively coupled plasma atomic emission spectroscopy (ICPAES)
8	Total Sulphur	Turbidimetric method (Bhargava and Raghupathy, 1995)
9	Total Iron, manganese, zinc and copper	Diacid digestion and determination using Inductively coupled plasma atomic emission spectroscopy (ICPAES)
10	Heavy metals	Diacid digestion and ICPAES
11	Water soluble N,P,K	Filtered with the use of Buchner funnel fitted with Pressur pump and determined as detailed above.

3.2 EXPERIMENT II

The second experiment was carried out to find out the effect of biogas slurry on the germination of mango stones at the field lab attached to department of Soil Science and Agricultural Chemistry, College of Horticulture, Vellanikkara.

3.2.1 Materials used

Two varieties of mango *viz:* Bangalora and Moovandan (plate 4) were used for the study. Bangalora is a popular variety used by processing industry because of its increased pulp recovery where as Moovandan is a local polyembryonic variety commonly seen in homesteads of Kerala. Stones obtained as a single lot from the processing unit was washed thoroughly and spread over ground. After surface drying, the stones were presoaked /coated as per the treatment details for both the varieties. Biogas slurry required for the study was collected and standardized as detailed in section 3.1.2 , 3.1.3 and 3.1.9

3.2.2 Experimental details

Design - CRD (Completely Randomized Design)
Replications - 3
Treatments - 7
Varieties - 2

1. Bangalora
2. Moovandan

3.2.2.1 Treatment details of experiment

T_1 Storage in shade (control)

T_2 Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 Ash coating

T_4 Coating with biogas slurry having maximum manurial value from experiment 1

T_5 Pre-soaking with biogas slurry having maximum manurial value from experiment 1(12 hr)

T_6 Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 Pre-soaking with gobergas slurry from treatment 1 of experiment1(12 hr)

Fig. 2 Layout of experiment II

T_1R_1	T_1R_2	T_1R_3
T_2R_1	T_2R_2	T_2R_3
T_3R_1	T_3R_2	T_3R_3
T_4R_1	T_4R_2	T_4R_3
T_5R_1	T_5R_2	T_5R_3
T_6R_1	T_6R_2	T_6R_3
T_7R_1	T_7R_2	T_7R_3

3.2.3 Method of treatment

The first treatment was absolute control (storage in shade), for that the stones were allowed to germinate in the sand spread in the sack and covered with jute sack and moistened regularly. In the second treatment stones were presoaked with 1 % KNO_3 (100 gm in 10 L) for 10 minutes. The third treatment was ash coating of mango stones. Approximately 200 g ash was used for coating 1 Kg stones. In the fourth treatment stones were coated with biogas slurry having maximum manurial value (10 L slurry was used for coating 1 kg stones). In the fifth treatment the stones were pre-soaked with biogas slurry having maximum manurial value for 12 hours. Sixth treatment was coating the stones with gobergas slurry from treatment 1 of experiment- 1(10 L slurry were used for coating 1 kg stones). Gum Arabic (0.5 %) was used as the binding material. The seventh treatment was pre-soaking with gobergas slurry from treatment 1 of experiment- 1 for 12 hr. After treatments allocation, the mango stones were allowed to germinate on the sand spread in the tray and covered with jute sack and moistened regularly .Vigor index was calculated with the formula

Vigor index = Seedling length 'X' germination percent

3.2.4 Raising of seedlings

Immediately after germination, the stones were transferred to polythene bags (15*20cm) filled with potting mixture consisting soil and FYM in the ratio 1:1. Only one seedling was planted in each polybag (plate 5). Five such polythene bags were retained in each replication for all the treatments. The experimental site was the orchard of Department of Pomology and Floriculture, College of Horticulture. The

soil used for the study was laterite of the order ultisols belonging to Vellanikkara series. The growth of plants was monitored for three months.

3.2.5 Biometric observations of seedlings

Biometric observations were recorded at biweekly interval for three months. Plant height, number of leaves per plant, plant girth were the biometric observations recorded. Vigour index was calculated from the biometric observations.

3.2.6 Potting mixture analysis

The pH, EC, organic carbon, available nitrogen, and available phosphorous and available potassium were estimated before and after the experiment. The details of potting mixture analysis are given in Table 3.

3.2.7 Biochemical analysis of mango stones

3.2.7.1 Total sugars

The total sugar content was estimated as per the method described by AOAC (1980 and expressed as mg g^{-1}.

3.2.7.2 Reducing sugars

Reducing sugar content was estimated by Fehlings solution method (AOAC, 1980). To 10 gm of ground material, distilled water was added. After thorough mixing the solution was clarified with neutral lead acetate and potassium oxalate solution and made up to 250 ml volume. The solution was filtered and an aliquot of

this solution was titrated against a mixture of Fehling solution A and B using methylene blue as indicator. The reducing sugar was expressed in mg g^{-1}.

3.2.7.3 Non reducing sugars

The difference between total sugar and reducing sugar was worked out and expressed as mg g^{-1} (AOAC, 1980).

3.2.7.4 Total carbohydrate

The total carbohydrate content was determined by phenol sulphuric acid method suggested by AOAC (1980). Hundred mg of the sample was hydrolysed with hydrochloric acid. After neutralizing with sodium carbonate the volume was made upto100 ml. Yellow colour was developed with phenol and concentrated sulphuric acid and the colour was read at 490 nm using spectrophotometer. The total carbohydrate content was expressed as mg g^{-1}.

3.2.7.5 Starch

The starch content was estimated colorimetrically using the anthrone reagent as suggested by Sadhasivam Manickam (1992). The sample (0.5 g) was extracted repeatedly with 80 % ethanol to remove sugars completely. The residue was dried over a water bath and 5 ml water and 6.5 ml 52 % perchloric acid were added and extracted at 0°C for 20 minutes. The sample was centrifuged and reextracted with fresh perchloric acid. The supernatant was pooled and made up to 100 ml. Pipetted out 0.2 ml of the supernatant and made up to one ml with water and 4 ml of anthrone reagent, heated for 8 minutes, cooled rapidly and read the OD at 630nm using spectrophotometer and expressed as mg kg^{-1}.

3.2.7.6 Protein

The protein content was estimated by Lowry's method suggested by Sadhasivam Manickam (1992). 0.1 g of weighed sample was grinded with water (5-10 ml). After centrifugation, equal quantity saturated lead acetate and 10 % potassium hydroxide were added till white precipitate persists and centrifuged at 5 min at 10,000 rpm and added 5 ml of 10 % TCA to the supernatant. Again centrifugation was carried out and supernatant was discarded. To the sample 1ml of distilled water and 5 ml of alkaline copper sulphate was added. After through mixing it was incubated at room temperature for 10 minutes and then added 0.5 ml of Folin Ciocalteau solution and incubated in dark for 30 minutes and read the OD at 660 nm and expressed as mg kg^{-1}.

3.2.8 Elemental analysis

The nutrient content of mango stones of both the varieties was estimated. For that stones were washed thoroughly and fresh weight was recorded. The stones were shade dried and then oven dried and again the weight was recorded for calculating the moisture content. Then the seed coat was removed and powdered finely and analysis were carried out using standard procedures as outlined in table 4.

3.2.9 Plant analysis

After 90 days duration the seedlings were uprooted and the different portions such as leaf, shoot and root were separated. Fresh weight was recorded for each part, shade dried and then oven dried till it attained a constant weight. The plant parts were ground to fine powder and analysed for nutrient content in each part. The standard procedures used for analysis were mentioned in table 4.

3.2.10 Nutrient uptake study

Based on the uptake of different major nutrients by the crop, the total uptake of nutrients was computed by the formula

Nutrient uptake = dry weight 'X' nutrient content

3.3 Statistical analysis

Data were subjected to analysis of variance (ANOVA) (Panse and Sukhatme, 1985) using statistical package 'MSTAT-C' package (Freed, 2006). Wherever the F test was significant (at 5 % level) multiple comparison among the treatments were done with Duncan's Multiple Range test (DMRT).

Plate 4. Mango varieties Moovandan and Bangalora

Plate 5. Mango seedlings at thirty days after planting (Experiment II)

Table 3. Methodology for chemical analysis of potting mixture

Sl No	Parameters	Methodology
1	pH	pH meter in 1:2.5 soil water suspension (Jackson, 1958)
2	EC	Conductivity meter in the supernatent liquid used for pH determination (Jackson, 1958)
3	Available nitrogen	Alkaline permanganometry (Subbiah and Asija, 1956)
4	Available phosphorus	Extracted (Bray and Kurtz, 1945) and estimated calorimetrically by reduced molybdate ascorbic acid blue colour method (Watanabe and Olsen, 1965)
5	Available potassium	Neutral normal ammonium acetate extraction and estimation by flame photometry (Jackson, 1958)
6	Available calcium and magnesium	Neutral normal ammonium acetate extraction followed by Atomic Absorption Spectrophotometry (Jackson, 1958)
7	Available Sulphur	0.15% $CaCl_2$ extraction (Tabatabai, 1982) Estimation: Massoumi and Cornfield, 1963
8	Available Fe	HCl extraction followed by Atomic Absorbtion Spectrophotometry (Sims and Johnson, 1991)
9	Available Mn	HCl extraction followed by Atomic Absorbtion Spectrophotometry (Sims and Johnson, 1991)
10	Available Zn	HCl extraction followed by Atomic Absorbtion Spectrophotometry (Sims and Johnson, 1991)
11	Available Cu	HCl extraction followed by Atomic Absorbtion Spectrophotometry (Sims and Johnson, 1991)

Table 4. Methodology for chemical analysis of mango stones

Sl No	Parameter	Method
1	Toatal C and N	Estimated by CHNS analyzer (Model : Elementar's vario EL Cube)
2	Total Phosphorus	Diacid digestion and Vanodomolybdate yellow colour method (Piper,1966)
3	Total Potassium	Diacid digestion and Flame photometric determination (Jackson, 1958)
4	Total Sulphur	Estimated by CHNS analyzer (Model : Elementar's vario EL Cube)
5	Total Calcium and Magnesium	Diacid digestion and Atomic Absorbtion Spectrophotometry (Piper, 1966)
6	Total Iron,manganese, zinc and copper	Diacid digestion of sample followed by filtration and determination using Atomic Absorbtion Spectrophotometry (Piper, 1966)

Results

4. RESULTS

The results of the study on the "Production and effective utilization of biogas from fruit waste are presented here.

4.1 Experiment 1: Standardization of optimum combination of cow dung and fruit waste for maximum biogas production

4.2 Experiment 2: Effect of biogas slurry on the germination of mango stones

4.1 STANDARDIZATION OF OPTIMUM COMBINATION COW DUNG AND FRUIT WASTE FOR MAXIMUM BIOGAS PRODUCTION

4.1.1 Composition of biogas

The standardization of optimum combination of cow dung and fruit waste for maximum gas production was studied using completely randomized design with six treatments and three replications (section 3.1.4). The composition of biogas generated was studied using gas chromatography and it is detailed in table 5.

The highest methane content of 65.30% was recorded in T_4 which was on par with T_5 (63.81%) and T_3 (62.29 %) and was significantly higher than T_1 (60.00 %) and T_2 (46.46 %). From the results it is clear that co-digestion of cow dung with fruit waste increased the methane content only up to 1:1.5 ratio. With the increase of fruit waste proportion with cow dung as 1:2 methane generation decreased to 52.42 %.

From the data in table 5, it is also evident that CO_2 concentration varied significantly between the treatments. It was found to be the highest in T_2 (50 86 %)

and the lowest in T_4 (32.00 %). The recorded CO_2 concentration in T_6, T_1, T_3, T_5 were 45.37, 37.48 35.31 and 34.47 % respectively

Table 5. Composition of biogas as influenced by different treatments

Parameter / Treatments	Methane	Carbon dioxide	Other gases
	(%)		
T_1	60.00 ^{b}	37.48^{c}	2.52 ^{a}
T_2	46.46 ^{d}	50.86^{a}	2.67 ^{a}
T_3	62.29^{ab}	35.31^{cd}	2.39^{a}
T_4	65.30 ^{a}	32.00 ^{e}	2.70 ^{a}
T_5	63.81 ^{a}	34.47^{de}	1.72 ^{a}
T_6	52.42 ^{c}	45.37^{b}	2.21 ^{a}
CD(0.05)	3.29	2.65	NS

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

4.1.2 Temperature inside the digester as compared to atmospheric temperature

During February and March 2015, the daily variation in atmospheric temperature and temperature inside the digester was recorded. The pooled data for every 5 days interval was worked out and presented in table 6.

Table 6. Effect of different treatments on variations in temperature (^{0}C) inside the digester at five days interval

Treatments / Interval in days	Atmospheric temperature	T_1	T_2	T_3	T_4	T_5	T_6
1-5	28.81	31.65	31.93	31.65	31.88	32.21	31.65
6-10	31.54	32.18	32.08	31.84	32.60	32.68	32.70
11-15	28.98	32.70	32.79	32.62	32.99	32.68	32.69
16-20	29.25	33.39	33.18	33.05	33.78	33.40	33.28
21-25	28.45	31.52	31.28	31.20	31.20	31.50	31.02
25-30	28.71	30.60	31.80	30.80	30.70	30.60	30.90
31-35	29.99	31.52	31.28	31.20	31.20	31.50	31.02
36-40	29.98	31.30	31.21	31.29	31.54	31.07	31.06
41-45	30.40	30.60	31.80	30.80	30.70	30.60	30.90
46-50	30.28	30.10	30.34	30.46	30.60	30.90	30.21

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

The highest atmospheric temperature was recorded at the second interval (31.54^{0}C). Correspondingly the highest temperature inside the digester was recorded by T_6 (32.70 ^{0}C) and least by T_2 (32.08 ^{0}C). During the period of study the least atmospheric temperature was recorded at 21-25 days interval (28.45 ^{0}C). The treatment T_4 recorded the highest value (33.78 ^{0}C) of temperature inside the digester at 16-20 days interval and the lowest value by T_6 at 46-50 days interval (30.21 ^{0}C).

4.1.3 Hydraulic Retention Time (HRT) and volume of gas generated

HRT is the time taken for maximum gas production and it is presented in table 7 along with the total volume of gas generated in m^3/day.

Table 7. Hydraulic retention time and volume of gas as influenced by different treatments

Treatments	HRT (days)	Total volume of gas (m^3/day)
T_1	20^c	0.35^c
T_2	24^a	0.28^d
T_3	15^e	0.40^b
T_4	17^d	0.44^a
T_5	19^c	0.39^b
T_6	22^b	0.36^c
CD(0.05)	1.26	0.02

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

The Hydraulic Retention Time (HRT) was minimum (15 days) in the treatment T_3 (cow dung+ fruit waste, 1: 0.5) followed by T_4 (cow dung + fruit waste, 1: 1) with 17 days. The highest HRT of 24 days was observed in treatment T_2 (fruit waste alone) whereas the treatments T_1 (cow dung alone) and T_5 (cow dung+ fruit waste, 1:1.5) was recorded 20 days and19 days. The HRT of T_6 was 22 days.

The volume of gas was maximum (0.44 m^3/day) in the treatment T_4 (cow dung+ fruit waste, 1: 1) which was followed by T_3 (cow dung + fruit waste, 1: 0.5) with

0.40 m^3/day. The lowest volume of 0.28 m^3/day was observed in treatment T_2 (fruit waste alone) whereas the treatments T_1 (cow dung alone) and T_5 (cow dung + fruit waste, 1:1.5) was recording 0.35 m^3/day and 0.39 respectively and the total volume in the treatment T_6 was 0.36 m^3/day

4.1.4 Mean Volume of gas produced in each treatment at interval of five days during the study period

Throughout the period of study the volume of gas generated from the respective treatments was in the order $T_4 > T_3 > T_5 > T_1 > T_6 > T_2$. It is also evident that that the maximum volume of gas was generated during the fourth, fifth, sixth and seventh interval of study. The highest mean volume for gas was recorded in T_4 (0.41 m^3/day) during the 15-20 days interval and the lowest for T_2 at 1-5 days interval (0.09 m^3/day) .The maximum gas was generated during the fourth interval and minimum at the first interval irrespective of the treatments. Almost in all intervals of study, the gas generation was found to be the least in T_1 and T_2.

Table 8. Effect of different treatments on mean volume of gas produced at five days interval (m^3/day)

Treatments / Interval(days)	T_1	T_2	T_3	T_4	T_5	T_6
1-5	0.11	0.09	0.12	0.13	0.11	0.10
6-10	0.16	0.12	0.21	0.25	0.22	0.13
11-15	0.25	0.22	0.35	0.39	0.30	0.27
16-20	0.27	0.25	0.40	0.41	0.39	0.35
21-25	0.35	0.28	0.40	0.41	0.39	0.36
25-30	0.32	0.28	0.39	0.40	0.35	0.35
31-35	0.31	0.28	0.39	0.40	0.35	0.35
36-40	0.29	0.27	0.38	0.40	0.34	0.30
41-45	0.27	0.25	0.38	0.39	0.34	0.30
46-50	0.26	0.25	0.37	0.38	0.33	0.29

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

4.1.5 Physico-chemical composition of substrates

The substrates used for anaerobic digestion were cow dung and pineapple waste and their chemical compositions is detailed in Table 9.

Table 9. Physico-chemical composition of cow dung and fruit waste

Parameters	Cow dung	Fruit waste
Moisture (%)	75.05	82.42
Dry matter (%)	24.95	17.58
pH	8.38	3.66
EC (d S/m)	0.38	0.25
Crude protein (%)	7.75	9.06
Crude fibre (%)	17.23	15.75
C:N ratio	27.14	34.17
Total macro nutrients (%)		
Carbon	26.6	41.01
Nitrogen	0.89	1.20
Phosphorous	0.49	0.14
Potassium	0.65	1.55
Calcium	0.67	0.12
Magnesium	0.06	0.05
Sulphur	0.19	0.17
Total micro nutrients (mg kg^{-1})		
Iron	118.00	475.00
Manganese	538.00	184.00
Zinc	79.00	9.40
Copper	13.20	23.70

The moisture content in cow dung and pineapple waste was 75.05 % and 82.42 % respectively. The pH and EC of cow dung was 8.40 and 0.39, respectively whereas it was 3.66 and 0.25 respectively in pineapple waste. The crude protein, and crude fibre of pineapple waste were recorded as 9.06 % and 15.75 % respectively and that of cow dung was 7.75 % and 17.25 % respectively. The C/N ratio of pineapple waste was 34.17 and that of cow dung was 27.14. Total carbon was recorded as 41.01 % in pineapple waste and 26.60 % in cow dung. The N, P and K content of cow dung were 0.89 %, 0.49 % and 0.65 % and that of pineapple waste was 1.20 %, 0.14 %, and 1.55 % respectively. The calcium (0.67 %) magnesium (0.06%) and sulphur (0.29%) content of the cow dung were higher as compared to that of pineapple waste. The Ca, Mg and S content of pineapple waste were 0.12 %, 0.05 % and 0.17 % respectively

The micronutrients content in cow dung were higher compared to that of pineapple waste. The micronutrients like Fe, Mn, Zn and Cu in cow dung and pineapple waste were 118.00, 538.00, 79.00, 13.20 mg kg^{-1} and 475.00, 184.00, 9.40, 23.70 mg kg^{-1}, respectively.

4.1.6 Total quantity of slurry

The quantity of biogas slurry generated in each treatment was presented in table 10. T_6 recorded the highest quantity of slurry (92 L) followed by T_5 (75 L), T_4 (66 L),T_3 (55 L) and the treatments T_1 and T_2 were on par recording 44 L.

Table 10. Total quantity of slurry generated in each treatment at 5 days interval during the study

Treatments	Quantity of slurry (litre)
T_1	44^e
T_2	44^e
T_3	55^d
T_4	66^c
T_5	75^b
T_6	92^a
CD(0.05)	1.39

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

4.1.6.1 Mean Quantity of slurry generated at different periods of interval (ml)

Table 11. Mean quantity of slurry generated at five days interval during the study period (ml)

Treatments / Interval(days)	T_1	T_2	T_3	T_4	T_5	T_6
1-5	1750	1800	2156	2815	2826	2915
6-10	2156	2256	2256	2879	2846	2976
11-15	4456	4732	5896	6150	6841	7852
16-20	6652	4958	8569	8678	9256	9962
21-25	7895	7895	8956	8846	9259	9976
25-30	6651	6821	6881	6821	7925	7646
31-35	6552	6721	6820	6810	6881	6856
36-40	6251	6271	6290	6650	6678	6682
41-45	5281	5331	5681	5691	5945	5941
46-50	5235	5281	5291	5330	5345	5389

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

The highest quantity of slurry was recorded for T_6 during the 21-25 days after initiation of the experiment. During the same period, the least quantity was generated from T_1 and T_2 treatments with 7895 ml. The least quantity of slurry was obtained from T_1 (1750 ml) during the first interval of study and during this period and the highest quantity was obtained from T_6. Irrespective of the treatments the maximum quantity was generated during the fifth interval. However treatment variation was reflected during the 5^{th} interval of study with the order $T_6 > T_3 > T_4 > T_1 = T_2 > T_5$. Similar trend was seen at different intervals of study.

4.1.7 Physico- chemical composition of biogas slurry

The total solids, pH, EC, organic carbon and C/N ratio of slurry obtained from different treatments are given in table 12.

Table 12. Physico- chemical composition of biogas slurry as influenced by different treatments

Parameter / Treatments	Total solids (%)	pH	Slurry EC (dS m^{-1})	Organic carbon in slurry (%)	C:N ratio
T_1	6.55 [a]	8.0[a]	0.52 [d]	24.36[c]	20.85[b]
T_2	4.42 [b]	6.4 [e]	0.70[b]	27.09[a]	25.55[a]
T_3	3.99 [c]	7.1[b]	0.56 [c]	20.54 [e]	16.04[c]
T_4	3.30[d]	7.1[b]	0.79 [a]	19.83[f]	13.86[d]
T_5	2.27 [e]	6.9[c]	0.73[ab]	23.83[d]	13.46[d]
T_6	2.10 [e]	6.8[d]	0.73[ab]	26.48[b]	10.26[e]
CD(0.05)	0.41	0.13	0.08	0.49	3.20

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

4.1.7.1 Total solids in slurry

The total solids varied significantly in different treatments with treatment T_1 registering the highest value of 6.55 % whereas the lowest total solids (2.10 %) was

obtained in T_5. The total solids in T_2, T_3, T_4 and T_6 were 4.42, 3.99 and 3.30, 2.27 % respectively.

4.1.7.2 pH of slurry

The data on pH of the slurry (table12) revealed that the pH varied significantly in treatments recording the highest in T_1 (8.0) to the lowest in T_2 (6.4). The pH of slurry in treatment T_3 was 7.1 which were on par with T_4. The pH of other treatments T_5 and T_6 were 6.9 and 6.8, respectively.

4.1.7.3 EC of slurry

The effects of different treatments on EC of slurry were shown in table 12. The treatment T_4 recorded the highest EC in slurry (0.79 dS m^{-1}) followed by T_2 (0.70 dS m^{-1}) which was on par with T_5 (0.73 dS m^{-1}) and T_6 (0.73 dS m^{-1}). This was followed by T_3 (0.56 dS m^{-1}) and the lowest EC was recorded with T_1 (0.52 dS m^{-1}).

4.1.7.4 Organic carbon in slurry

The results of available organic carbon in slurry are furnished in Table 12. The organic carbon content was the highest in T_2 recording 27.09 % whereas the lowest content (19.84 %) was in T_4. The organic carbon content in T_6 was 26.48 % followed by T_1 (24.36 %), T_5 (23.83 %) and T_3 (20.54 %).

4.1.7.5 C: N ratio of slurry

The effects of different treatments on C: N ratio of slurry is presented in table 12. The treatment T_2 recorded the highest C: N ratio in slurry (25.55) followed by T_1

(20.58), T_3 (16.04) and T_4 (13.84). This was followed by T_5 (13.46) and the lowest C:N ratio was recorded with T_6 (10.26).

4.1.8 Macro nutrient content in slurry

The major nutrients like N, P, K, Ca, Mg and S content of slurry is recorded in table 13.

Table 13. Macro nutrient content in slurry as influenced by different treatments

Parameter / Treatments	N	P	K	Ca	Mg	S
	(%)					
T_1	1.12 ^{e}	0.49 ^{d}	1.29^{e}	1.28^{a}	0.24^{c}	0.31 ^{c}
T_2	0.96^{f}	0.37^{c}	1.56 ^{d}	0.32^{d}	0.15 ^{e}	0.17^{e}
T_3	1.28^{d}	0.67 ^{b}	1.54^{d}	0.52 ^{c}	0.19 ^{d}	0.24 ^{d}
T_4	1.43^{c}	0.79^{a}	1.76^{c}	0.66^{bc}	0.29 ^{b}	0.61^{a}
T_5	1.77 ^{b}	0.81^{a}	2.03 ^{b}	0.72^{b}	0.21^{d}	0.27 ^{cd}
T_6	2.58^{a}	0.82^{a}	2.23 ^{a}	0.71^{b}	0.55^{a}	0.37^{b}
CD(0.05)	0.13	0.04	0.18	0.16	0.02	0.05

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

4.1.8.1 Total nitrogen content of slurry

T_6 recorded the highest total nitrogen content (2.58 %) .The treatments T_5, T_4, T_3, T_1 and T_2 recorded 1.77, 1.43, 1.28, 1.12, 0.96 % nitrogen respectively.

4.1.8.2 Total phosphorous content of slurry

The highest phosphorous content of 0.82 % was recorded in the treatment T_6 and the lowest in T_2 with 0.37 %. The content of phosphorous (P) in the slurry was increased by increasing the quantity of fruit waste with cow dung. The treatments T_1, T_3, T_4 and T_5 recorded 0.49, 0.67, 0.79, 0.81 % P respectively

4.1.8.3 Total potassium content of slurry

The highest content of K was recorded in T_6 (2.23 %) and lowest in T_1 (0.29 %). The other treatments T_5, T_4, T_3 and T_2 were found to contain 2.03, 1.76, 1.54, 1.56 % K respectively.

4.1.8.4 Total Calcium and Magnesium contents in slurry

The highest calcium content was recorded for T_1 (1.28 %) followed by T_5 (0.72 %) which was on par with T_6 (0.71 %). This was followed by T_4 (0.66 %) and T_3 (0.52 %) and the lowest Ca content was registered in T_2 (0.52 %).

The highest content of Mg was recorded in T_6 (0.55 %) and minimum in T_2 (0.15 %). The magnesium content in T_4 (0.29 %) which was followed by T_1 (0.24 %). The Mg content of T_5 was recorded as 0.21 % which was on par with T_3 (0.19 %)

4.1.8.5 Total Sulphur content in slurry

Statistical analysis revealed that all the treatments were significantly different to each other. The highest sulphur content was recorded for the slurry from T_4 (0.61

%), followed by T_6 (0.37 %) and T_1 (0.31 %) which was on par with T_5 (0.27 %) and T_3 (0.24 %). The least value for sulphur was recorded in T_2 (0.17 %).

4.1.9 Micronutrients in slurry

Table 14. Effect of different treatments on micro nutrient contents in slurry

parameter / Treatments	Fe	Mn	Zn	Cu
	(mg kg^{-1})			
T_1	19.27 [a]	6.50[b]	3.55[d]	0.16[a]
T_2	5.52 [e]	2.39 [d]	1.28 [e]	0.09 [a]
T_3	3.92 [f]	1.64[e]	1.38[e]	0.22 [a]
T_4	12.24 [c]	5.29 [c]	7.02[c]	0.08 [a]
T_5	11.78[d]	6.38 [b]	10.33 [b]	0.11 [a]
T_6	14.98[b]	7.29[a]	17.68 [a]	0.07 [a]
CD(0.05)	0.47	0.45	0.43	NS

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

The results pertaining to the effect of treatments on Fe content in slurry are depicted in Table 14. The treatment (T_1) recorded the highest Fe content in slurry (19.27 mg kg^{-1}) which was followed by T_6 (14.98 mg kg^{-1}), T_4 (12.24 mg kg^{-1}), T_5 (11.78 mg kg^{-1}), T_2 (5.52 mg kg^{-1}) and the lowest content was in T_3 (3.92 mg kg^{-1}).

The results on Mn content of slurry are presented in table 14. The treatment T_6 recorded maximum Mn content (7.29 mg kg^{-1}) in slurry compared to all other treatments. The Mn content of slurry in treatment T_1 was 6.50 mg kg^{-1} which was on par with T_5 (6.38 mg kg^{-1}) and it was followed by T_4 (5.29 mg kg^{-1}), T_2 (2.39 mg kg^{-1})

and the treatment T_3 recorded the lowest Mn content of 1.64 mg kg^{-1} which was significantly lower than all other treatments.

The data with respect to Zn content in soil are given in Table 14. The highest Zn content was recorded in T_6 (17.68 mg kg^{-1}) and the lowest Zn content was in T_2 (1.28 mg kg^{-1}) which was on par with T_3 (1.38 mg kg^{-1}). The Zn content in the treatments T_5, T_4, T_1 were 10.33, 7.02, 3.55 mg kg^{-1}, respectively.

The data on Copper content in slurry are illustrated in Table 14. The Cu content in slurry ranged from (0.22 mg kg^{-1}) in T_3 to (0.07 mg kg^{-1}) in T_5. However there was no significant difference among the treatments

4.1.10 Heavy metals in slurry

The heavy metals contents in slurry (Hg, As, Cr, Ni, and Pb) are shown in table 15

Table 15. Heavy metals in slurry as influenced by different treatments

Heavy metal / Treatments	Hg	As	Cr	Ni	Pb
T_1	0.02^{f}	0.07^{c}	0.05^{c}	0.06^{a}	0.23^{a}
T_2	0.08^{d}	0.05^{d}	0.08^{c}	0.02^{a}	0.08^{a}
T_3	0.07^{e}	0.10^{b}	0.07^{c}	0.03^{a}	0.07^{a}
T_4	0.13^{c}	0.02^{f}	0.09^{bc}	0.06^{a}	0.09^{a}
T_5	0.16^{b}	0.12^{a}	0.12^{ab}	0.06^{a}	0.22^{a}
T_6	0.17^{a}	0.04^{e}	0.14^{a}	0.10^{a}	0.43^{a}
CD (0.05)	0.003	0.002	0.004	NS	NS

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

The data pertaining to Hg content of slurry are presented in Table 15. The mercury content in slurry ranged from 0.17 mg kg^{-1} (T_6) to 0.02 mg kg^{-1} (T_1). The mercury content recorded in slurry of T_5 was 0.16 mg kg^{-1} which was followed by T_4 (0.13 mg kg^{-1}), T_2 (0.08 mg kg^{-1}) and T_3 (0.07 mg kg^{-1}), respectively. The highest As content was recorded in T_5 (0.12 mg kg^{-1}) which was followed by T_3 with 0.1mg kg^{-1}, T_1 (0.07 mg kg^{-1}), T_2 (0.05 mg kg^{-1}), T_6 (0.04 mg kg^{-1}) and the lowest As content was in T_4 (0.02 mg kg^{-1}). The highest Cr content was recorded in T_1 (0.14 mg kg^{-1}), which was significantly higher than all other treatments, however statistically it was on par with T_5 (0.12 mg kg^{-1}) which was on par with T_4 (0.09 mg kg^{-1}) and this was on par with the remaining treatments T_2 (0.08 mg kg^{-1}), T_3 (0.08 mg kg^{-1}) and T_1 (0.05 mg kg^{-1}). The nickel content in slurry ranged from 0.1mg kg^{-1} in T_6 to 0.02 mg kg^{-1} in T_2. The treatments did not show any significant difference on Ni content in slurry.

The treatment T_6 recorded the highest Pb content in slurry with 0.43 mg kg^{-1} and the lowest Pb content was noted in T_3 (0.07mg kg^{-1}). There was no significant difference among the treatment.

4.1.11 Soluble nutrients in the slurry

Table 16. Effect of treatments on soluble nutrient contents in slurry

Parameter / Treatments	Water soluble N	Water soluble P	Water soluble K
	(mg L^{-1})		
T_1	7.16^{d}	2.12^{c}	5.15^{c}
T_2	4.90^{e}	2.10^{c}	4.90^{d}
T_3	9.70^{b}	2.46^{bc}	6.03^{bc}
T_4	11.03^{a}	2.60^{b}	6.12^{b}
T_5	8.36^{c}	2.50^{bc}	6.21^{a}
T_6	11.50^{a}	2.81^{a}	6.30^{a}
CD (0.05)	1.20	0.04	0.10

T_1 : Cow dung alone

T_2 : Fruitwaste alone

T_3 : Cow dung+ fruitwaste (1: 0.5)

T_4 : Cow dung+ fruitwaste (1:1)

T_5 : Cow dung+ fruitwaste (1: 1.5)

T_6 : Cowdung +fruitwaste (1:2)

Table 16 shows the effect of treatments on water soluble N, P, K in slurry The water soluble N was found to be maximum with T_6 (11.5 mg L^{-1}) closely followed by T_4, T_3, T_5 and T_1. The least value (4.9 mg L^{-1}) was recorded in T_2. Almost the same trend was observed with water soluble P with the highest in T_6 (2.81 mg L^{-1}) and the least in T_2 (2.1 mg L^{-1}). The other treatments recorded 2.6, 2.5, 2.46, 2.12 mg/L in the order T_4, T_3, T_5, T_1 respectively. The water soluble K content was maximum with T_6 (6.3 mg L^{-1}) and minimum with T_2 (4.9 mg L^{-1}).The other treatments were 6.21, 6.12, 6.03, 5.15 mg L^{-1} in the order T_5, T_4, T_3, T_1, respectively.

4.2 EFFECT OF BIOGAS SLURRY ON GERMINATION OF MANGO STONES

The slurry obtained from different treatments was evaluated for the maximum manurial value. It was found that cow dung and fruit waste in the ratio of 1:2 contained the maximum nutrient contents with 2.58 % N, 0.82 % P and 2.23 % K, respectively. In order to study the effect of biogas slurry on germination of mango stones this particular biogas slurry was utilized.

4.2.1 Effect of biogas slurry on Germination percent and vigour index of mango stones

The germination % and vigour index of the varieties Moovandan and Bangalora as influenced by different treatments are furnished in table 17.

4.2.1.1 Moovandan

The difference in germination % of mango variety moovandan was found to be significantly different among the treatments. Presoaking with biogas slurry from cow dung and fruit waste, 1:2 ratio for 12 h (T_5) recorded the maximum germination % (74.66 %) and it was on par with the treatment T_7 (Presoaking with gober gas slurry for 12 h) i.e.; 73.33 %. The treatment T_3 (Ash coating) was found to be inferior to control recording 50.66 %. The germination % in T_6 was 65.33 % which was on par with T_4 (61.33 %) where as T_2 recorded 57.33 % germination, almost on par with T_4 (Table 17).

The treatments significantly influenced the seedling vigour. The highest vigour index was recorded in the treatment T_5 (1241.04) followed by T_7 (1135.13) and the

lowest in T_3 (572.61) which was found to be less than control T_1 (634.85). Seedling vigour of treatments T_4 (880.05) and T_6 (895.08) were on par.

Table 17. Effect of biogas slurry on germination of mango varieties (Moovandan and Bangalora)

	Germination (%)		Vigour index	
Varieties / Treatments	Moovandan	Bangalora	Moovandan	Bangalora
T_1	52.00^{d}	50.66^{c}	634.85^{e}	732.16^{c}
T_2	57.33^{c}	53.33^{c}	740.97^{d}	819.92^{c}
T_3	50.66^{d}	49.33^{c}	572.61^{c}	792.09^{c}
T_4	61.33^{bc}	$62..00^{b}$	880.05^{c}	1033.24^{b}
T_5	74.66^{a}	70.667^{a}	1241.04^{a}	1259.06^{a}
T_6	65.33^{b}	64.00^{ab}	895.08^{c}	1083.60^{b}
T_7	73.33^{a}	69.33^{a}	1135.13^{b}	212.44^{a}
CD(0.05)	4.58	6.70	86.27	112.64

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.2.1.2 Bangalora

The germination % of mango variety Bangalora was found to be significantly different among the different treatments. Presoaking with biogas slurry from cow dung and fruit waste,1:2 ratio for 12 h (T_5) recorded the highest germination % % (70.66 %) and it was on par with the treatment T_7 (Presoaking with gobergas slurry for 12 h) that recorded 69.33 %. The treatment T_3 (Ash coating) was found to be

inferior to control recording a value of 49.33 %. The germination % in T_6 was (64 %) was found to be on par with T_7 and T_4 (62 %) where as T_2 recorded the 53.33 % germination almost on par with T_1 and T_3.

The vigour index of the variety Bangalora was significantly influenced by different treatments. The results were on line with that of moovandan. The highest vigour index was recorded by the treatment T_5 (1259.60) which were on par with T_7 (1212.44) and the lowest vigour index was recorded by the control (732.16).

4.2.2 Seedling height at biweekly interval as influenced by different treatments

The effect of treatments on seedling height at biweekly interval on variety Moovandan and Bangalora are given in table 18 and 19, respectively.

4.2.2.1 Moovandan

An attempt to understand the effect of different pre germination treatments on seedling height revealed that height of mango seedlings were significantly affected by the treatment. Presoaking the stones with biogas slurry generated from cow dung and fruit waste in 1:2 ratios (T_5) was found to be significantly superior to all other treatments even 90 days after planting (34.42 cm). The treatment T_6 was found to be on par with T_5 at 75 days after planting (32.72 cm). The minimum plant height was recorded for control (24.08 cm) at 90 days after planting. The seedling height in other treatments T_7, T_6, T_4, T2, T3 were 32.72, 31.89, 31.11, 2.93, 26.42 cm, respectively at ninety days after planting.

Table 18. Effect of treatments on seedling height at biweekly intervals of variety Moovandan

Treatments	Seedling height (cm)					
	15DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T_1	13.62 ^{cd}	15.50 ^{bc}	16.57 ^{b}	18.22^{b}	22.89 ^{d}	24.08 ^{g}
T_2	12.66 ^{d}	14.56 ^{c}	15.46 ^{b}	16.83 ^{b}	23.65^{bcd}	27.93 ^{e}
T_3	12.68 ^{d}	15.45 ^{bc}	17.95 ^{b}	20.14 ^{b}	23.51^{cd}	26.42 ^{f}
T_4	14.35 ^{c}	16.93 ^{b}	18.11 ^{b}	19.87 ^{b}	26.78^{abc}	31.11 ^{d}
T_5	16.68 ^{a}	20.67 ^{a}	22.67 ^{a}	26.20 ^{a}	26.98 ^{ab}	34.42 ^{a}
T_6	15.42 ^{b}	19.17 ^{a}	22.99 ^{a}	25.66 ^{a}	29.33 ^{a}	31.89 ^{c}
T_7	15.82 ^{ab}	20.51 ^{a}	21.47 ^{a}	21.44 ^{ab}	27.19 ^{a}	32.72 ^{b}
CD(0.05)	1.06	2.14	3.16	5.26	3.42	0.75

DAP – Days After Planting

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.2.2.2 Bangalora

Seedling of the variety Bangalora was taller than those of variety Moovandan and the effect of treatments gave almost the same results as that of variety Moovandan. Presoaking the stones with biogas slurry generated from cow dung and fruit waste in 1:2 ratio (T_5) gave the best results (34.42 cm) even after 90 days after planting which was on par (33.86 cm) with coating with cow dung slurry from treatment 1 of experiment 1 (T_6) and the lowest seedling height at 90 days after planting was recorded by the treatment T_3 (22.97 cm) which was comparable to other

treatments like T_1 (24.96 cm) and T_1 (24.99 cm). At 75 days after planting T_6 recorded the highest seedling height (32.53 cm) (Table 19).

Table 19. Effect of different treatments on seedling height at biweekly interval of variety Bangalora

Treatments	Seedling height (cm)					
	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T_1	14.88 ^{c}	18.09^{bc}	19.34 ^{c}	20.22 ^{b}	22.28 ^{c}	24.96 ^{c}
T_2	15.39 ^{c}	14.68^{c}	19.08 ^{c}	20.05 ^{b}	23.64 ^{bc}	24.99 ^{c}
T_3	15.62 ^{c}	19.24^{abc}	20.23 ^{c}	21.41 ^{b}	22.63 ^{bc}	22.97 ^{c}
T_4	16.64 ^{b}	22.68 ^{ab}	24.10 ^{ab}	27.00 ^{a}	27.88 ^{abc}	30.49^{ab}
T_5	17.81 ^{a}	23.47 ^{a}	25.16 ^{a}	27.36 ^{a}	27.55 ^{abc}	34.04 ^{a}
T_6	16.96 ^{ab}	19.84^{ab}	21.22^{bc}	21.65 ^{b}	32.53 ^{a}	33.86 ^{a}
T_7	17.51 ^{ab}	22.98 ^{a}	25.26 ^{a}	27.89 ^{a}	28.24 ^{a}	28.03 ^{bc}
CD(0.05)	0.96	4.65	3.56	3.98	5.79	5.38

DAP – Days After Planting

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.2.3 Effect of treatments on girth of mango seedlings

The effect treatments on seedling girth of mango varieties Moovandan and Bangalora at biweekly interval are presented in table 20 and 21 respectively.

4.2.3.1 Moovandan

Seedlings of mango are mainly used for grafting purpose for which satisfactory girth is an important pre requisite. Assessment of the effect of different pre germination treatments on seedling girth indicated that treatments were significantly different up to 30 days after planting. The seedling girth at 30 days after planting ranged between 0.13 to 0.17 cm. The maximum seedling girth was recorded by T_5 (presoaking for 12 h with biogas slurry from cow dung and fruit waste in 1:2 ratio).

4.2.3.2 Bangalora

The seedling girth of the variety Bangalora also followed a similar trend as that of variety Moovandan. Presoaking for 12 h with biogas slurry from cow dung and fruit waste in 1:2 ratio (T_5) gave the best results till 90 days after planting (0.55 cm) and it was on par with T_7 (0.50 cm). The effect of treatments on girth was found to be non significant at 75 days after planting. The minimum girth was recorded for the control almost all the intervals of growth period (Table 21).

Table 20. Effect of treatments on seedling girth at biweekly intervals of variety Moovandan

Treatments	Girth (cm)					
	15DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T_1	0.18^{d}	0.14 ^{bcd}	0.16^{a}	0.18^{a}	0.35^{a}	0.43^{a}
T_2	0.13^{bcd}	0.13 ^{cd}	0.15	0.17 ^{a}	0.36 ^{a}	0.45 ^{a}
T_3	0.12^{cd}	0.13^{cd}	0.17	0.19^{a}	0.45^{a}	0.45^{a}
T_4	0.14^{abc}	0.16^{ab}	0.18	0.21 ^{a}	0.39^{a}	0.41^{a}
T_5	0.16^{a}	0.17^{a}	0.19	0.22 ^{a}	0.42 ^{a}	0.45^{a}
T_6	0.18^{d}	0.12 ^{d}	0.16	0.19 ^{a}	0.44 ^{a}	0.45^{a}
T_7	0.15^{ab}	0.15 ^{abc}	0.19	0.21 ^{a}	0.46 ^{a}	0.46^{a}
CD(0.05)	0.02	0.02	NS	NS	NS	NS

DAP – Days After Planting

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

Table 21. Effect of treatments on seedling girth at biweekly intervals of variety Bangalora

Treatments	Girth (cm)					
	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T_1	0.10 ^{d}	0.11 ^{d}	0.13^{d}	0.15 ^{d}	0.25^{a}	0.36 ^{c}
T_2	0.11 ^{cd}	0.12 ^{cd}	0.15 ^{cd}	0.17 ^{cd}	0.26 ^{a}	0.48 ^{bc}
T_3	0.12^{bc}	0.14 ^{bcd}	0.16^{bcd}	0.19 ^{bc}	0.27 ^{a}	0.44 ^{bc}
T_4	0.13 ^{bc}	0.15 ^{abc}	0.17 ^{abc}	0.19 ^{bc}	0.26 ^{a}	0.43 ^{bc}
T_5	0.15 ^{a}	0.17 ^{a}	0.21 ^{a}	0.24 ^{a}	0.29 ^{a}	0.55 ^{a}
T_6	0.13 ^{bc}	0.14 ^{bcd}	0.18 ^{abc}	0.20 ^{ab}	0.27 ^{a}	0.44 ^{bc}
T_7	0.14 ^{ab}	0.16 ^{ab}	0.19 ^{ab}	0.22 ^{ab}	0.29 ^{a}	0.50 ^{ab}
CD(0.05)	0.02	0.03	0.041	0.03	NS	0.09

DAP – Days After Planting

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.2.4 Effect of different treatments on number of leaves of mango seedlings

Effect of treatments on number of leaves of mango varieties Moovandan and Bangalora are shown in table 22 and 23, respectively.

4.2.4.1 Moovandan

The effect of treatments on leaf number of variety Moovandan indicated that the treatments were significantly different up to 60th days after planting. The highest

number of leaves at sixty days after planting was recorded by T_7 (9.81) which was on par with T_5 (9.38). The least number of leaves was recorded by T_2 (5.42) which was on par with control. Treatments did not exhibit any significant difference with respect to this parameter at 75th and 90 th days after planting (Table 22).

4.2.4.2 Bangalora

The influence pattern of treatments on leaf number of seedlings of variety Bangalora was different from that of the variety Moovandan. Though number of leaves of mango variety Bangalora was influenced by the treatments at 90 days after planting, it was found to be non significant till 60 days after planting. The coating with gobergas slurry (T_6) and presoaking with fruit waste slurry (T_5) were on par at 90 days recording (16.20 and 15.07, respectively) with respect to this parameter (Table 23).

Table 22. Effect of different treatments on number of leaves/seedling of variety Moovandan

Treatments	Number of leaves					
	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T_1	4.03^{c}	4.47^{bc}	5.26^{c}	6.01^{c}	9.30^{a}	12.66^{a}
T_2	4.47^{bc}	4.56^{bc}	4.99^{c}	5.42^{c}	8.20^{a}	10.93^{a}
T_3	3.77^{c}	3.93^{c}	5.11^{c}	6.41^{bc}	12.23^{a}	14.45^{a}
T_4	4.61^{bc}	4.78^{b}	6.29^{bc}	7.30^{bc}	15.83^{a}	17.58^{a}
T_5	6.24^{a}	6.88^{a}	8.06^{a}	9.38^{a}	13.88^{a}	16.33^{a}
T_6	5.06^{b}	5.08^{b}	6.79^{ab}	8.21^{ab}	12.71^{a}	14.33^{a}
T_7	6.26^{a}	7.04^{a}	7.49^{ab}	9.81^{a}	13.93^{a}	16.66^{a}
CD (0.05)	0.894	0.71	1.501	1.68	NS	NS

DAP – Days After Planting

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

Table 23. Effect of treatments on number of leaves/seedling of variety Bangalora

Treatments	Number of leaves (cm)					
	15 DAP	30 DAP	45 DAP	60 DAP	75 DAP	90 DAP
T_1	3.47[a]	3.97[a]	5.31[a]	6.00[a]	7.71[c]	10.80[bcd]
T_2	4.32[a]	5.41[a]	5.75[a]	7.08[a]	7.48[c]	8.73[d]
T_3	4.49[a]	5.19[a]	5.76[a]	6.53[a]	7.90[c]	9.13[cd]
T_4	3.52[a]	4.12[a]	7.23[a]	8.06[a]	11.51[b]	13.93[ab]
T_5	5.68[a]	6.33[a]	7.82[a]	8.93[a]	13.17[ab]	15.07[a]
T_6	5.25[a]	5.96[a]	7.12[a]	8.40[a]	15.01[a]	16.20[a]
T_7	5.20[a]	6.37[a]	7.70[a]	8.53[a]	11.22[b]	13.00[abc]
CD (0.05)	NS	NS	NS	NS	2.78	3.88

DAP – Days After Planting

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.2.5 Mineral nutrient content in mango stones

The nutrient content of variety Bangalora and Moovandan are depicted in table 24.

The moisture content totals solids and organic carbon of stones of variety Bangalora was 72, 28, and 45.26 % respectively whereas the content in variety Moovandan was 69.00, 31.00, and 44.69 % respectively.

The content of nitrogen was more in stones of variety Bangalora (1.32 %) than Moovandan (1.09 %).The P, K, Ca and Mg content of stones of both the variety were similar. The micronutrients Fe, Mn, Zn, and Cu content of variety Bangalora were 82.00, 100.00, 240.00, 180.00 mg kg^{-1}, respectively whereas that of variety Moovandan was 130.00, 108.70, 160.00, and 190.00 mg kg^{-1}, respectively

Table 24. Mineral nutrient content in mango stones before germination

Varieties / Parameter	Bangalora	Moovandan
Moisture(%)	72.00	69.00
Total solids (%)	28.00	31.00
Total macro nutrients (%)		
Organic carbon	45.26	44.69
N	1.32	1.09
P	0.12	0.13
K	0.67	0.65
Ca	0.65	0.97
Mg	0.05	0.05
S	0.13	0.09
Total micronutrients (mg kg^{-1})		
Fe	82.00	130.00
Mn	100.00	108.70
Zn	240.00	160.00
Cu	180.00	190.10

4.2.6 Biochemical constituents in seeds stone before germination

The reducing sugar, non reducing sugar, total sugar and total carbohydrate of Moovandan were 2.03, 2.6, 4.84 mg g-1, respctively and that of Bangalora was 2.67, 2.17, 4.63 mg g^{-1} (Table 25). Starch and Protein content of Moovandan was 251.00, 12.10 mg kg^{-1} and that of Bangalora was 217 and 8.9 mg kg^{-1}, respectively.

Table 25. Biochemical constituents of the stones before germination of varieties Moovandan and Bangalora

Varieties / Biochemical constituents	Moovandan	Bangalora
Reducing sugar (mg g^{-1})	2.03	2.67
Non reducing sugar (mg g^{-1})	2.6	2.17
Total sugar (mg g^{-1})	4.84	4.63
Starch (mg kg^{-1})	251	217
Protein (mg kg^{-1})	12.1	8.9
Total carbohydrate (mg kg^{-1})	10.16	12.4

4.2.7 Biochemical constituents in stones after germination

4.2.7.1 Moovandan

Effect of treatments on biochemical constituents (reducing sugar, non reducing sugar, total sugar, starch and protein) in stones of Mango variety Moovandan after germination is given in table 26.

The reducing sugar in stones of variety Moovandan after germination ranged from 5.1 mg g^{-1} (T_1) to 9.9 mg g^{-1} in T_5 followed by T_6 (8.9 mg g^{-1}), T_4 (7.8 mg g^{-1}) and T_7 (7.1 mg g^{-1}) T_2 (6.0 mg g^{1}) and T_3 (5.7 mg g^{-1})

Non reducing sugar in stones varied from 15.65 mg g^{-1} to 22.90 mg g^{-1}. The non reducing sugar content was recorded in T_1 (22.90 mg g^{-1}) which was followed by T_3, T_2, T_5, T_4, T_6, T_7 recording 21.20, 19.10, 18.65, 18.25, 18.15, 15.65 mg g^{-1} respectively.

The total sugar content in the treatment T_5 recorded the highest value of 28.55 mg g^{-1} which was followed by T_1 (27.90 mg g^{-1}). The total sugar content in other treatments were T_6 (27.15 mg g^{-1}), T_3 (26.96 mg g^{-1}), T_4 (26.15 mg g^{-1}), T_2 (25.10 mg g^{-1}).The lowest value was recorded in T_7 (22.75 mg g^{-1}) which was significantly lower than all the treatments.

Total carbohydrate in stones of mango variety Moovandan after germination was found to be highest in T_5 (38.90 mg g^{-1}) followed by T_7 (38.20 mg g^{-1}), T_4 (38.00 mg g^{-1}), T_6 (37.00 mg g^{1}), T_2 (33.00 mg g^{-1}), T_1 (32.60 mg g^{-1}) and the lowest value was recorded in T_3 (30.16 mg g^{-1}).

Starch content in stones of mango variety Moovandan after germination ranged from 105.0 mg kg^{-1} (T_3) to 158.00 mg kg^{-1} (T_5). The starch content in other treatments T_2, T_1, T_4, T_7, T_6 were 115.0, 116.0, 128.0, 132.0, 136.0 mg kg^{-1}, respectively.

The protein content in stones of variety Moovandan after germination was found to be highest in T_5 (10.95 mg kg^{-1}) which was on par with T_4 (10.04 mg kg^{-1}).

The treatments T_7, T_2, T_6, T_3, T_1 were on par recording 9.99, 9.20, 8.86, 8.80, 8.60 respectively.

Table 26. Effect of different treatments on biochemical constituents in stones of variety Moovandan after germination

Parameter / Treatments	Reducing sugar (mg g^{-1})	Non reducing sugar (mg g^{-1})	Total sugar (mg g^{-1})	Total carbo-hydrate (mg g^{-1})	Starch (mg kg^{-1})	Protein (mg kg^{-1})
T_1	5.0^{g}	22.90^{a}	27.90^{b}	32.60^{f}	116.0^{e}	8.60^{b}
T_2	6.0^{e}	19.10^{e}	25.10^{f}	33.00^{e}	115.0^{f}	9.20^{b}
T_3	5.7^{f}	21.20^{b}	26.90^{d}	30.16^{g}	105.0^{g}	8.80^{b}
T_4	7.8^{c}	18.25^{d}	26.15^{e}	38.00^{c}	128.0^{d}	10.04^{a}
T_5	9.9^{a}	18.65^{d}	28.55^{a}	38.90^{a}	158.0^{a}	10.95^{a}
T_6	8.9^{b}	18.15^{d}	27.15^{c}	37.00^{d}	136.0^{b}	8.86^{b}
T_7	7.1^{d}	15.65^{e}	22.75^{g}	38.20^{b}	132.0^{c}	9.99^{b}
CD(0.05)	0.50	0.82	0.15	0.10	3.21	1.10

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.2.7.2 Bangalora

Effect of treatments on biochemical constituents (reducing sugar, non reducing sugar, total sugar, starch and protein) in stones of Mango variety Bangalora after germination is given in table 27.

The reducing sugar in stones of variety Moovandan after germination ranged from 5.1 mg g^{-1} (T_1) to 8.9 mg g^{-1} in T_5 followed by T_6 (8.2 mg g^{-1}), T_4 (7.7 mg g^{-1}) and T_7 (7.2 mg g^{-1}) T_2 (6.2 mg g^{1}) and T_3 (5.8 mg g^{-1}).

Non reducing sugar in stones varied from 18.62 mg g^{-1} (T_6) to 24.81 mg g^{-1} (T_1). The non reducing sugar content was recorded in T_4 (24.12 mg g^{-1}) which was followed by T_3, T_2, T_5, T_7 recording 24.00, 23.21, 20.81, 19.65 mg g^{-1} respectively.

The total sugar content in the treatment T_4 recorded the highest value of 31.82 mg g^{-1} which was on par with T_5 (29.71 mg g^{-1}). The total sugar content in other treatments were T_1 (29.91 mg g^{-1}), T_3 (29.80 mg g^{-1}), T_2 (29.41 mg g^{-1}) were found to be on par. The lowest value was recorded in T_6 (26.82 mg g^{-1}) which was on par with T_7 (26.85 mg g^{-1})

Total carbohydrate in stones of mango variety Moovandan after germination was found to be highest in T_7 (34.00 mg g^{-1}) followed by T_3 (33.26 mg g^{-1}), T_5 (33.00 mg g^{-1}), T_6 (32.60 mg g^{-1}), T_2 (32.00 mg g^{-1}), T_1 (31.60 mg g^{-1}) and the lowest value was recorded in T_4 (31.00 mg g^{-1}).

Starch content in stones of mango variety Moovandan after germination ranged from 148 mg kg^{-1} (T_5) to 184.00 mg kg^{-1} (T_1). The starch content in other treatments T_3, T_2, T_4, T_7, T_6, were 177, 174, 156, 156, 155 mg kg^{-1}, respectively.

The protein content in stones of variety Moovandan after germination was found to be highest in T_4 (9.31 mg kg^{-1}) which was followed by T_3, T_2, T_5, T_1, T_6, T_7 recording 9.20, 8.90, 8.81, 8.60, 8.23, 8.10 mg g^{-1}, respectively.

Table 27. Effect of different treatments on biochemical constituents in stones of variety Bangalora after germination

Parameter / Treatments	Reducing sugar (mg g^{-1})	Non reducing sugar (mg g^{-1})	Total sugar (mg g^{-1})	Total carbo-hydrate (mg g^{-1})	Starch (mg kg^{-1})	Protein (mg kg^{-1})
T_1	5.1^{g}	24.81^{a}	29.91^{b}	31.60^{f}	184.0^{a}	8.60^{e}
T_2	6.2^{e}	23.21^{b}	29.41^{b}	32.00^{e}	174.0^{c}	$8..90^{c}$
T_3	5.8^{f}	24.00^{a}	29.80^{b}	33.26^{c}	177.0^{b}	9.20^{b}
T_4	7.7^{c}	24.12^{a}	31.82^{a}	31.00^{g}	156.0^{d}	9.31^{a}
T_5	8.9^{a}	20.81^{c}	29.71^{b}	33.00^{b}	148.0^{f}	8.81^{d}
T_6	8.2^{b}	18.62^{d}	26.82^{c}	32.60^{d}	155.0^{e}	8.23^{f}
T_7	7.2^{d}	19.65^{d}	26.85^{c}	34.00^{a}	156.0^{d}	8.10^{f}
CD (0.05)	0.25	0.86	1.10	0.24	0.56	0.16

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.3. EFFECT OF TREATMENTS ON PARTITIONING OF DRY MATTER

4.3.1 Moovandan

The effect of treatments on partitioning of dry matter in seedlings of variety Moovandan is presented in table 28.

The highest shoot weight was recorded in T_5 (9.97 g) and lowest in T_1 (2.40 g). The shoot weight in other treatments T_7, T_4, T_6, T_3, T_2, T_1 were 8.69, 6.84, 5.85, 5.60, 3.95, 2.40 g, respectively. The highest root weight (4.92 g) was recorded in T_5 and the lowest was recorded in T_1 (1.27 g). The shoot weight in other treatments T_7, T_6, T_4, T_3, T_2 were 3.63, 3.07, 2.78, 2.46, 1.41 g respectively.

4.3.2 Bangalora

The effect of treatments on partitioning of dry matter in seedlings of variety Bangalora is given in table 29. The highest shoot weight was recorded in T_5 (9.03 g) and lowest for T_2 (3.9 g).The shoot weight in other treatments T_4, T_7, T_6, T_3, T_1 were 7.9, 7.88, 7.67, 5.55, 4.6 g respectively.

The highest root weight (4.51 g) was recorded in T_7 and lowest in T_1 (1.53 g). The root weight in other treatments were T_5 (4.27 g), T_4 (3.2 g), T_2 (1.94 g), T_3 (1.6 g), T_6 (1.58 g).

Table 28. Effect of different treatments on partitioning of dry matter of seedlings of variety Moovandan

Treatments	Shoot weight (g)	Root weight (g)
T_1	2.40^g	1.27^g
T_2	3.95^f	1.41^f
T_3	5.60^e	2.46^e
T_4	6.84^c	2.78^d
T_5	9.97^a	4.92^a
T_6	5.85^d	3.07^c
T_7	8.69^b	3.63^b
CD(0.05)	0.25	0.12

Table 29. Effect of different treatments on partitioning of dry matter in seedlings of variety Bangalora

Treatments	Shoot weight (g)	Root weight (g)
T_1	4.6^e	1.53^f
T_2	3.9^f	1.94^d
T_3	5.55^d	1.6^e
T_4	7.9^b	3.2^c
T_5	9.03^a	4.27^b
T_6	7.67^c	1.58^f
T_7	7.88^b	4.51^a
CD(0.05)	0.03	0.07

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.4 NUTRIENT UPTAKE

The effect of treatments on nutrient uptake by seedlings of mango varieties Moovandan and Bangalora is furnished in tables 30, 31, 32, 33, 34, 35, 36, 37, respectively.

4.4.1 Major nutrients uptake by shoot at ninety days after planting

4.4.1.1 Moovandan

The uptake of major nutrients by shoot in mango variety Moovandan like N, P, K, Ca, Mg, S were furnished in table 30.

The total N uptake (mg plant $^{-1}$) by shoot ranged from 77.8 (T_1) to 251.2 mg plant $^{-1}$ in T_5 followed by T_7 (248.8 mg plant $^{-1}$), T_4 (228.2 mg plant $^{-1}$) and T_6 (191.9 mg plant $^{-1}$) T_3 (157.9 mg plant $^{-1}$) and T_2 recorded 132.7 mg plant $^{-1}$.

P uptake by shoot varied from 6.9 mg plant $^{-1}$ to 40.4 mg plant $^{-1}$. The highest P uptake was recorded in T_5 (40.4 mg plant $^{-1}$) which was followed by T_7, T_6, T_4, T_2, T_3, T_1 recording 32.6, 24.4 20.3, 19.7, 14.7 mg plant $^{-1}$ respectively. The lowest P uptake of 6.9 mg plant $^{-1}$ was observed in control.

For potassium uptake, the treatment T_5 recorded the highest value of 157.9 mg plant $^{-1}$ which was on par with T_7 (154.1 mg plant $^{-1}$). Potassium uptake in other treatments were T_4 (110.5mg plant $^{-1}$), T_6 (98.5 mg plant $^{-1}$), T_3 (87.7 mg plant $^{-1}$), T_2 (73.0 mg plant $^{-1}$).The lowest value was recorded in T_1 (35.1 mg plant $^{-1}$) which was significantly lower than all the treatments.

There was no significant difference between the treatments in case of calcium uptake with highest value in T_4 (60.4 mg plant^{-1}) and lowest in control (51.2 mg plant^{-1})

The magnesium uptake by shoot ranged from 12.6 to 21.1 mg plant^{-1} T_5 recorded the highest Mg uptake which was followed by T_7, T_4, T_6, T_3, T_2, T_1 recording 19.9,17.5,16.4, 16.2, 14.6, 12.6 mg plant $^{-1}$respectively .

From table 30 it was found that the sulphur uptake by shoot ranged from 17.0 mg plant^{-1} (control) to 19.6 mg plant^{-1} (T_5). There was no significant difference between the treatments in the case of sulphur.

Table 30. Effect of different treatments on uptake of major nutrients by shoot in seedlings of variety Moovandan

Parameter / Treatments	N	P	K	Ca	Mg	S
	mg plant $^{-1}$					
T_1	77.80^{g}	6.90^{g}	35.00^{f}	51.20^{a}	12.60^{g}	17.00^{g}
T_2	132.70^{f}	19.70^{e}	73.00^{c}	56.50^{a}	14.60^{f}	17.70^{f}
T_3	157.90^{e}	14.70^{f}	87.70^{d}	54.00^{a}	16.20^{e}	18.30^{d}
T_4	228.20^{c}	20.30^{d}	110.5^{b}	60.40^{a}	17.50^{c}	18.50^{c}
T_5	251.20^{a}	40.40^{a}	157.9^{a}	60.10^{a}	21.10^{a}	19.60^{a}
T_6	191.90^{d}	24.40^{c}	98.5^{c}	57.10^{a}	16.40^{d}	17.30^{e}
T_7	248.80^{b}	32.60^{b}	154.1^{a}	58.50^{a}	19.90^{b}	17.60^{b}
CD (0.05)	0.17	0.03	0.05	NS	0.02	0.04

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.4.1.2 Bangalora

At three months after planting the highest N uptake (table 31) by shoot in seedlings of mango variety Bangalora was recorded in T_6 (274.3 mg plant^{-1}) followed by T_2 (250.3) which was on par with T_5 (247.7 mg plant^{-1}) T_7 (241.1 mg plant^{-1}), T_4 (225.2 mg plant^{-1}) and T_3 (193.5 T_2 (250.3). The lowest value was noticed in control (152.3 mg plant^{-1}).

The results on the P uptake by shoot are illustrated in table 31. The highest phosphorus uptake by shoot was obtained in T_4 (23.7 mg plant^{-1}) and the lowest value

was noticed in T_1 (22.0 mg plant^{-1}). However there was no significant difference between the treatments.

From table 31, it was found that the potassium uptake was significantly influenced by the treatments. The highest uptake of potassium by shoot was noticed in T_5 (145.9 mg plant^{-1}) which was significantly higher than all other treatments. This was followed by T_6 (138.6 mg plant^{-1}) and T_4 (127.7 mg plant^{-1}) which was on par with T_2 (125.2 mg plant^{-1}) and T_7 (122.7 mg plant^{-1}).

The results on the effect of treatments on Ca uptake by shoot are presented in table 31. Among the treatments T_5 (82.8 mg plant^{-1}) showed the highest value for calcium, followed by T_6 (75.7 mg plant^{-1}) on par with T_7 (73.1 mg plant^{-1}) and followed by T_4 (66.3 mg plant^{1}) which was significantly higher than other treatments..The data on the total Mg uptake by shoot are presented in table 31. Magnesium uptake ranged from in 18.6 mg plant^{-1} (T_5) to in 18.1 mg plant^{-1} in T_1. The treatments did not show any significant difference with respect to Mg uptake.The results on the S uptake are illustrated in table 31.The highest S uptake by shoot was obtained in T_7 (20.5 mg plant^{-1}) and the lowest value was noticed in T_2 (20.0 mg plant^{-1}). However there was no significant difference between the treatments.

Table 31. Effect of different treatments on uptake of major nutrients by shoot in seedlings of variety Bangalora

Parameter / Treatments	N	P	K	Ca	Mg	S
	mg plant $^{-1}$					
T_1	152.3^{f}	22.0^{c}	81.1^{d}	50.0^{d}	18.1^{a}	20.1^{a}
T_2	250.3^{b}	22.3^{bc}	125.2^{c}	47.4^{d}	18.1^{a}	20.0^{a}
T_3	193.5^{e}	22.7^{bc}	86.6^{d}	51.5^{d}	18.2^{a}	20.2^{a}
T_4	225.2^{d}	23.7^{a}	127.7^{c}	66.3^{c}	18.3^{a}	20.4^{a}
T_5	247.7^{b}	22.9^{b}	145.9^{a}	82.8^{a}	18.6^{a}	20.2^{a}
T_6	274.3^{a}	23.0^{b}	138.3^{b}	73.1^{b}	18.5^{a}	20.3^{a}
T_7	241.1^{c}	22.3^{bc}	122.7^{c}	75.7^{b}	18.5^{a}	20.5^{a}
CD (0.05)	0.41	NS	0.62	0.56	NS	NS

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.4.2 Micronutrient uptake by shoot at ninety days after planting

4.4.2.1 Moovandan

Table 32 shows the total Fe uptake by shoot sample at three months after planting. The highest Fe uptake was recorded in T_7 with 10.16 mg plant^{-1} which was on par with T_5 (7.36 mg plant^{-1}), T_6 (5.46 mg plant^{-1}), T_4 (4.75mg plant^{-1}), T_3 (4.64 mg plant^{-1}), T_2 (3.21 mg plant^{-1}) and significantly higher than T_1 (1.96 mg plant^{-1}).

The data on the Mn uptake by mango shoot are furnished in table 32. The highest manganese uptake was found in T_5 (6.92 mg plant^{-1}) which was followed by T_7 (5.51 mg plant^{-1}), T_3 (3.61 mg plant^{-1}), T_6 (3.47 mg plant^{-1}), T_4 (3.17 mg plant^{-1}), T_2 (2.74 mg plant^{-1}). Control recorded lowest Mn content of 1.23 mg plant^{-1}.

The results pertaining to total Zn uptake by mango shoot in seedlings of variety Moovandan are given in table 32. When the effect of the treatments on Zn uptake were compared, it was seen that the highest Zn uptake was recorded inT_7 (0.17 mg plant^{-1}) which was followed by T_3 (0.15 mg plant^{-1}), T_5 (0.10 mg plant^{-1}), T_2 (0.08 mg plant^{-1}), T_4 (0.05 mg plant^{-1}), T_6 (0.04 mg plant^{-1}) and T_1 (0.02 mg plant^{-1}).

The data on total Cu uptake are presented in table 32. With respect to copper uptake by shoot T_7 recorded the highest concentration of 0.23 mg plant^{-1} which was on par with T_5 (0.23 mg plant^{-1}) and significantly higher than all other treatments. The lowest copper content was recorded in T_5 (0.02 mg kg^{-1})

Table 32. Effect of different treatments on Micronutrient uptake by shoot in seedlings of variety Moovandan

Parameter / Treatments	Fe	Mn	Zn	Cu
	mg plant $^{-1}$			
T_1	1.96 ^{c}	1.23 ^{g}	0.02^{g}	0.04 ^{d}
T_2	3.21 ^{bc}	2.74 ^{f}	0.08 ^{d}	0.23 ^{c}
T_3	4.64 ^{bc}	3.61 ^{c}	0.15 ^{b}	0.03 ^{d}
T_4	4.75 ^{bc}	3.17 ^{e}	0.08 ^{d}	0.05^{d}
T_5	7.36 ^{ab}	6.92 ^{a}	0.10 ^{c}	0.02 ^{d}
T_6	5.46 ^{bc}	3.47^{d}	0.07 ^{c}	0.13 ^{b}
T_7	10.16 ^{a}	5.51 ^{b}	0.17 ^{a}	0.23 ^{a}
CD (0.05)	4.50	0.35	0.01	0.04

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.4.2.2 Bangalora

When the effect of treatments on Fe uptake (table 33) by shoot were compared, T_5 showed the highest uptake of iron (775.0 mg kg^{-1}) by shoot which was on par with T_1 (686.3 mg kg^{-1}), T_2 (649.6 mg kg^{-1}), T_3 (672.3 mg kg^{-1}), T_6 (765.0 mg kg^{-1}), T_7 (636.0 mg kg^{-1}) and significantly higher than all the remaining treatments. The lowest value was noticed in control (600.0 mg kg^{1}). The data are furnished in Table 33.

The results pertaining to the effect of treatments on Mn uptake by shoot are depicted in table 33. The highest Mn uptake was noticed in T_7 (4.60 mg plant^{-1}) which

was followed by T_5 (4.56 mg plant^{-1}), T_4 (4.02 mg plant $^{-1}$), T_1 (2.61 mg plant^{-1}), T_6 (2.50 mg plant^{-1}), T_3 (2.01 mg kg^{-1}) and T_2 (1.44 mg plant $^{-1}$).

The data on total Zn uptake by shoot in seedlings at 90 days after planting are presented in table 33. Pre soaking with gobergas slurry from treatment 1 of experiment 1 (T_7) recorded the highest Zn uptake (0.26 mg plant $^{-1}$) which was followed by T_5 (0.19 mg plant $^{-1}$) and it was on par with T_6 (0.18 mg plant^{-1}) and T_4 (0.18 mg plant^{-1}). The Zn uptake in T_3, T_1 and T_2 were 0.17, 0.12 , 0.07 mg plant^{-1} respectively.

The data from table 33 revealed that the highest copper uptake was noticed in T_2 with 0.10 mg plant^{-1} which was on followed by T_4 (0.07 mg plant^{-}1) which was on par with all the remaining treatments.

Table 33. Micronutrient uptake by shoot in seedlings of variety Bangalora as influenced by different treatments

Parameter / Treatments	Fe	Mn	Zn	Cu
	mg plant $^{-1}$			
T_1	3.03 ^{d}	2.61 ^{d}	0.12 ^{c}	0.07^{b}
T_2	2.66 ^{e}	1.44 ^{g}	0.07 ^{d}	0.10 ^{a}
T_3	2.16 ^{f}	2.01 ^{f}	0.17 ^{b}	0.07^{b}
T_4	2.96^{d}	4.02 ^{c}	0.18^{b}	0.07 ^{b}
T_5	4.33 ^{b}	4.56^{b}	0.19 ^{b}	0.07 ^{b}
T_6	4.55^{a}	2.50^{e}	0.18 ^{b}	0.07 ^{b}
T_7	4.06 ^{c}	4.60 ^{a}	0.26 ^{a}	0.07^{b}
CD (0.05)	0.25	0.08	0.05	0.02

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.4.3 Major nutrients uptake by root at ninety days after planting

4.4.3.1 Moovandan

The uptake of major nutrients by root in seedlings of mango variety Moovandan like N, P, K, Ca, Mg, S are furnished in table 34.

At three months after planting the highest N uptake by root in seedlings of mango variety Moovandan was recorded in T_5 (27.6 mg plant^{-1}) on par with T_7 (27.5 mg plant^{-1}) which was followed by T_4 (25.0 mg plant^{-1}) followed by T_6 (22.0 mg

plant^{-1}), T_2 (18.6 mg plant^{-1}) and T_3 (15.8 mg plant^{-1}).The lowest value was noticed in control (12.4 mg plant^{-1}).

The result on the P uptake by root is illustrated in table 34 showed that treatments are significantly different. The highest phosphorus uptake by root (6.8 mg plant^{-1}) was obtained in T_5 and the lowest value was noticed in T_1 (2.7 mg plant^{-1}). The P uptake in other treatments T_6, T_4, T_7, T_3, T_2 were 5.9, 5.5, 5.3, 5.2, 3.4 mg plant^{-1} respectively.

From table 34, it was found that the potassium uptake was significantly influenced by the treatments. The highest uptake of potassium by root was noticed in T_5 (29.8 mg plant^{-1}) which was significantly higher than all other treatments. This was followed by T_6 (24.1 mg plant^{-1}) and T_7 (22.2 mg plant^{-1}), T_4 (20.1mg plant^{-1}) and T_3 (19.0 mg plant^{-1}), T_2 (12.6 mg plant^{-1}), T_1 (9.2 mg plant^{-1}).

The results of the effect of treatments on Ca uptake by root are presented in table 34. Among the treatments T_5 (5.3 mg plant^{-1}) showed the highest value for calcium which was followed by T_7 (4.8 mg plant^{-1}), T_6 (3.6 mg plant^{-1}) and followed by T_3 (3.3 mg plant^{-1}) which was on par with T_4 (3.3 mg plant^{-1}) and significantly higher than other treatments T_2 (2.2 mg plant^{-1}), T_1 (1.4 mg plant^{-1}).

The data on the total Mg uptake by root is presented in table 34. Magnesium uptake ranged from 2.5mg plant^{-1} T_5 to in 2.1 mg plant^{-1} in T_1. The treatments did not show any significant difference with respect to Mg uptake.

The results on the S uptake are illustrated in table 34. The highest sulphur uptake by root in seedlings of mango variety Moovandan was obtained in T_5 (3.5 mg

plant^{-1}) and the lowest value was noticed in T_6 (3.0 mg plant^{-1}). However there was no significant difference between the treatments.

Table 34. Major nutrient uptake by root in seedlings of variety Moovandan as influenced by different treatments

Parameter / Treatments	N	P	K	Ca	Mg	S
	mg plant $^{-1}$					
T_1	12.4 ^{f}	2.7 ^{g}	9.2 ^{g}	1.4 ^{f}	2.1	3.3
T_2	15.8^{e}	3.4 ^{f}	12.6 ^{f}	2.2 ^{e}	2.4	3.4
T_3	18.6 ^{d}	5.2 ^{e}	19.0 ^{e}	3.3 ^{d}	2.2	3.1
T_4	25.0 ^{b}	5.5 ^{c}	20.1 ^{d}	3.1 ^{d}	2.4	3.2
T_5	27.6^{a}	6.8 ^{a}	29.8 ^{a}	5.3 ^{a}	2.5	3.5
T_6	22.0^{c}	5.9 ^{b}	24.1 ^{b}	3.6 ^{c}	2.5	3.0
T_7	27.5 ^{a}	5.3 ^{d}	22.2 ^{c}	4.8 ^{b}	2.2	3.1
CD (0.05)	0.10	0.01	0.12	0.22	NS	NS

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.4.3.2 Bangalora

The uptake of major nutrients by root in seedlings of mango variety Bangalora like N, P, K, Ca, Mg, S are furnished in table 35.

The total N uptake (mg plant $^{-1}$) in root ranged from 24.0 (T_1) to 25.5 in T_7. However there was no significant difference between the treatments.

P uptake in root varied from 6.6 mg plant $^{-1}$ to 2.5 mg plant $^{-1}$. The highest P uptake was recorded in T_5 (6.6 mg plant $^{-1}$) which was followed by T_7, T_4, T_2, T_3, T_6 recording 6.2, 5.8, 4.1, 3.9, 3.3. 2.5 mg plant $^{-1}$ respectively.

For potassium uptake, the treatment T_7 recorded the highest value of 34.6 mg plant $^{-1}$ which was followed by T_5 (33.7 mg plant $^{-1}$). The potassium uptake in other treatments were T_4 (19.7 mg plant $^{-1}$) T_2 (15.8 mg plant $^{-1}$), T_6 (11.6 mg plant $^{-1}$) T_3 (11.5 mg plant $^{-1}$).The lowest value recorded inT_1 with 10.5 mg plant $^{-1}$ which was significantly lower than all the treatments.

The calcium uptake in root ranged from2.4 to 6.6 mg plant^{-1}. T_7 recorded the highest Mg uptake (6.6 mg plant^{-1}) which was followed by T_5, T_4, T_2, T_3, T_2, T_1,T_6 recording 6.2, 5.8, 4.0, 6.2, 3.9, 3.1, 2.4 mg plant $^{-1}$ respectively.

There was no significant difference between the treatments in case of magnesium uptake with highest value for T_7 (2.6 mg plant^{-1}) and lowest for control (2.1 mg plant^{-1}).

From Table36, the sulphur uptake in root ranged from 3.9 mg plant^{-1} (control) to 4.3 mg plant^{-1} (T_7). There was no significant difference between the treatments in the case of sulphur uptake.

Table 35. Major nutrient uptake by root in seedlings of mango variety Bangalora as influenced by different treatments

Parameter / Treatments	N	P	K	Ca	Mg	S
	mg plant $^{-1}$					
T_1	24 .0^{a}	3.3^{f}	10.5^{f}	3.1^{f}	2.1^{a}	3.9^{a}
T_2	24.2^{a}	4.1^{d}	15.8^{d}	4.0^{d}	2.2^{a}	4.0^{a}
T_3	24.1^{a}	3.9^{e}	11.5^{e}	3.9^{e}	2.3^{a}	4.2^{a}
T_4	24.3^{a}	5.8^{c}	19.7^{c}	5.8^{c}	2.4^{a}	3.9^{a}
T_5	24.8^{a}	6.6^{a}	33.7^{b}	6.2^{b}	2.5^{a}	4.2^{a}
T_6	24.4^{a}	2.5^{g}	11.6^{e}	2.4^{g}	2.1^{a}	4.1^{a}
T_7	25.5^{a}	6.2^{b}	34.6^{a}	6.6^{a}	2.6^{a}	4.3^{a}
CD (0.05)	NS	0.01	0.05	0.01	NS	NS

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.4.4 Micro nutrients uptake by root at thirty days after planting

4.4.4.1 Moovandan

When the effect of treatments on Fe uptake (table 36) were compared, it was seen that T_7 treatment showed highest content of iron (4.02 mg plant^{-1}) which was followed by T_5 (3.02 mg plant^{-1}), T_6 (2.66 mg plant^{-1}), T_3 (2.44 mg plant^{-1}), T_4 (2.10 mg plant^{-1}), T_2 (1.54 mg plant^{-1}). The lowest value was noticed in control (1.01 mg plant^{-1}.

The results pertaining to the effect of treatments on Mn uptake in root are depicted in table 36. The highest Mn uptake was noticed in T_5 (0.16 mg plant^{-1}) which was followed by T_6 (0.13 mg plant^{-1}), T_3 (0.12 mg plant $^{-1}$), T_7 (0.11 mg plant^{-1}), T_4 (0.06 mg plant^{-1}), T_2 (0.05 mg plant^{-1}) and T_1 (0.03 mg plant $^{-1}$).

The data on total Zn content uptake are presented in table 36. T_3 was recorded the highest Zn uptake (0.06 mg plant $^{-1}$). However there was no significant difference between treatments.

There was no significant difference between the treatments for Cu uptake by root in seedlings of mango variety Moovandan (table 36).

Table 36. Micro nutrient uptake by root in seedlings of variety Moovandan as influenced by treatments

Parameter / Treatments	Fe	Mn	Zn	Cu
	mg plant $^{-1}$			
T_1	1.01 ^{g}	0.03 ^{g}	0.02	0.02
T_2	1.54 ^{f}	0.05 ^{f}	0.02	0.02
T_3	2.44^{d}	0.12 ^{c}	0.06	0.02
T_4	2.10 ^{e}	0.06^{e}	0.04	0.02
T_5	3.02 ^{b}	0.16 ^{a}	0.02	0.01
T_6	2.66 ^{c}	0.13 ^{b}	0.02	0.01
T_7	4.02 ^{a}	0.11 ^{d}	0.03	0.02
CD (0.05)	0.31	0.01	NS	NS

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.4.4.2 Bangalora

The data from table 37 shows the total Fe uptake by root sample at three months after planting in seedlings of variety Bangalora. The highest Fe uptake was recorded in T_7 with 3.95 mg plant $^{-1}$ which was followed by T_5 (3.47 mg plant^{-1}), T_4 (2.59 mg plant^{-1}), T_2 (1.76 mg plant^{-1}), T_3 (1.68 mg plant^{-1}), T_1 (1.67 mg plant^{-1}) and lowest in T_7 (1.49 mg plant^{-1}).

The data on the Mn uptake by mango root is furnished in table 37. The highest manganese uptake was found in T_5 (0.09 mg plant^{-1}) which was followed by T_3 (0.08 mg plant^{-1}), T_7 (0.06 mg plant^{-1}), T_4 (0.06 mg plant^{-1}), T_1 (0.03 mg plant^{-1}), T_6 (0.03mg plant^{-1}).

The results pertaining to total Zn uptake by root of seedlings of variety Moovandan are given in table 37. When the effect of the treatments on Zn uptake were compared, it was seen that the highest Zn uptake was recorded inT_3 (0.08 mg plant^{-1}) and the lowest in T_1 (0.01mg plant^{-1}). However there was no significant difference between the treatments.

The data on total Cu uptake are presented in table 37. With respect to copper uptake by root there was no significant difference between the treatments.

Table 37. Micro nutrient uptake by root in seedling of variety Bangalora as influenced by different treatments

Parameter / Treatments	Fe	Mn	Zn	Cu
	mg plant^{-1}			
T_1	1.67 ^{e}	0.03 ^{d}	0.01	0.03
T_2	1.76 ^{d}	0.01 ^{e}	0.02	0.03
T_3	1.68^{e}	0.08 ^{b}	0.08	0.03
T_4	2.59 ^{c}	0.06 ^{c}	0.06	0.03
T_5	3.47 ^{b}	0.09 ^{a}	0.02	0.03
T_6	1.49 ^{f}	0.03 ^{d}	0.02	0.03
T_7	3.95 ^{a}	0.06 ^{c}	0.02	0.03
CD(0.05)	0.05	0.01	NS	NS

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.5 NUTRIENT ANALYSIS OF POTTING MIXTURE BEFORE AND AFTER THE EXPERIMENT

4.5.1 Initial nutrient contents of potting mixture

The nutrient status of potting mixture before the experiment was studied and the results are presented in table 39. The soil was acidic in reaction with a pH of 5.62 and EC of 0.07. It was found that available N content of the potting mixture was 140.88 mg kg^{-1}. In the case of available P it was found to be 9.07 mg kg^{-1} and available K content was 180.75 mg kg^{-1}. The Ca, Mg, and S content of potting

mixture were 31.74, 33.88, 17.77 mg kg^{-1} respectively. Among the micronutrients the content of Fe, Mn, Zn, Cu were 17.26, 33.20, 11.76, 14.09 mg kg^{-1} respectively.

Table 38. Initial nutrient content of potting mixture

Nutrient	Value
pH	5.62
EC (dS m^{-1})	0.07
Available nutrients (mg kg^{-1})	
N (mg kg^{-1})	140.88
P (mg kg^{-1})	9.07
K (mg kg^{-1})	180.75
Ca (mg kg^{-1})	31.74
Mg (mg kg^{-1})	33.88
S (mg kg^{-1})	17.77
Fe (mg kg^{-1})	17.26
Mn (mg kg^{-1})	33.30
Zn (mg kg^{-1})	11.76
Cu (mg kg^{-1})	14.09

4.5.2 Nutrient content of potting mixture after the removal of seedlings of variety Moovandan at ninety days after planting

The nutrient status (available N, P, K, Ca, Mg, S and micronutrients) of potting mixture after the removal of the seedlings of the variety Moovandan is given in table 39 and 40.

4.5.2.1 Available nitrogen

The available N ranged from 127.37 mg kg^{-1} in T_3 to 70.68 mg kg^{-1} in T_5, which was on par with T_6 (75.14 mg kg^{-1}).The available N in T_4 (82.44 mg kg^{-1}), T_7 (88.54 mg kg^{-1}) and T_1 (99.40 mg kg^{-1}) ,T_2 (104.46 mg kg^{-1}).

4.5.2.2 Available phosphorous

The effect of different treatments on available P content indicated that T_5 recorded the highest available phosphorus content (9.19 mg kg^{-1}) and the lowest content by T_6 (7.22 mg kg^{-1}). The available P in T_7, T_2, T_1, T_3, T_6, T_4 were 8.71, 8.41, 7.65, 7.44, 7.22, 6.87 mg kg^{-1} respectively.

4.5.2.3 Available potassium

Table 39 shows the available K content in potting mixture of variety Bangalora after the removal of seedlings at 90 after planting. The highest content of potassium was noticed in T_2 (147.33 mg kg^{-1}) and which was on par with T_4 (147.33 mg kg^{-1}), T6 (135.83 mg kg^{-1}), T_7(135.62 mg kg^{-1}), T_1 (135.50 mg kg^{-1}),T_3 (135.16 mg kg^{-1}), T_5 (128.33 mg kg^{-1}).

4.5.2.4 Available Calcium

The results of available Ca content in potting mixture are presented in Table 39. The available calcium content ranged from 22.52 mg kg^{-1} (T_1) to 30.81 mg kg^{-1} (T_5). The Ca content in other treatments T_2, T_4, T_7, T_6, T_3 were 26.80, 28.72, 29.07, 29.36, 30.00 mg kg^{-1} respectively.

4.5.2.5 Available Magnesium

The data pertaining to Mg content of potting mixture at ninety days after planting are presented in Table 40. The treatments were not significantly different.

4.5.2.6 Available Sulphur

The data furnished in Table 40 revealed that the highest available sulphur content was recorded in T_3 (16.47 mg kg^{-1}) and the lowest content was in T_6 (11.30 mg kg^{-1}).the S content in other treatments T_5, T_4, T_1, T_7, T_2 were 12.60, 13.22, 13.64, 13.88, 15.70 mg kg^{-1} respectively.

Table 39. Post treatment analysis of potting mixture for macro nutrients (variety Moovandan)

Parameter / Treatments	N	P	K	Ca	Mg	S
	(mg kg^{-1})					
T_1	99.40^{c}	7.65^{d}	135.5 0^{b}	22.52^{c}	31.96	13.64^{b}
T_2	104.46^{b}	8.41^{c}	148.00^{a}	26.80^{b}	31.63	15.70^{a}
T_3	127.37^{a}	7.44^{e}	132.16^{b}	30.00^{ab}	31.82	16.47^{a}
T_4	82.44^{e}	6.87^{g}	147.33^{a}	28.72^{ab}	33.03	13.22^{b}
T_5	70.68^{f}	9.19^{a}	128.83^{b}	30.81^{a}	31.17	12.60b^{c}
T_6	75.14^{f}	7.22^{f}	135.83^{b}	29.36^{ab}	31.70	11.30^{c}
T_7	88.54^{d}	8.71^{b}	135.62^{b}	29.07^{ab}	32.28	13.88^{b}
CD (0.05)	7.12	0.35	8.21	16.21	NS	3.96

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.5.2.7 Available micronutrients

The data on available Fe content in potting mixture at ninety days after planting are presented in Table 40. The available iron content in potting mixture ranged from18.30 mg kg^{-1} in T_1 to 10.46 mg kg^{-1} in T_2 which was on par with T_7 (18.26 mg k^{-1}). The available Fe in other treatments T_5, T_3, T_1, T_4, T_6 were 14.52, 13.40, 12.56, 12.30, 10.54 mg kg^{-1}, respectively.

The results pertaining to the effect of treatments on Mn content in potting mixture are depicted in Table 40. The highest available manganese content of 33.920 mg kg^{-1} was obtained in T_4 while lowest value was noticed in T_5 (23.37 mg kg^{-1}). The available Mn content in other treatments T_3, T_2, T_1, T_7, T_6 were 26.10, 27.54, 27.92, 29.47, 29.62 mg kg^{-1} respectively.

The data with respect to Zn content in potting mixture are given in Table 40. The highest available Zn content was recorded in T_6 (4.18 mg kg^{-1}) which was significantly higher than all other treatments. The available Zn content in other treatments T_6, T_2, T_3, T_5, T_7, T_1 were 1.81, 1.63, 1.39, 1.29, 1.24, 1.23 mg kg^{-1} , respectively.

Table 40 shows the Cu content in potting mixture at ninety days after planting. T_5 recorded the highest available copper content (6.17 mg kg^{-1}) in potting mixture and the lowest copper content was noted in T_3 (4.64 mg kg^{-1}). The available Cu content in other treatments T_6, T_2, T_4, T_7, T_1 were 6.14, 5.55, 5.15, 4.91, 4.81 mg kg^{-1}, respectively.

Table 40. Post treatment analysis of potting mixture for micro nutrients (variety Moovandan)

Parameter / Treatments	Fe	Mn	Zn	Cu
	(mg kg^{-1})			
T_1	12.56 ^{cd}	27.92^{bc}	1.23^{d}	4.81^{d}
T_2	18.30 ^{a}	27.54 ^{bc}	1.63^{bc}	5.55 ^{b}
T_3	13.40 ^{c}	26.10 ^{bc}	1.39^{cd}	4.64 ^{d}
T_4	12.30 ^{d}	33.95 ^{a}	4.18^{a}	5.15 ^{c}
T_5	14.52 ^{b}	23.77 ^{c}	1.29^{d}	6.17^{a}
T_6	10.54 ^{e}	29.62 ^{ab}	1.81^{b}	6.14^{a}
T_7	18.26 ^{a}	29.47 ^{ab}	1.24^{d}	4.91^{cd}
CD(0.05)	4.31	4.56	3.14	0.68

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.5.3 Nutrient content of potting mixture after the removal of seedlings of variety Bangalora at ninety days after planting

The nutrient status (available N, P, K, Ca, Mg, S and micronutrients) of potting mixture after the removal of seedlings of the variety Bangalora at ninety days after planting is given in table 41 and 42.

4.5.3.1 Available nitrogen

The available N ranged from 78.72 mg kg^{-1} in T_5 to 109.67 mg kg^{-1} in T_2 which was on par with T_1 (109.38 mg kg^{-1}). The treatments T_4 (93.75 mg kg^{-1}), T_6 (94.34

mg kg^{-1}) and T_7 (93.30 mg kg^{-1}) were found to be on par. The available N status of T_3 was 100.00 mg kg^{-1}.

4.5.3.2 Available phosphorous

The effect of different treatments on available P content indicated that T_3 recorded the highest available phosphorus content (9.64 mg kg^{-1}) which was followed by T_4 (8.66 mg kg^{-1}) and T_6 (6.85 mg kg^{-1}) which was on par with T_2 (6.19 mg kg^{-1}).This was followed by T_1 (4.90 mg kg^{-1}) which was on par with T_5 (4.67 mg kg^{-1}) and T_7 (4.15 mg kg^{-1}).

4.5.3.3 Available potassium

The available K content in potting mixture of variety Bangalora at 90 days after planting. is presented in table 41. The highest content of potassium was noticed in T_3 (176.64 mg kg^{-1}) and the lowest value was recorded in T_5 (137.20 mg kg^{-1}). The available K content n T_4 (146.16 mg kg^{-1}), T_1 (146.80 mg kg^{-1}), T_7 (147.30 mg kg^{-1}) were on par. The treatments T_6 and T_2 were on par recording 168.79 and 169.52 mg kg^{-1} respectively.

4.5.3.4 Available Calcium

The results of available Ca content in potting mixture are presented in table 41. The available calcium content ranged from 31.62 mg kg^{-1} (T_3) to 25.01 mg kg^{-1} (T_1). There was no significant difference between the treatments in case of calcium content.

4.5,3.5 Available Magnesium

The data pertaining to Mg content of potting mixture at ninety days after planting are presented in table 41. At ninety days after planting magnesium content in potting mixture ranged from 32.77 mg kg^{-1} (T_1) to 30.76 mg kg^{-1} (T_5). T_1 gave highest magnesium content in soil with 32.77 mg kg^{-1} which was on par with T_2 (32.37 mg kg^{-1}), T_4 (31.86 mg kg^{-1}), T_6 (31.82 mg kg^{-1}), T_7 (32.47mg kg^{-1}) and T_3 (31.51 mg kg^{-1}). The available Mn content in T_5 was 30.76 mg kg^{-1}.

4.5.3.6 Available Sulphur

The data furnished in table 41 revealed that the highest available sulphur content was recorded in T_3 (16.17 mg kg^{-1}) and the lowest content was in T_6 (11.20 mg kg^{-1}). The available S content in other treatments The available s content in other treatments T_1, T_2, T_4, T_5, T_7 were 15.12, 14.22, 12.18, 11.85, 10.18 mg kg^{-1} respectively.

Table 41. Post treatment analysis of potting mixture for macro nutrients (variety Bangalora)

Parameter / Treatments	N	P	K	Ca	Mg	S
	(mg kg^{-1})					
T_1	109.38 ^{a}	4.90^{d}	146.80^{c}	25.00^{a}	32.77 ^{a}	15.12 ^{b}
T_2	109.67^{a}	6.19^{c}	169.52^{b}	31.00^{a}	32.37^{ab}	14.22 ^{b}
T_3	100.00 ^{b}	9.64^{a}	176.64^{a}	31.60^{a}	31.51^{bc}	16.17 ^{a}
T_4	93.75^{c}	8.66 ^{b}	146.16^{c}	29.50^{a}	31.86^{abc}	12.18^{c}
T_5	78.72^{d}	4.67 ^{de}	137.20^{d}	28.40^{a}	30.76 ^{c}	11.8^{cd}
T_6	94.34^{c}	6.85^{c}	168.79^{b}	31.04^{a}	31.82^{abc}	11.20 ^{d}
T_7	93.30 ^{c}	4.15^{e}	147.30^{c}	28.90^{a}	32.47^{ab}	10.18 ^{e}
CD (0.05)	9.01	0.98	8.16	NS	0.06	0.85

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

4.5.3.7 Available micronutrients

The data on available Fe content in potting mixture are presented in table 42. T The treatments show significant difference on available Fe content in potting mixture. The available iron content in soil ranged from16.83 mg kg^{-1} in T_3 to 9.39 mg kg^{-1} in T_7. The available Fe content in other treatments T_1, T_2, T_4, T_5, T_6 were 13.58, 11.15, 9.69, 11.57, 12.25, respectively.

The results pertaining to the effect of treatments on Mn content in potting mixture are depicted in table 42. The highest available manganese content of 31.72

mg kg^{-1} was obtained in T_3 while the lowest value was noticed in T_5 (20.86 mg kg^{-1}). The available Mn content in other treatments T_6, T_2, T_1, T_7, T_4 were 30.83, 28.56, 25.49, 24.66, 22.09 mg kg^{-1} respectively.

The data with respect to Zn content in potting mixture are given in table 42. The highest available Zn content was recorded in T_6 (3.08 mg kg^{-1}) which was significantly higher than all other treatments and on par with T_3 (2.84 mg kg^{-1}) and T_2 (2.74 mg kg^{-1}).The available Zn content in other treatments T_5, T_7, T_1, T_4 were 2.41, 1.83, 1.36, 1.33 mg kg^{-1} respectively.

The Cu content in potting mixture at ninety days after planting is given in table 42.The treatment T_5 recorded the highest available copper content (4.67 mg kg^{-1}) and the lowest copper content was noted in T_3 (3.29 mg kg^{-1}). There was no significant difference between the treatments.

Table 42. Post treatment analysis of potting mixture for micro nutrients of variety Bangalora

Parameter / Treatments	Fe	Mn	Zn	Cu
	(mg kg^{-1})			
T_1	13.58^{b}	25.49^{bcd}	1.36^{c}	3.51^{a}
T_2	11.15^{c}	28.56^{abc}	2.74^{a}	3.72^{a}
T_3	16.83^{a}	31.72^{a}	2.84^{a}	3.29^{a}
T_4	9.69^{d}	22.09^{d}	1.33^{c}	4.04^{a}
T_5	11.57^{c}	20.86^{d}	2.41^{ab}	4.67^{a}
T_6	12.25^{bc}	30.83^{ab}	3.08^{a}	3.93^{a}
T_7	9.39^{d}	24.66^{cd}	1.83^{bc}	3.42^{a}
CD(0.05)	3.71	0.81	0.56	NS

T_1 : Storage in shade (control); T_2 : Pre-soaking with KNO_3 (1 %) for 10 minutes

T_3 : Ash coating ; T_4 : Coating with biogas slurry having maximum manurial value

T_5 : Pre-soaking with biogas slurry having maximum manurial value (12 h)

T_6 : Coating with gobergas slurry from treatment 1 of experiment- 1

T_7 : Pre-soaking with gobergas slurry from treatment 1 of experiment- 1(12 h)

Discussion

5. DISCUSSION

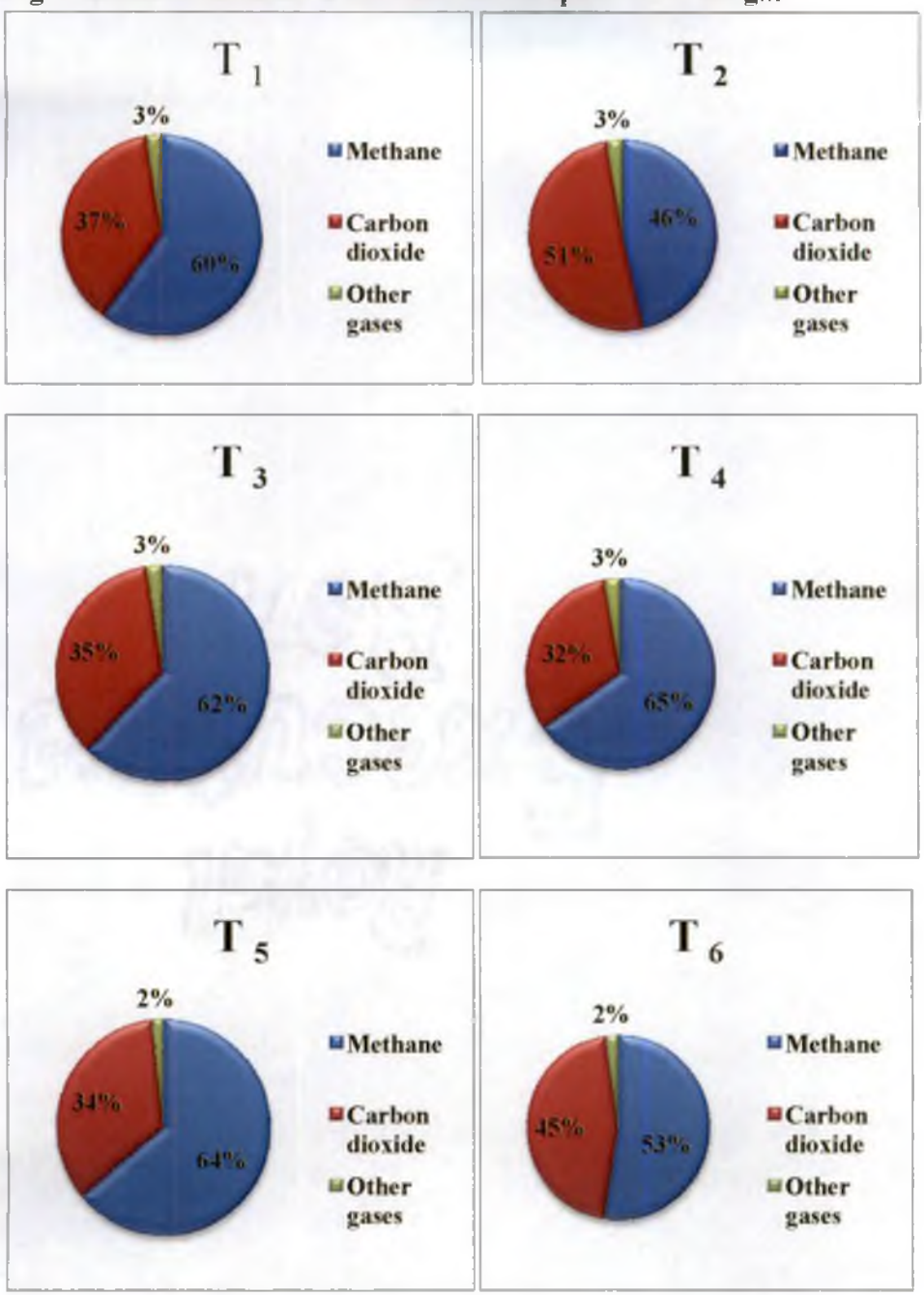
In order to determine the composition of biogas generated from fruit waste and to examine the effect of biogas slurry on germination of mango stones, the research project entitled as "Production and Effective Utilization of Biogas from Fruit waste" was undertaken. The results obtained from the various experiments related to the study are outlined in chapter 4 and the findings are discussed in detail here in this section.

5.1 STANDARDIZATION OF OPTIMUM COMBINATION OF COW DUNG AND FRUIT WASTE FOR MAXIMUM BIOGAS PRODUCTION

5.1.1 Composition of biogas

The data in section 4.1.1 and Fig. 3 depicts the composition of biogas generated from fruit waste when co -digested with cow dung. The highest methane content of 65.30 % was recorded in T_4 (cow dung + fruit waste in 1:1) which was on par with T_5 (cow dung + fruit waste in 1:1.5) and T_3 (cow dung +fruit waste 1:0.5) and significantly higher than cow dung alone (T_1) and fruit waste alone (T_2). The lowest methane content was reported in T_2 (fruit waste alone). The digester performance is highly sensitive to the quality of the substrate loaded to biogas plant. The yield and kinetics of biological reaction involved in anaerobic digestion strongly dependent upon the composition of substrate. Presence of rich organic matter and anaerobes facilitated enhanced biogas production in the process of co-digestion. In co-digestion, availability of additional nutrients also leads to enhanced methane yield. The ratio for optimum composition of biogas production indicates an optimum C: N ratio for methanogenesis and microbial activity.

Fig. 3 Effect of different treatments on composition of biogas



T_1 : Cow dung alone

T_2 : Fruit waste alone

T_3 : Cow dung + Fruit waste (1:0.

T_4 : Cow dung + Fruit waste (1:1)

T_5 : Cow dung + Fruit waste (1:1.5)

T_6 : Cow dung + Fruit waste (1:2)

It is also clear that co-digestion of cow dung with fruit waste increases the methane content of the treatment up to 1:1.5 ratio, but further increasing the fruit waste proportion with cow dung as in T_6 (1:2 ratio) methane generation decreases to 52.42 %. The lowest content of methane was in fruit waste alone treatment (46.46 %). The higher proportion of fruit waste may cause reduction in pH and in turn increase the production of volatile fatty acids. This will result in the reduction in activity of methanogenic bacteria, leading to decreased methane production. The pH of the digester is a function of volatile fatty acid (VFA) produced in the digester. The results are in agreement with that obtained by Tanticharoen *et al.,* (1995) in the case of pineapple waste. Improvement of biogas production with co-digestion of organic waste with cow dung has been mentioned in the works of Banu *et al.,* 2007 and Prakash and Singh (2013)

5.1.2 Temperature inside the digester as compared to Atmospheric temperature

The result in section 4.1.2 and Fig. 4 shows the atmospheric temperature and temperature inside the digester at five days interval during 50 days anaerobic digestion period. It reveals that digestion process was mesophilic in nature. The temperature inside the digester was found to be higher compared to atmospheric temperature due to liberation of heat generated during anaerobic digestion. The highest mean temperature was recorded during the fourth interval (16-20 days after treatment initiation) for the treatment T_4 (33.98 ^{o}C) and thereafter it decreased. The other treatments also followed similar trend (Fig. 4). The highest mean temperature during the period corresponds to the maximum microbial activity and increased anaerobic digestion. It also indicated that the optimum temperature for maximum biogas production is between 32 and 35 ^{0}C. These results are also in accordance with the findings of Adelekan & Bamgboye (2009). At this temperature the C/N ratio of the substrate was brought down to an optimum value for high microbial activity and

methanogenesis. This is also clear from the section 4.1.3 that HRT of treatments varied from 15 to 24 days and length of fermentation period was dependent on temperature both inside and outside of the digester.

5.1.3 Hydraulic Retention Time (HRT) and volume of gas generated

The data presented in section 4.1.3 and Fig. 5 indicates that the shortest HRT (15 days) was in T_3 (cow dung + fruit waste, 1:0.5 ratio) and the longest HRT was on T_2 (fruit waste alone). The pH decreased inside the digester in the treatment. High C: N ratio of the substrate in this particular treatment prolonged the period of activity of both acidogenenic and methanogenic bacteria which might have increased the HRT. The pH of the digester should be kept within a desired range of 6.8 to 7.2 for optimum gas production. The higher microbial activity and temperature inside the digester may be favourable for the lowest HRT as indicated in T_3.

The effect of different treatments on total volume of biogas production during anaerobic digestion period of different substrate used for the study described in section 4.1.3 and Fig. 6. The highest gas volume was recorded by T_4 (cow dung + fruit waste, 1: 1 ratio) which was on par with T_3 (cow dung+ fruit waste 1: 0.5 ratio). Volume and HRT of biogas production obtained in these treatments are in agreement with the findings of Viswanth *et al.,* 1992, Kalia *et al.,* 1992 and Somayaji, 1992. Fruit waste with cow dung decreased the digestion time because cow dung increases the methanogenic activity in digestion. The co-digestion process may balance the nutrient ratio (C: N) required for the anaerobic process. The co-digestion with the cow dung improves the efficiency due to the positive synergism with the supply of required nutrients to methanogenic bacteria.

Fig 4. Effect of different treatments on variation in temperature inside the digester as compared to atmospheric temperature

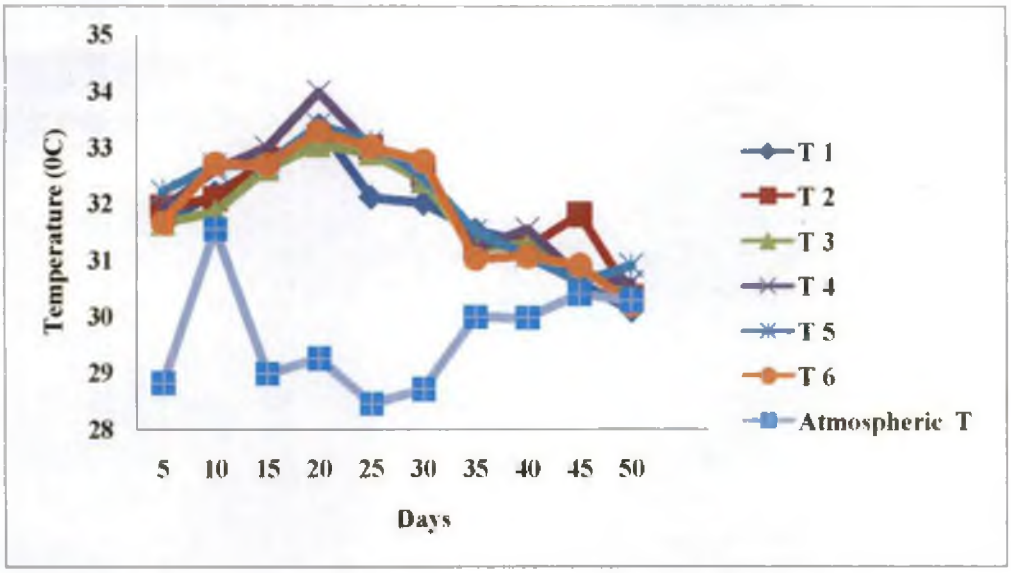
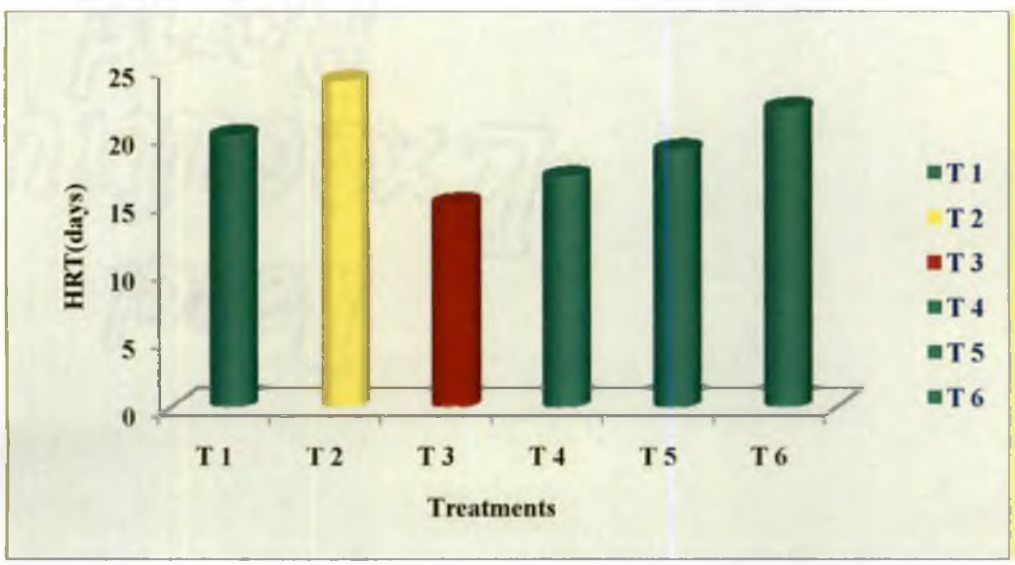


Fig. 5 Effect of different treatments on Hydraulic Retention Time (HRT)



T_1 : Cow dung alone

T_2 : Fruit waste alone

T_3 : Cow dung + Fruit waste (1:0.

T_4 : Cow dung + Fruit waste (1:1)

T_5 : Cow dung + Fruit waste (1:1.5)

T_6 : Cow dung + Fruit waste (1:2)

5.1.4 Mean volume of gas production at 5 days interval

From the section 4.1.4 and Fig. 7, it is evident that volume of gas production is low during initial days and attained maximum at the interval (16 to 25 days). There was a sequential increase in pH value from acidic to neutral range although there is an initial fall during the first week of fermentation, at which gas production was very low. Since activities of aerobes and facultative anaerobes are essential to produce relevant acidic metabolites, which are acted upon by methanogenic bacteria to produce methane. So biogas production requires a minimum time for stabilization. Anaerobic micro organism need excess substrate for growth and so at the end point of digestion rate of biogas production decreases and reaches constant values.

5.1.5 Chemical composition of substrate

From the section 4.1.5.and table 9 it is clear that the high moisture content of both substrates and C: N ratio facilitates anaerobic digestion. In fact the optimum C:N ratio for the substrate for anaerobic digestion is 30:1. The total solids were almost in agreement with that obtained by Nand (1994). The pineapple waste was comparatively rich in macronutrients than cow dung. Both the substrates maintained an optimum micronutrient (Fe, Mn, Zn and Cu) status for anaerobic digestion. Cow dung obtained from a rumen animal is known to contain the native microbial flora that helps in further biogas production.

Fig. 6 Effect of different treatments on total volume of gas produced

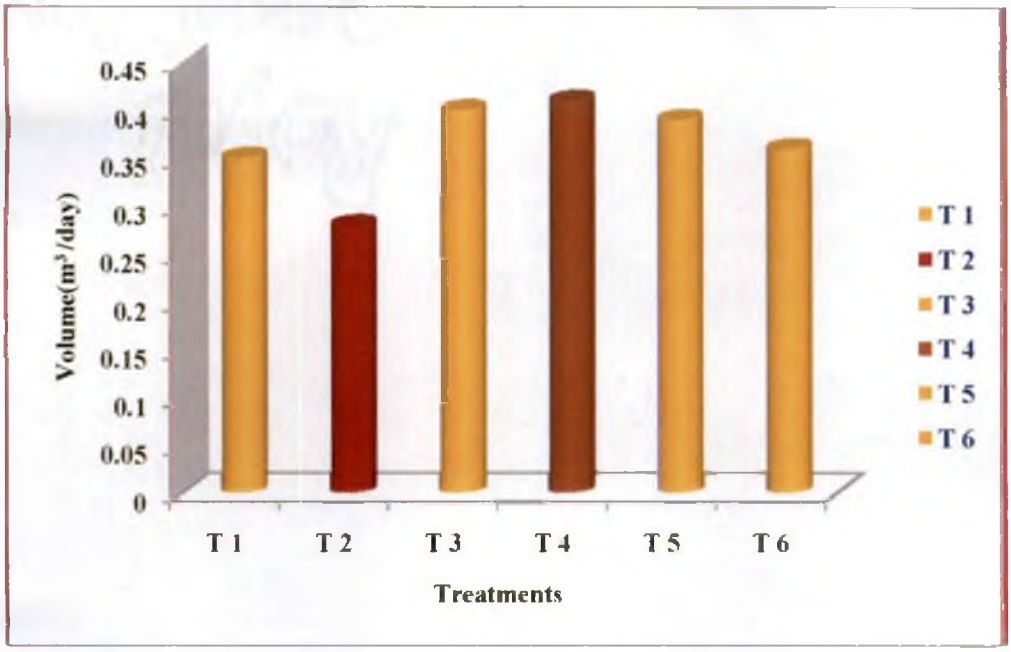
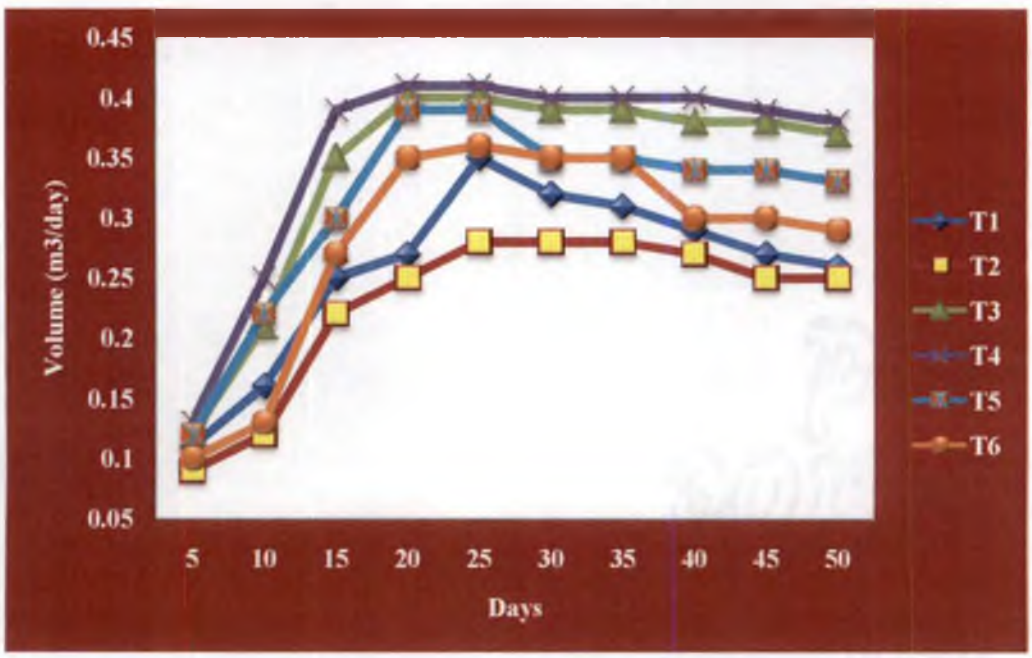


Fig. 7 Effect of different treatments on mean volume of gas produced at five days interval



T_1 : Cow dung alone

T_2 : Fruit waste alone

T_3 : Cow dung + Fruit waste (1:0.

T_4 : Cow dung + Fruit waste (1:1)

T_5 : Cow dung + Fruit waste (1:1.5)

T_6 : Cow dung + Fruit waste (1:2)

5.1.6 Quantity of biogas slurry

The section 4.16 and Fig. 8 revealed that while comparing the treatments, the total quantity of slurry was more in T_6 (cow dung + fruit waste, 1:2), because of higher proportion of fruit waste in the treatment which contain more water content and organic carbon.

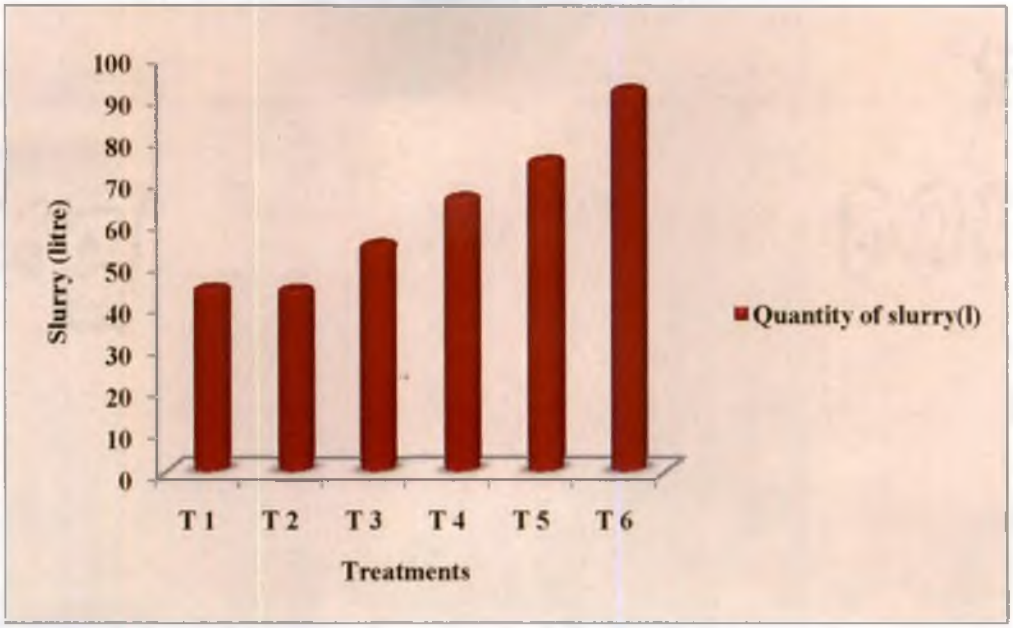
The mean slurry output at five days interval indicated that during the initial period the slurry output decreased. Then there was gradual increase in the consequent period due to more microbial activity. After this period there was a decline due to decreased digestion and microbial activity.

5.1.7 Physico- chemical composition of biogas slurry

5.1.7.1 Total solids

It was found that during anaerobic digestion there was reduction in (section 4.1.7) total solids compared to the substrate. It may be due to the loss of organic carbon in the formation of methane and carbon dioxide during biogas production. Total solids was found to be the highest in first treatment (cow dung alone) and it is due to more dry matter content in the cow dung as compared to fruit waste, which increase the solid content in the slurry. When the proportion of fruit waste increased the total solids decreased due to increased water content in the substrate. The findings are in accordance with that of Fry and Merrill (1973).

Fig. 8 Effect of different treatments on total quantity of slurry produced



T_1 : Cow dung alone

T_2 : Fruit waste alone

T_3 : Cow dung + Fruit waste (1:0.

T_4 : Cow dung + Fruit waste (1:1)

T_5 : Cow dung + Fruit waste (1:1.5)

T_6 : Cow dung + Fruit waste (1:2)

5.1.7.2 pH of slurry

The pH of enriched slurry was near neutral to alkaline range (section 4.1.7 and Fig. 9) irrespective of the treatments. The highest pH was recorded for cow dung alone (T_1) because of alkaline nature of substrate and the lowest (6.4) in fruit waste alone (T_2). The lower pH of the substrate in turn reduces the methanogenic activity which may be due to reduced population of methanogenic organisms. The pH of treatments T_4 and T_3 were on par recording 7.1. Thus the corresponding combination transforms the pH of substrate to near neutral (T_4 and T_3) which is favourable for increased methanogenic activity.

5.1.7.3 Organic carbon and C: N ratio

Organic carbon content of slurry (section 4.1.7 and Fig. 10) was the highest in T_2 (fruit waste alone) because of high carbon content of original substance. The wide C/N ratio of substrate may in turn result in reduced methane production and increased carbon dioxide production. The C: N ratio ranging from 20 to 30 is considered as optimum for anaerobic digestion. When the C: N ratio is very high, the nitrogen will be consumed rapidly by methanogens for meeting their protein requirements and will no longer react on the left over C content of the material. As a result, gas production will be low. On the other hand, if the C: N ratio is low 'N' will be liberated and accumulated in the form of ammonia which will increase the pH of the contents in the digester. A pH more than 8.5 will show toxic effect on methanogenesis. The wide C/N ratio may result in N immobilization and resulting low N content of slurry. The lowest organic carbon in T_4 may due to increased methane generation by the treatment.

Fig. 9 Effect of different treatments on pH of slurry as compared to substrate

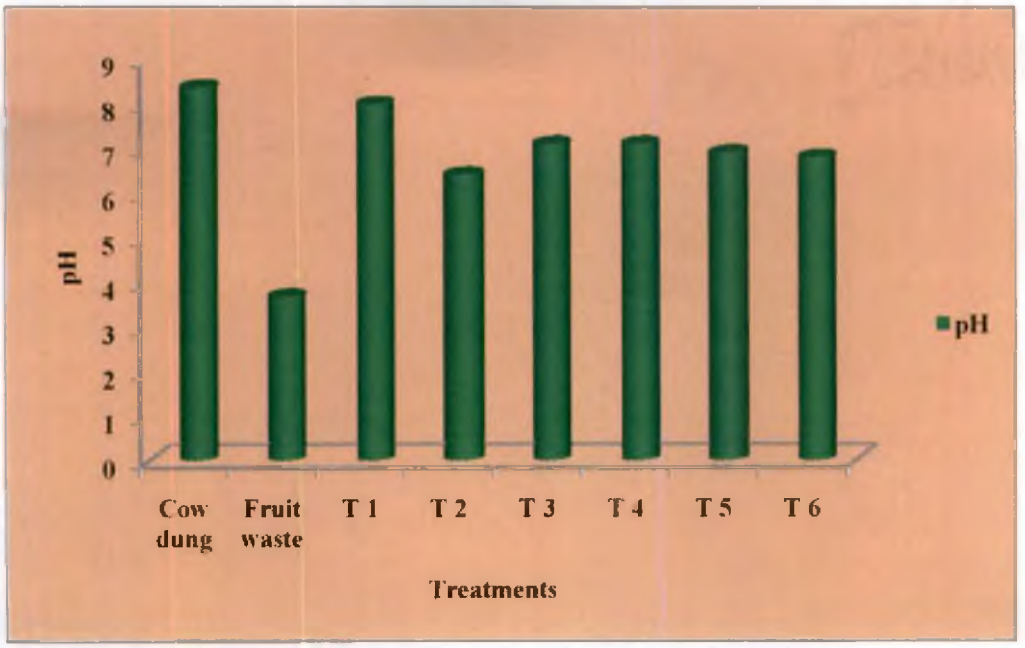
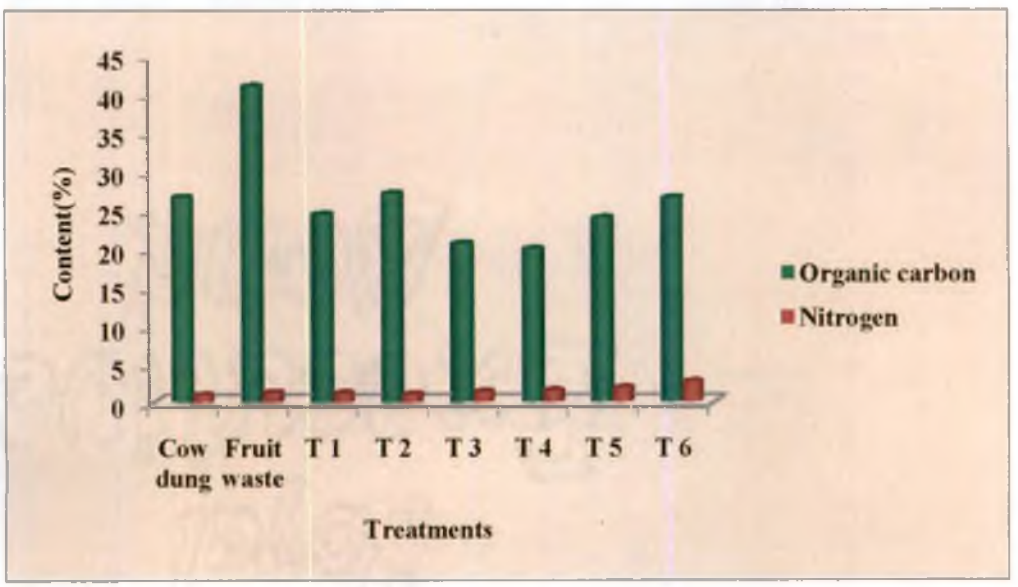


Fig. 10 Effect of different treatments on Organic carbon and Nitrogen contents in slurry as compare to substrate



T_1 : Cow dung alone

T_2 : Fruit waste alone

T_3 : Cow dung + Fruit waste (1:0.

T_4 : Cow dung + Fruit waste (1:1)

T_5 : Cow dung + Fruit waste (1:1.5)

T_6 : Cow dung + Fruit waste (1:2)

5.1.7.4 Macronutrients in the slurry

During anaerobic digestion organic forms of nutrients are converted to available forms. These elements are retained in the slurry and become available for plant uptake, making the slurry a valuable bio-fertilizer. The nutrient status (N, P, and K) of slurry (section 4.1.8 and Fig. 11) was found to be enhanced in all treatments compared to substrate. The highest N and K content of slurry T_6 (cow dung + fruit waste 1:2) may be due to the presence of higher contents of N and K in the substrate, pineapple waste. The lowest content was obtained in T_2 (fruit waste alone) which may be due to lack of microbial inoculum for the transformation of nutrients.

The content of P was on par with the treatments T_6, T_5 & T_4 and the lowest content was recorded in T_2. It was clear that anaerobic digestion did not cause much more change in P content compared to the substrate. This is in agreement with the findings of Schenkel (2009).

The Ca status of slurry revealed that the highest Ca content (section 4.1.8. and Fig. 12) was for T_1 (cow dung alone). It may be due to the high proportions of Ca in animal diets. The Ca content of T_4, T_5 & T_6 was on par indicating stabilization of nutrients. The highest Mg content was obtained for T_6 (0.56 %).The S content was more in the treatment T_4. The favourable condition in methanogenesis may help in the process of S transformation.

5.1.7.5 Micronutrients in slurry

The micronutrient content (section 4.1.9. and Fig. 13) like Fe, Mn, Zn and Cu were found to be reduced during anaerobic digestion. It may be due to the lack of

bacteria which transforms the micronutrients or may be due to microbial immobilization to balance the optimum ratio.

The highest Fe content (19.27 mg/L) was found in T_1 (cow dung alone) and the lowest in T_3. The highest Mn content was found in T_6 and the lowest in T_3. The highest Zn content (17.68 mg/L) was recorded in $T_6$and the lowest in T_2 which is on par with T_3. There was no significant difference between the treatments in the Cu content, whereas the highest was recorded in T_3 (0.22 mg/L) and the lowest in T_6 (0.07 mg/L).

5.1.7.6 Heavy metal content in slurry

The heavy metal content (section 4.1.10) of the slurry generated by different treatments was in the traceable amounts as that of the substrates used for the study. This may be probably due to the inability of putrefactive bacteria to degrade these elements during hydrolysis, acetogeneis and methanogenesis. Also, the contents of heavy metals did not exceed the limit prescribed by Fertilizer Control Order (1985) for organic manures.

5.1.7.7 Soluble nutrients

During anaerobic digestion organic forms of nitrogen are converted into ammoniacal form and P and K to water soluble fractions (section 4.1.10 and Fig. 14). It is well known that pH played an important role in stabilizing ammoniacal nitrogen in the slurry. So the higher ammoniacal nitrogen content was observed in T_4. This may be the result of active methanogenesis under optimum pH and C: N ratio. It is in accordance with the findings of Fry and Merrill (1973).

Fig. 11 Effect of different treatments on primary nutrient contents in slurry

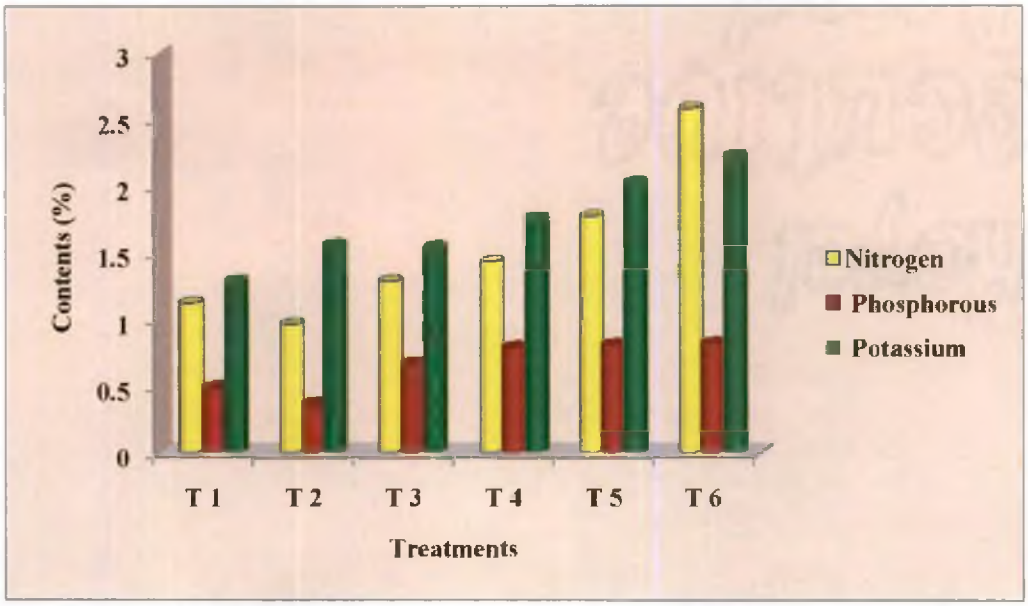
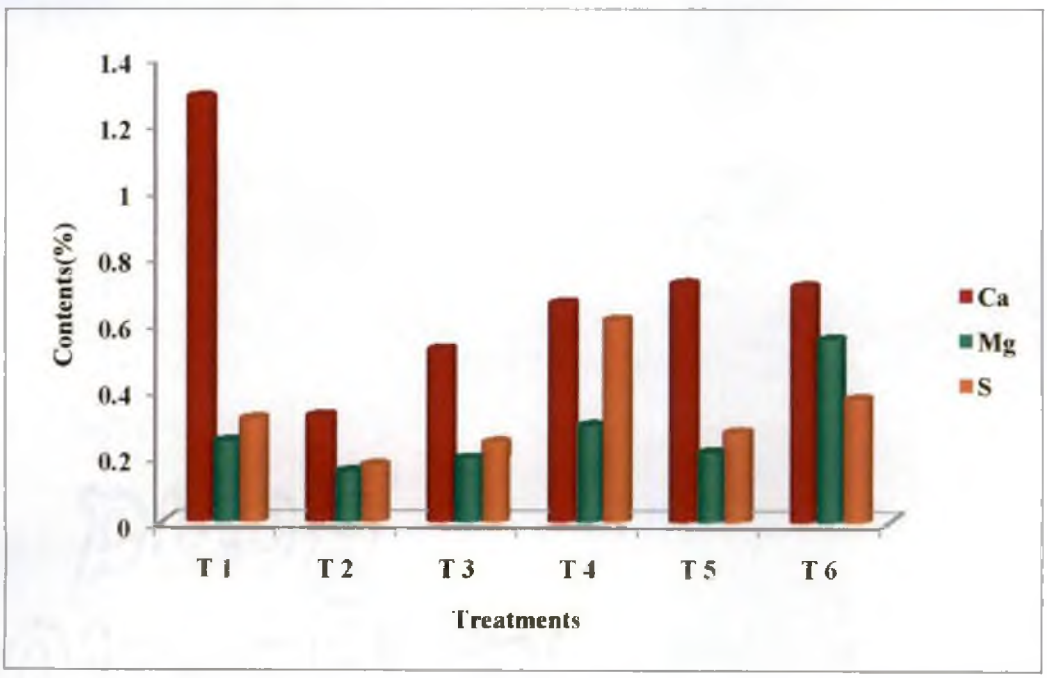


Fig. 12 Effect of different treatments on secondary nutrient contents in slurry



T_1 : Cow dung alone

T_2 : Fruit waste alone

T_3 : Cow dung + Fruit waste (1:0.

T_4 : Cow dung + Fruit waste (1:1)

T_5 : Cow dung + Fruit waste (1:1.5)

T_6 : Cow dung + Fruit waste (1:2)

Fig. 13 Effect of different treatments on micronutrient contents in slurry

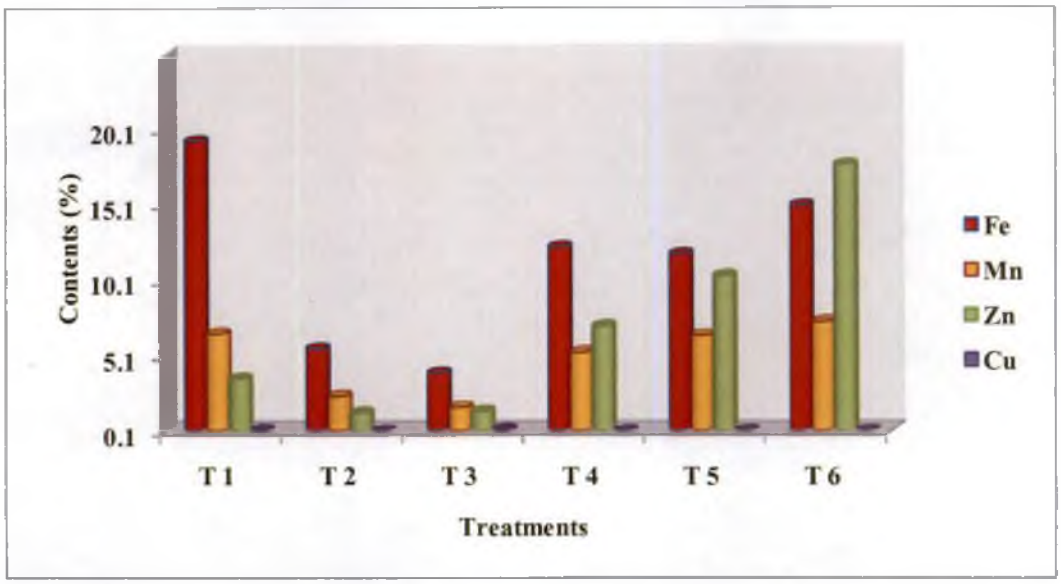
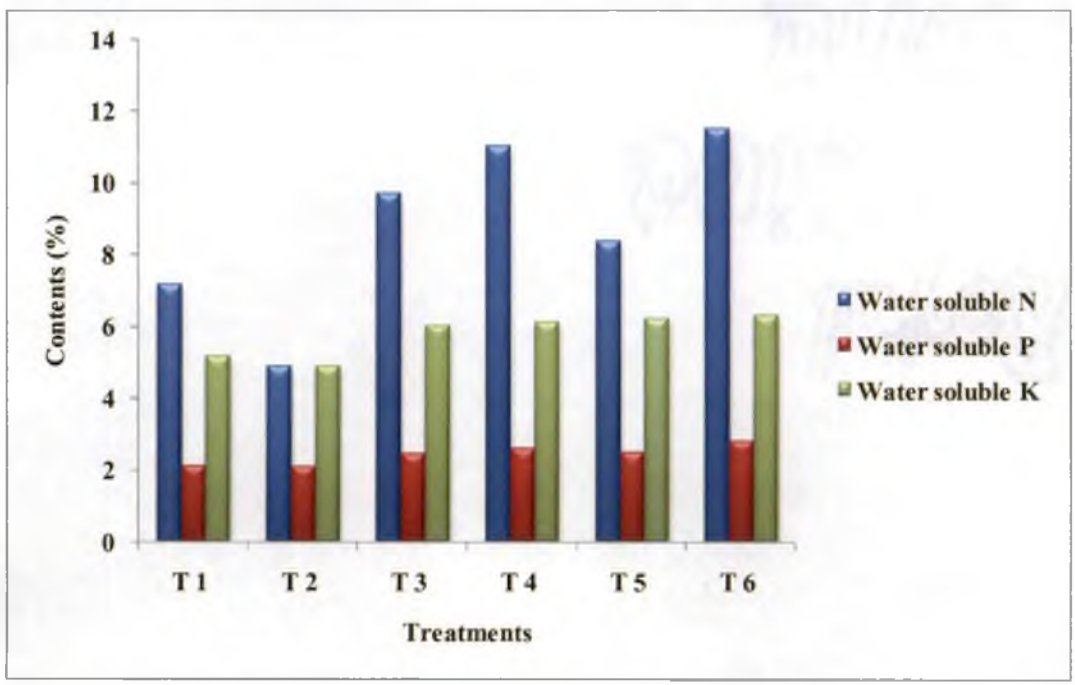


Fig. 14 Effect of different treatments on water soluble nutrient contents in slurry



T_1 : Cow dung alone

T_2 : Fruit waste alone

T_3 : Cow dung + Fruit waste (1:0.

T_4 : Cow dung + Fruit waste (1:1)

T_5 : Cow dung + Fruit waste (1:1.5)

T_6 : Cow dung + Fruit waste (1:2)

5.2 EFFECT OF BIOGAS SLURRY ON THE GERMINATION OF MANGO STONES

Seeds made up of an embryo surrounded by variable amount of endosperm which is the major source of food. The mature seed is a compact independent biological entity with the capacity to develop into a new plant under favourable conditions. Freshly harvested mango stones do not germinate immediately after extraction and show a delay in germination which is called dormancy. Breaking the dormancy depends upon increased availability of energy to embryo. Germination, the awakening of the dormant embryo is an irreversible process. For germination, the seed must be viable, non dormant and to be placed in a suitable environment. By water absorption, the protoplasm resumes the vigorous physiological activities. The swelling of embryo as a result of water imbibition enables it to burst through the seed coats.

5.2.1 Effect of treatments on germination and vigour index of mango stones

The data presented in section 4.2.1 and Fig. 15 indicated that germination % in the range of 52.00 % to 74.66 % for variety Moovandan and 50.66 % to 70.68 % for variety Bangalora. Effect of treatments on germination was found to be significant and the soaking treatments (plate 6 and 7) registering high value in both the varieties. This may be due to better mobilization of nutrients, hydrolyzation of reserved carbohydrates and better enzyme activity. This results in rapid degradation of proteins to amino acids and finally initiation of embryo. The coating treatments also followed the presoaking treatments but the effects are comparatively less. This may be due to reduced imbibition of water by seeds compared to soaking treatments. The most important parameter in the germination is the breaking of dormancy in recalcitrant seeds by the imbibition of water by the endosperm. Presoaking with the slurry

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regulates the transport of water to seed which acts as a water reservoir. In this way, slurry soaking might have improved germinating ability of seeds.

Apart from N and K status as in KNO_3 both the cow dung and fruit waste slurry, contain the enzymes and hormones which trigger the germination process. The treatment ash coating was found to be inferior to the treatment, control, in the case of both the varieties. The lower germination % in ash coating may be due to hardening of seed coat. Significant enhancement of germination was noticed for different pre-soaking treatments with organics by Padma and Reddy, (1998), Rao, (2002) and Shalini *et al.*, (1999) in mango.

Seedling vigour was also significantly influenced by the treatments. Since the vigour index is the product of seedling height and germination %, the effect of treatments especially the soaking and coating process, were more pronounced on the same. As the seedling height of Bangalora variety is comparatively higher than that of Moovandan (section 4.2.1 and Fig. 16) the vigour index registered higher value for Bangalora compared to Moovandan. The stones presoaked with fruit waste slurry recorded higher vigour index (1241.04) in variety Moovandan, but in variety Bangalora, the stones presoaked with fruit waste slurry (1259.06) showed a marginal improvement but remained on par with presoaking with gobergas slurry. Coating of mangostones with either biogas or gobergas slurry was found to be on par in both the varieties. This could be due to the presence of beneficial microbial biomass and nutrient status in slurry along with various growth promoting substances like hormones and enzymes. Zhicheng (1991) reported that seeds soaked with biodigested slurry improved germination rate and vigour index of sorghum.

Plate 6. Germination of mango variety Moovandan

Plate 7. Germination of mango variety Bangalora

Fig. 15 Effect of different treatments on germination of mango varieties Moovandan and Bangalora

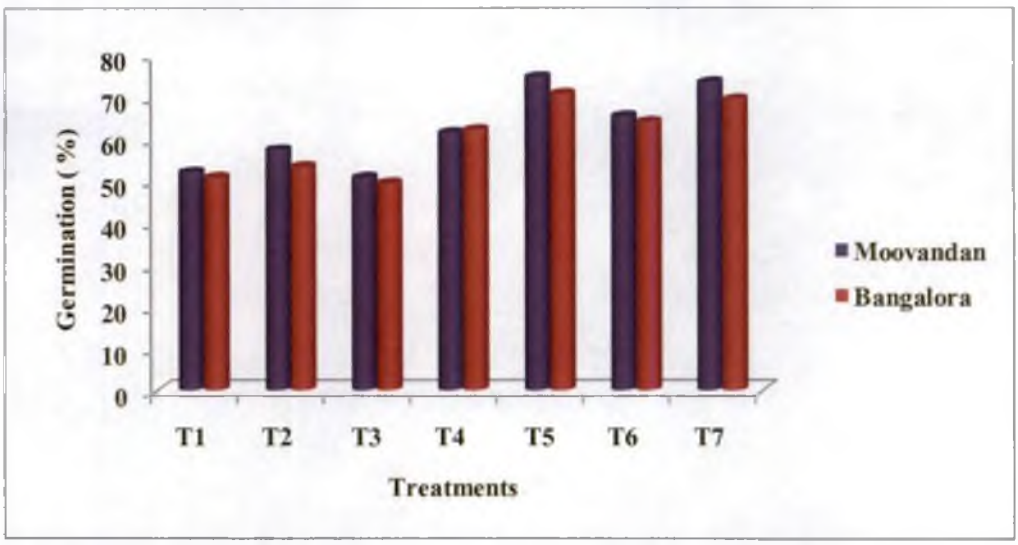
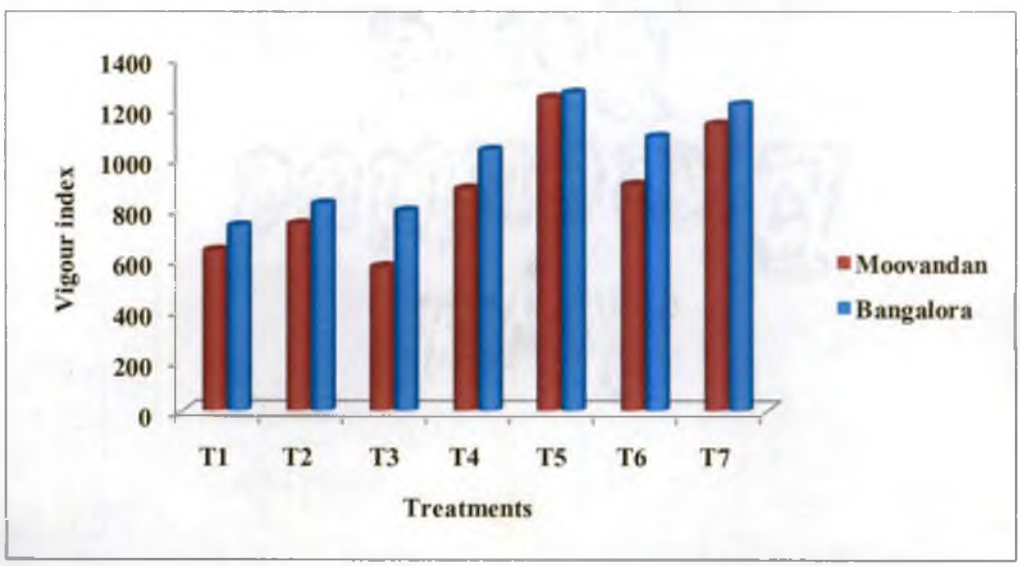


Fig. 16 Effect of different treatments on vigour index of mango varieties Moovandan andBangalora



T_1-Control T_2- Pre-soaking with KNO_3 (1%) for 10 minutes T_3 –Ash coating

T_4- Coating with biogas slurry having maximum manurial value from experiment 1

T_5- Pre -soaking with biogas slurry having maximum manurial value from experiment 1 for 12 hours

T_6- Coating with gobergas slurry from treatment 1 of experiment 1

T_7 - Pre -soaking with gobergas slurry from treatment 1 of experiment 1 for 12 hours

5.2.2 Effect of treatments on seedling height, girth and leaf number of mango seedlings

The effect of treatments on seedling height (plate 8) was evident in both the varieties (section 4.2.2 and Fig. 17 and 18). The highest seedling height (34.42 cm) at 90 days after planting was recorded in the presoaking treatment with biogas slurry (T_5), in variety Moovandan. But in variety Bangalora the seedling height was recorded as the highest in T_5 which was on par with coating treatments and the lowest for ash coating (22.97 cm). The lowest seedling height in variety Moovandan was recorded for the treatment, control. Increased plant height in seed soaking with slurry may be due to the presence of ammoniacal nitrogen and other nutrients (Zodhy and Din, 1983).

Seedlings of mango are mainly used for grafting purpose as root stock for which sufficient girth is an important prerequisite. Assessment of different soaking treatments on seedling girth of variety Moovandan revealed that the treatments were significantly different during the initial two months but at 90 days after planting (section 4.2.2 and Fig. 19) the highest girth was recorded in stones soaked with cow dung slurry. In variety Bangalora the treatments are significantly different at 90 days with highest value for presoaking with the biogas slurry (section 4.2.3.and Fig. 20).

The effect of treatments on number of leaves of seedling, variety Moovandan, were significant only at 60 days after planting and found to be non significant thereafter, the highest number of leaves being recorded in T_4 at 60 days after planting (section 4.2.4). Among the treatments, the stones treated with biogas slurry were found to be the best, recording the maximum number of leaves. The soaking treatments influenced the number of leaves of seedlings of mango variety Bangalora at 90 days after planting (section 4.2.4). The treatment coating with cow dung slurry

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recorded the highest value (16.20) which was on par with soaking treatments (section 4.2.7 and table 26). The supremacy of soaking might be due to better root proliferation which is evident from the root weight of corresponding treatments.

Fig. 17 Effect of different treatments on seedling height of mango variety Moovandan

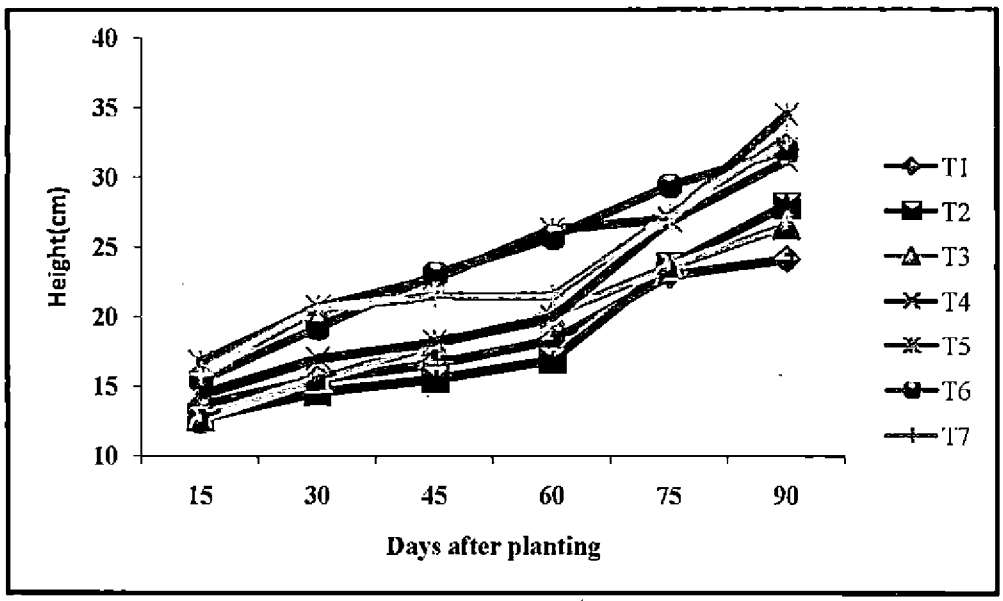
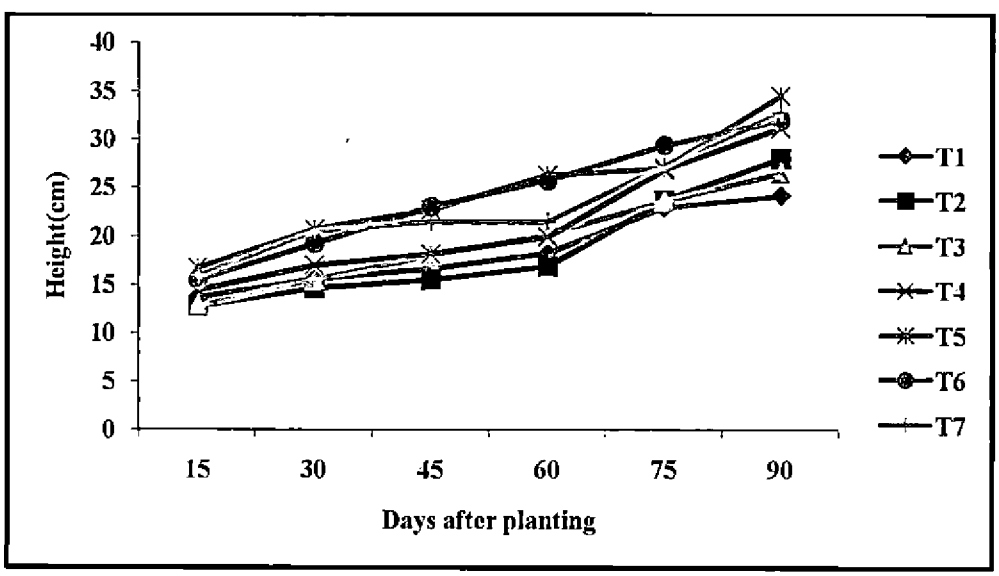


Fig. 18 Effect of different treatments on seedling height of mango variety Bangalora



T_1-Control T_2- Pre-soaking with KNO_3 (1%) for 10 minutes T_3 –Ash coating

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T_7 - Pre -soaking withgobergas slurry from treatment 1 of experiment 1 for 12 hours

Fig. 17 Effect of different treatments on seedling height of mango variety Moovandan

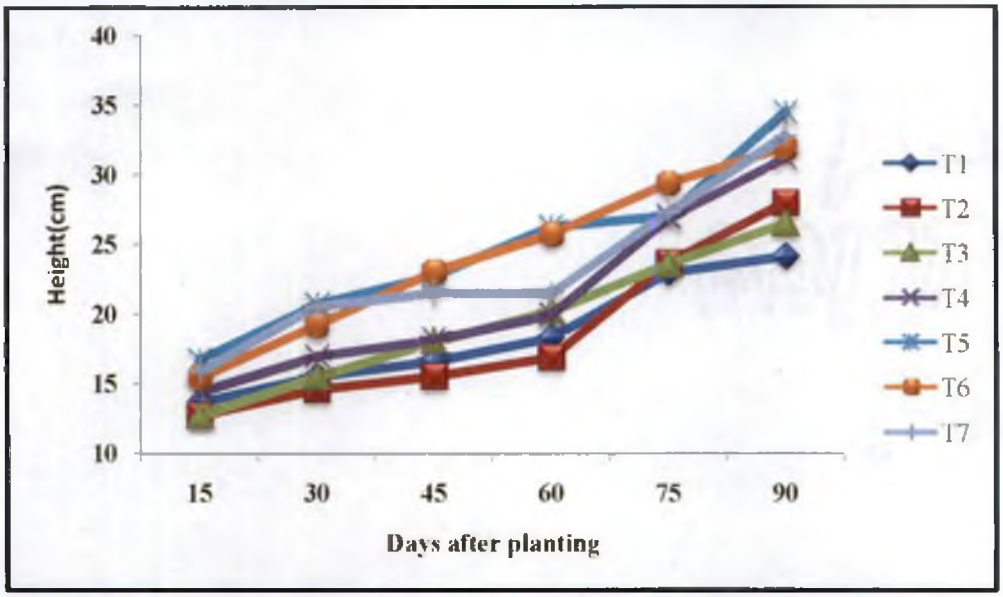
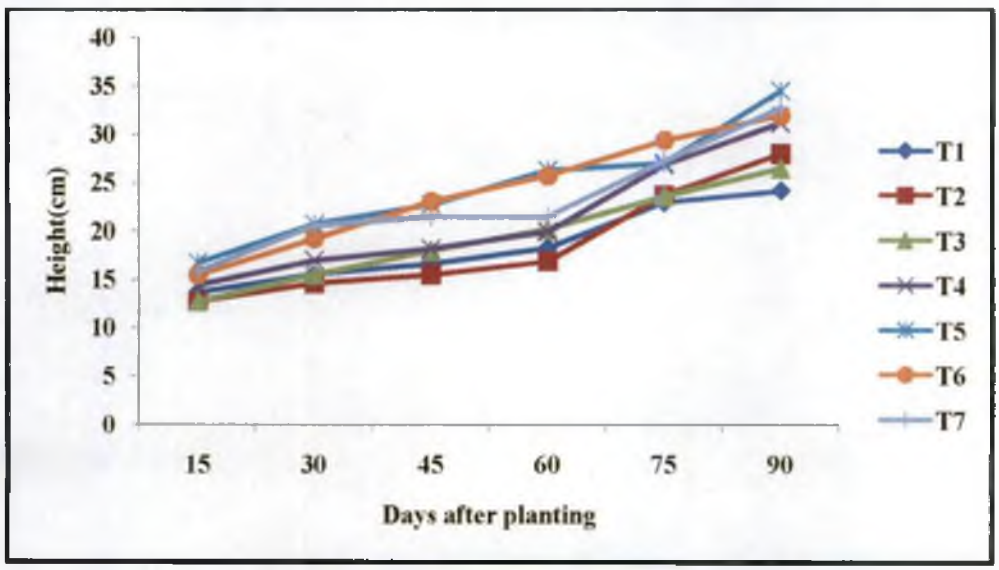


Fig. 18 Effect of different treatments on seedling height of mango variety Bangalora



T_1-Control T_2- Pre-soaking with KNO_3 (1%) for 10 minutes T_3 –Ash coating

T_4- Coating with biogas slurry having maximum manurial value from experiment 1

T_5- Pre -soaking with biogas slurry having maximum manurial value from experiment 1 for 12 hours

T_6- Coating with gobergas slurry from treatment 1 of experiment 1

T_7 - Pre -soaking withgobergas slurry from treatment 1 of experiment 1 for 12 hours

Fig. 19 Effect of different treatments on girth of mango varietyMoovandan

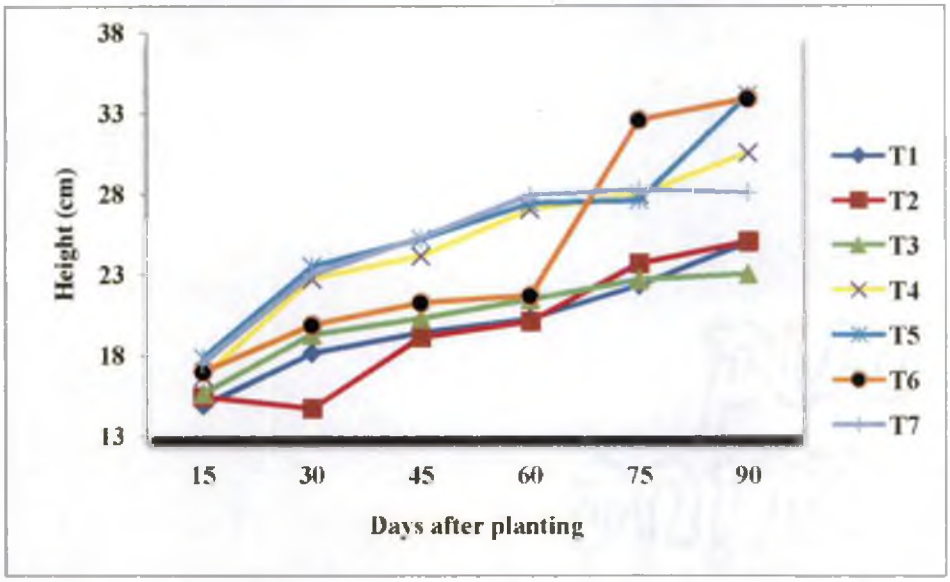
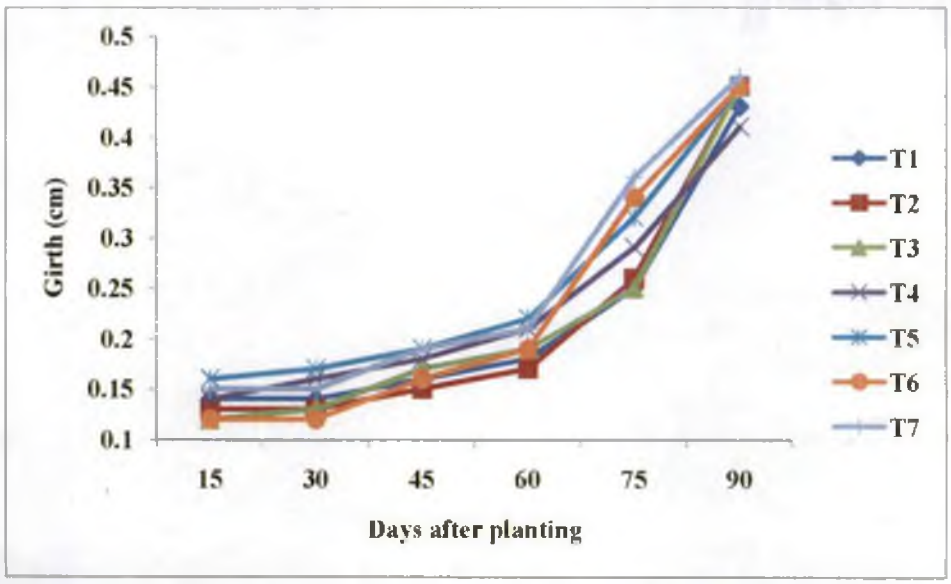


Fig. 20 Effect of different treatments on girth of mango varietyBangalora



T_1-Control T_2- Pre-soaking with KNO_3 (1%) for 10 minutes T_3 –Ash coating

T_4- Coating with biogas slurry having maximum manurial value from experiment 1

T_5- Pre -soaking with biogas slurry having maximum manurial value from experiment 1 for 12 hours

T_6- Coating with gobergas slurry from treatment 1 of experiment 1

T_7 - Pre -soaking with gobergas slurry from treatment 1 of experiment 1 for 12 hours

Plate 8. Mango seedlings at ninety days after planting (Experiment II) (contd...)

Plate 8. Mango seedlings at ninety days after planting (Experiment II)

5.2.3 Nutrient composition and biochemical constituents in mango stone

Macro nutrient status of both the varieties is almost similar. The micronutrient (Fe, Mn, Zn, and Cu) contents of Bangalora were 82.00, 100.00, 240.00, 180.00 mg kg^{-1} respectively whereas in Moovandan, the content of nutrients were 130.00, 108.70, 160.00, 190.00 mg kg^{-1}, respectively. The highest values for the biochemical constituent's (non reducing sugar, total sugar, starch and protein) were recorded for Moovandan (Section 4.2.5 and table 29).

Effect of treatments on biochemical constituents immediately after germination revealed that reducing and non reducing sugars increased after germination in all treatments and both the varieties recording the highest value in presoaking treatment (8.9 and 17.65) and starch content was found to be decreased. Total carbohydrate content also increased indicating the hydrolysis of starch to simple sugars during germination.

The process of germination may be subdivided in the following series of events.

1. Imbibition - the physical water absorption
2. Hydration and activation
3. Cell division and cell extension
4. Protrusion – the physical emergence of embryo from seed.
5. The establishment of primary structures of plant.

The above mentioned events are clearly indicated by the soaking treatments. Since all these registered better mobilization of reserved food materials present in the seed. For instance, the essential reserve materials like carbohydrate, protein and fats found in the storage tissues are mobilized at germination. Such materials are the only

source of organic substances for seedlings. Carbohydrate mobilization involves degradation to mono or oligosaccharides by hydrolysis. Protein mobilization takes place by degradation to amino acids by proteases.

5.2.4 Effect of treatments on partitioning of dry matter

The highest values for root and shoot weights (4.27 and 9.97) were recorded in presoaking with biogas slurry in variety Moovandan (section 4.3) and in variety Bangalora the highest shoot weight was recorded in presoaking with biogas slurry whereas root weight was for presoaking with gobergas slurry (section 4.3) and the lowest dry weight was registered with control. The slurry treatments increased the rapid germination, better vigour index and this may influence the rapid growth as well as uptake of nutrients by the seedlings.

5.2.5 Effect of treatments on Nutrient uptake

5.2.5.1 Shoot uptake

The highest N, P, K uptake for the variety Moovandan was recorded for the soaking treatment and the lowest value for control (section 4.4.1 and Fig. 21) But in variety Bangalora the highest N & P uptake were recorded for coating with biogas slurry where as for K uptake the highest value recorded for presoaking with biogas slurry (section 4.4 and Fig. 22). The content of Ca, Mg and S content were also higher in presoaking treatments in both the varieties (section 4.4.1)

The dry weight of shoot and root at 90 days after planting indicated that the highest value was for presoaking with biogas slurry followed by presoaking with gobergas slurry and slurry coating treatments(section 4.3). It revealed that the soaking

treatments enhanced the plant metabolism and cell division which in turn enhanced the root proliferation; more shoot and root dry matter with corresponding higher uptake of these nutrients.

Micronutrient (Fe, Mn, Zn) uptake of variety (section 4.4.2 and table 32) Moovandan was more in presoaking with gobergas slurry and the lowest in control whereas Mn uptake was more in presoaking with biogas slurry. But in Bangalora (section 4.4.2 and table 33) the highest Fe uptake was noticed in coating with cow dung slurry and the highest Mn and Zn was noticed in presoaking with gobergas slurry and the highest Cu uptake was for KNO_3 treatment. This may be due to increased absorption of micronutrients due to better plant growth.

5.2.5.2 Root uptake

Root uptake of N, P, K, Ca, Mg and S (section 4.4.3, Fig. 23) was more in presoaking treatments and the lowest was in control in case of variety Moovandan. But in the case of variety Bangalora (section 4.4.3 and Fig. 24) the highest N, K, Ca, Mg uptake was for presoaking with gobergas slurry and the lowest for control whereas P and K uptake was more in presoaking with biogas slurry and S uptake was more for ash coating. Roots uptake of Fe and Cu of variety Moovandan was more in presoaking with gobergas slurry and the highest Mn uptake was in presoaking with fruit waste slurry and Zn in ash coating and the lowest in control (section 4.4.4 and table 36).

Micronutrient uptake by roots of variety Bangalora (section 4.4.4 and table 37) showed that highest Fe and Zn uptake was for presoaking with gobergas slurry treatment and the highest Mn uptake was for presoaking with fruit waste slurry and the highest Cu uptake was for coating with fruit waste slurry.

Fig. 21 Effect of different treatments on N,P,K uptake by shoot in seedlings of mangovarietyMoovandan at ninety days after planting

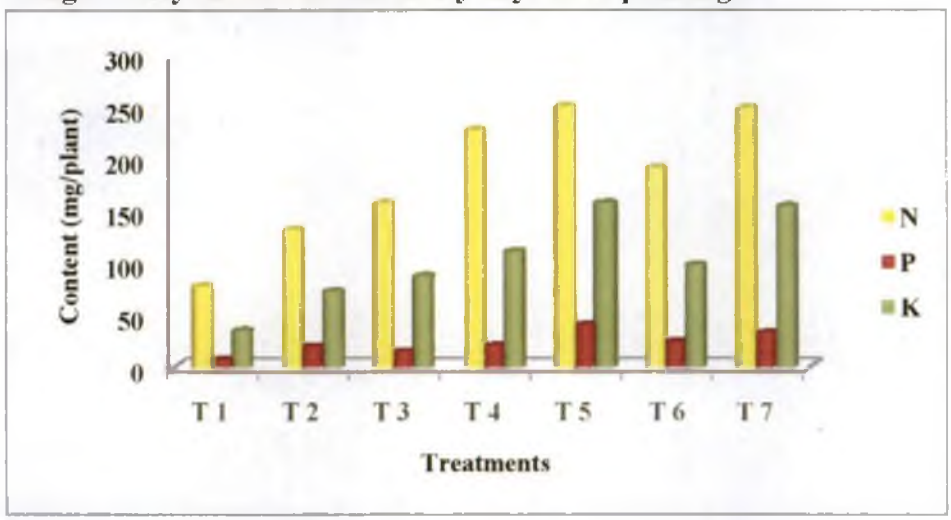
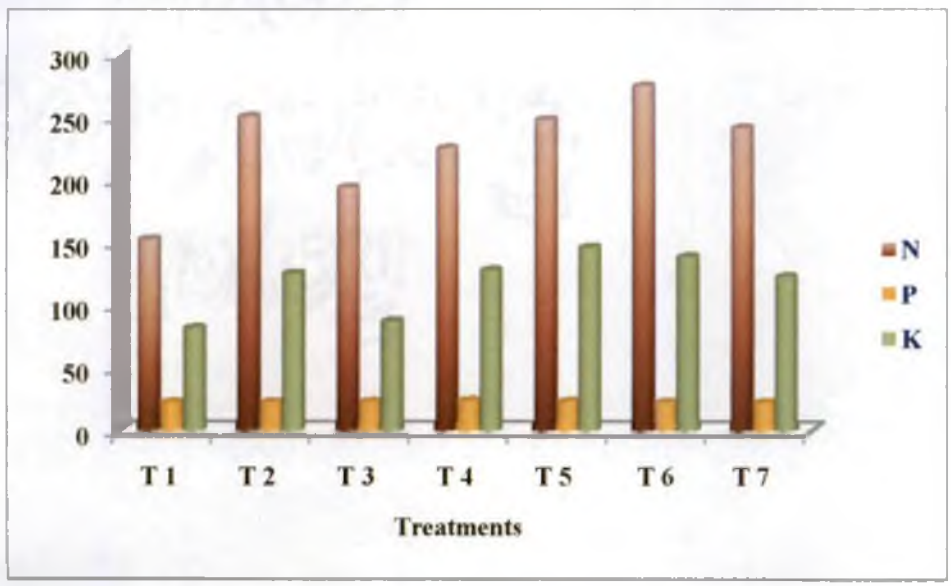


Fig. 22 Effect of different treatments on N, P, K uptake by shoot in seedlings ofmango variety Bangalora at ninety days after planting



T_1-Control T_2- Pre-soaking with KNO_3 (1%) for 10 minutes T_3 –Ash coating

T_4- Coating with biogas slurry having maximum manurial value from experiment 1

T_5- Pre -soaking with biogas slurry having maximum manurial value from experiment 1 for 12 hours

T_6- Coating with gobergas slurry from treatment 1 of experiment 1

T_7 - Pre -soaking with gobergas slurry from treatment 1 of experiment 1 for 12 hours

Fig. 23 Effect of different treatments on N, P, K uptake by root in seedlings of mango variety Moovandan at ninety days after planting

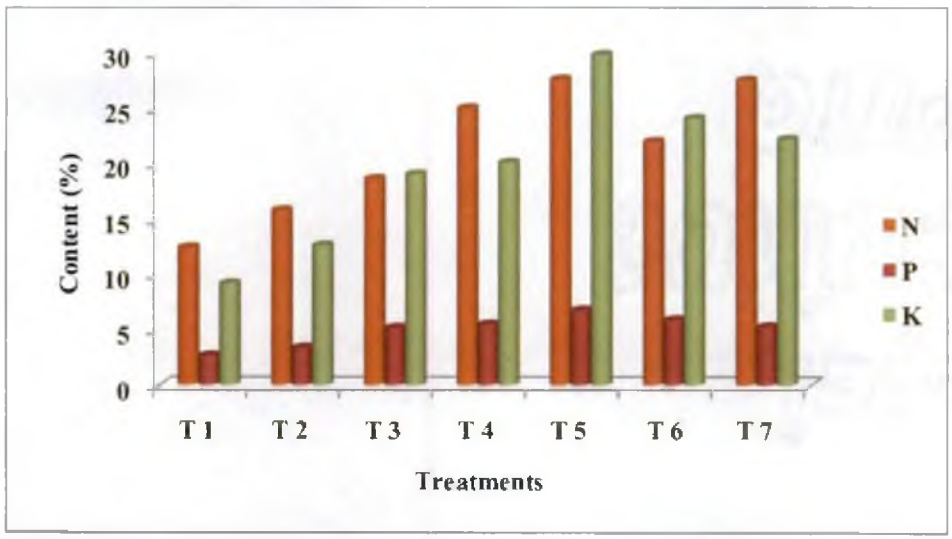
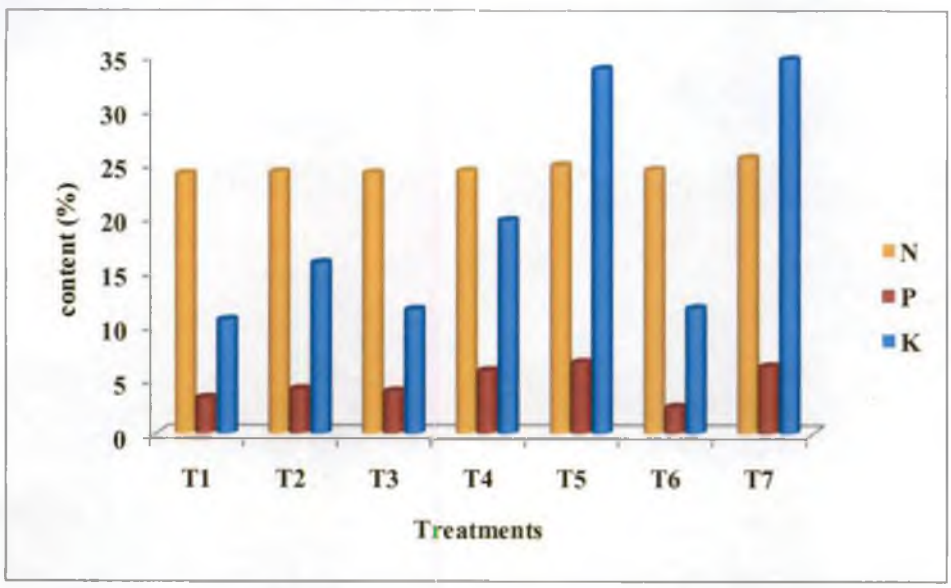


Fig. 24 Effect of different treatments on N, P, K uptake by root in seedlings of mango variety Bangalora at ninety days after planting



T_1-Control T_2- Pre-soaking with KNO_3 (1%) for 10 minutes T_3 –Ash coating

T_4- Coating with biogas slurry having maximum manurial value from experiment 1

T_5- Pre -soaking with biogas slurry having maximum manurial value from experiment 1 for 12 hours

T_6- Coating with gobergas slurry from treatment 1 of experiment 1

T_7 - Pre -soaking with gobergas slurry from treatment 1 of experiment 1 for 12 hours

5.2.6 Effect of treatments on nutrient contents in potting mixture at ninety days after planting

The nutrient content was reduced compared to initial nutrient status in all the treatments (section 4.5.1, 4.5.2). The highest N content in the potting mixture of variety Bangalora was recorded for soaking in KNO_3 and P, K content for ash coating whereas the lowest N content for pre soaking with gobergas slurry and lowest P and K for presoaking with fruit waste slurry. In the case of variety Moovandan the highest N content was recorded for ash coating and lowest for presoaking with gobergas slurry whereas the highest P was recorded in the treatment pre soaking with fruit waste slurry and the lowest P was recorded for coating with fruit waste slurry whereas the highest K content for pre soaking with gobergas slurry and lowest for presoaking with fruit waste slurry. The higher uptake of nutrients by the seedlings might have influenced the higher removal of the corresponding nutrients from the media.

5.3 PRACTICAL / SCIENTIFIC UTILITY OF THE STUDY

Co-digestion of fruit waste with cow dung is practically feasible for the generation of biogas with necessary methane content of combustible nature. By any chance the ratio between fruit waste and cow dung should not be more than 1:1.5. If we use fruit waste alone for biogas production, the methanogenic bacteria will become inactive due to high acidity.

However more quantity of slurry was produced from co-digestion of cow dung and fruit waste in 1: 2 ratio because of the more water content in fruit waste. Since the soaking with slurry treatments is found to be better, any of the combination

(either gobergas slurry or fruit waste biogas slurry) may be resorted for better root stock production in mango.

We can link all these findings for the better economic gains by the agro entrepreneurs. It is reported that the fruit and vegetable processing industries generate waste up to the extent of 25-40 % of the raw material used; the biological conversion of waste in to biogas is one of the viable method and along with this clean energy good and sizeable root stocks can be produced. Based on this practical implication of the study, the economics is calculated and the table is given in appendix II.

The processing industries may install a biogas unit of 1 m^3 capacity with five year life span with an initial cost of Rs. 22,000. For initial charging 50 kg cow dung with an approximate cost of Rs. 600 is required. The variable cost involves the labour cost for collection of the fruit waste and charging of the biogas plant. Interest on working capital 7.5 % @ annum is taken into account. The returns were accounted in terms of biogas generation equivalent to LPG and cost of mango seedlings. Since the stones are available in the processing unit, no additional cost is involved. Finally the benefit cost ratio is worked out and found that the biogas plant is viable with benefit cost ratio of 1.28. It is crystal clear that the agro entrepreneurs can effectively utilize the fruit waste from processing factories for energy and root stock production of mango seedlings.

5.4 FUTURE LINE OF WORK

- To study the presence of growth hormones / enzymes in the biogas slurry.
- Study on thermal and electrical efficiency of biogas generated from individual /co-digestion of substrates.

Summary

6. SUMMARY

An investigation on "Production and Effective Utilization of Biogas from fruit waste" was conducted during 2014-2015 at College of Horticulture, Vellanikkara. The objectives of the study were to evaluate the optimum ratio of cow dung and fruit waste for maximum biogas production and to identify the effect of biogas slurry on germination of mango stones. The salient findings are as follows.

6.1 Experiment I

- Among the different treatments under study, T_4 (Cow dung + fruit waste,1:1 ratio) resulted in the generation of biogas with 65.30 % methane and 32 % carbon dioxide which was closely followed by T_5 (Cow dung + fruit waste,1:1 ratio). Fruit waste alone was loaded in the 0.5 m^3 biogas plant which was found to be comparatively inferior in methane and carbon dioxide generation accounting to 46.46 % and 50.86 % respectively.

- Temperature inside the digester was recorded daily and it was correlated positively with the corresponding atmospheric temperature. It recorded a peak value of 33.98 ^{o} C in the treatment T_4 (Cow dung + fruitwaste, 1:1 ratio) during the digestion period (15 to 20 days). The temperature inside the digester was always found to be higher compared to the atmospheric temperature.

- Throughout the study period the volume of gas was generated in the order $T_4 > T_3 > T_5 > T_1 > T_6 > T_2$. Conducive environment for maximum methane production was judged as the optimum C:N ratio (30:1), pH (6.8-7.2) and moisture content (> 60 %).

- The HRT which indicated the time taken for complete digestion could be reduced from 24 days to 15 days by co digestion of fruit waste with cow dung in 1:1 ratio as compared to the digestion with either of the substrate.

- The quantity of slurry produced was measured on daily basis. Combination of cow dung and fruit waste (1:2 ratio) produced more quantity of slurry (92 L) compared to other treatments and the lowest in fruit waste / cow dung alone (44 L).

- The values of pH and EC varied from 6.4 to 8.0 and 0.52 to 0.79 dS/m respectively. Among the treatments the solids content ranged between 2.10 to 6.55 % and organic carbon content from 19.83 to 26.09 %. The highest C:N ratio was in fruit waste alone (27.19) and the lowest in the fruit waste and cow dung 1:1 ratio (9.48).

- The best combination with maximum manurial content was in fruit waste and cow dung 1:1 ratio (2.58 % N, 0.81 % P and 2.23 % K) which was selected for the second experiment.

6.2 Experiment II

- The germination % and vigour index was found to be maximum for presoaking with fruit waste slurry which was closely followed by presoaking with gobergas slurry.

- Both elemental and biochemical composition of mango stones are similar irrespective of varieties.

- The reducing sugar content of mango stones increased from 2.03 to 9.9 in variety Moovandan and 2.67 to 8.9 in variety Bangalora whereas the starch and carbohydrate content reduced after germination in both the varieties.

- The biometric observations on height, number of leaves and girth were registered the highest values in presoaking with fruit waste slurry and the least in control. Dry matter content of shoot and root showed the highest for the treatment T_5 followed by T_7.

- Total N uptake for variety Moovandan was in the order $T_5>T_7>T_4>T_6>T_3>T_2>T_1$ and P uptake was in the order $T_5>T_7>T_6>T_4>T_2>T_3>T_1$ and K uptake was in the order $T_5> T_7> T_4> T_6>T_3>T_2>T_1$. Almost similar results were obtained in the case of Bangalora.

- Total Ca, Mg, S and micronutrients uptake was in the order $T_5>T_7>T_4>T_6>T_3>T_2>T_1$ for both the varieties.

- The nutrient contents of potting mixture were reduced after 90 days of planting due to crop removal. The available N content recorded 78.72 mg kg^{-1} in T_3 for Moovandan and 109.67 mg kg^{-1} in T_5 for variety Bangalora. The available P in variety Moovandan 6.87 mg kg^{-1} in T_3 and 9.91 mg kg^{-1} in T_5 for Bangalora. Available K also followed the same trend in both the varieties.

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Appendices

Appendix I

Atmospheric temperature during anaerobic digestion period

Date	Temperature (^{0}C)	Date	Temperature (^{0}C)
01/02/2015	28.20	26/02/2015	29.4
02/02/2015	27.80	27/02/2015	29.55
03/02/2015	28.15	28/02/2015	30.05
04/02/2015	28.65	01/03/2015	28.90
05/02/2015	27.90	02/03/2015	31.00
06/02/2015	28.60	03/03/2015	30.60
07/02/2015	28.35	04/03/2015	29.75
08/02/2015	28.35	05/03/2015	29.65
09/02/2015	28.30	06//03/2015	29.85
10/02/2015	28.10	07/03/2015	30.15
11/02/2015	28.55	08/03/2015	30.50
12/02/2015	29.40	09/03/2015	30.25
13/02/2015	29.20	10/03/2015	31.30
14/02/2015	29.65	11/03/2015	30.35
15/02/2015	29.60	12/03/2015	30.00
16/02/2015	29.45	13/03/2015	29.75
17/02/2015	29.45	14/03/2015	29.90
18/02/2015	28.40	15/03/2015	30.05
19/02/2015	29.35	16/03/2015	30.70
20/02/2015	28.95	17/03/2015	31.00
21/02/2015	27.80	18/03/2015	31.55
22/02/2015	28.95	19/03/2015	29.85
23/02/2015	27.90	20/03/2015	30.20
24/02/2015	28.65	21/03/2015	30.35
25/02/2015	29.05	22/03/2015	31.20

Appendix II

a) Details of cost and returns from biogas plant of 1 m^3 for five years

	Year 1	Year 2	Year 3	Year 4	Year 5
Fixed cost					
Capital cost	22000	19800	17820	16038	14407
Depreciation	2200	1980	1782	16308	1440
Depreciated cost	19800	17820	16038	14407	
Cost for cow dung	600	-	-	-	-
Total	20400	17820	16038	14407	14407
Variable cost					
Labour cost	2150	2150	2365	2580	2880
Interest on working capital (7.5%p.a.)	150	150	177	193	216
Total	2300	2300	2542	2773	3096
Returns					
Interms of LPG	2100	2800	2800	3200	3200
Production of mango seedling	1050	1400	1400	1400	1400
Total	3150	4200	4200		

b) Calculation of B: C ratio at 15 % discount factor

Sl no	Particulars	Year 1	Y ear 2	Year 3	Year 4	Year 5
1	Capital cost	22000				
2	Recurring cost	2300	2300	2542	2773	3096
3	Total cost	24150	2150	2365	2580	2580
4	Benefits	3150	4200	4200	4600	4600
5	Depreciated value of structures					1440
6	Total benefits	3150	4200	4200	4600	6040
7	Net benefits	-21000	2050	1835	2020	3460
8	Discounting factor	15%				
9	Benefits/Cost ratio	1.28				

PRODUCTION AND EFFECTIVE UTILIZATION OF BIOGAS FROM FRUIT WASTE

By

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(2013-11-146)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the

requirement for the degree of

Master of Science in Agriculture

(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)

Faculty of Agriculture

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2015

ABSTRACT

Fruits are highly perishable commodities and generate huge amount of waste.Besides loss of freshfruits,waste is also generated during the processing stage. Fruits and vegetable processing industries generate waste up to the extent of 25-40 per cent of raw materials used. Disposal and proper management of these fruit waste has become a serious problem to agro-entrepreneurs. Biological conversion of biomass to methane has received increased attention during recent years

So the proposed study entitled "Production and effective utilization of biogas from fruit waste" was conducted at College of Horticulture to envisages the standardization of biogas production from fruit waste and the effect of biogas slurry on the germination of mango stones. The broad objective was to enable the agro-entrepreneurs to effectively utilize the fruit waste from processing factories.

In order to determine the optimum ratio of cow dung and fruit waste for maximum biogas production, the floating drum biogas digesters of 0.5 m^3 capacity were used. The experiment was conducted in completely randomized design and consists of six treatments and three replications (T_1 : Cow dung alone, T_2 : Fruit waste alone, T_3 : Cow dung + Fruit waste (1:0.5), T_4 : Cow dung + Fruit waste (1:1), T_5 : Cow dung + Fruit waste (1:1.5), T_6 : Cow dung + Fruit waste (1:2). The results indicated that mixing cow dung and fruit waste in a proportion of 1:1.resulted in the generation of biogas with 65.30 % methane and 32 % carbon dioxide which was closely followed by T_5 (Cow dung: fruit waste,1:1 ratio) . Fruit waste alone was loaded to the biogas plants which were found to be comparatively inferior in methane generation. The treatment T_5 (Cow dung: fruit waste, 1:1 ratio) also produced the highest volume of gas (0.44 m^3/day) within 17 days Hydraulic