

**POSSIBILITIES OF UTILISING HOME GARDEN WASTE
FOR PRODUCTION OF BIOGAS AND ORGANIC MANURE**

By

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I. INTRODUCTION

Energy has always been the key to man's greatest goals and to his dreams of a better world. The most distinguishing feature of the present day societies in contrast to the traditional ones is the high demand for energy. Contrary to the ancient civilisations which depended on their human slaves for all their work, today's world is entirely dependent on various hoards of energy slaves-machines, whose appetite for energy exceeds manifold the demand for food by the ancient slaves.

The conversion along the path of civilization started after man had utilised the energy in fire for heat and the energy in his body through the club and bow, for food and survival. In the centuries since then, man's quest for material well-being has been tried largely to the harnessing of various forms of energy-in coal, in petroleum and in electricity. With the development of science and industries, the countries aspiring for modernisation depend on large amounts of energy as a basic need and man has developed increasingly complex and effective means of tapping energy for more difficult goals, for accelerating economic growth and to provide a good standard of living for the people.

However, the recent oil crisis resulting in steep price hike of petroleum products and the importing of 2/3 oil needed with no means of reducing the

gap had led the nation to rethink on renewable energy sources and modes of energy usages. Moreover the fast dwindling supply of traditional fuels also poses a challenge in finding and developing new and infinite sources of energy for the future.

The global energy crisis has hit the domestic fuel consumption considerably. The fact that fuel is important in everyday cooking for preparing palatable meals, for lighting the house and for various other purposes also necessitated the country's energy policy to incorporate research for exploration of new energy resources and for the development of better methods of utilisation of conventional forms of energy.

The conversion of organic wastes to fuel is a step towards a healthier environment with the added bonus of providing some energy. Cowdung/gobar is an important raw material for producing fuel gas as well as superior quality organic manure. According to Srinivasan (1978) the conversion of waste to fertiliser or protein will not make any significant dent in the overall picture, this might make a greater contribution by relieving the energy subsidies going into production of fertilizers and livestock feed.

The Indian Agricultural Research Institute (IARI, 1974) enlightens that the dual purpose utilisation of bovine dung is being propagated in the country since the thirties. The recent hike in the price of crude oil by the oil producing countries has necessitated the consideration of this technology

by all directly or indirectly concerned with it . Specially in India where cowdung and agricultural wastes are used extensively as direct sources of energy, the present energy crisis has focussed much attention on the utilisation of biogas produced from such wastes.

Singh (1978) estimates that though this technology is still in its infancy the 50,000 plants installed under the Khadi and Village Industries Commission (KVIC) Biogas Programme are already producing 99.82 million cubic metres of gas equivalent to 62 million litres of gas valued at Rs. 62.49 million and 11.20 lakh tonnes of high quality organic manure worth Rs. 50.86 million. So promising are the fuel possibilities that the proper recycling of waste can produce as much energy as the Nation's entire consumption of oil.

Sathianathan (1975) opines that utilization of vegetable waste produces about 7 c.ft biogas for each pound of dry weight fed into the plant. He further states that the gas production with cowdung can be maximised by substituting a portion of vegetable waste for an equal amount of dung thus obtaining more gas from the same amount of fertilizer.

Tamhane et al (1970) reveal that organic fertilizers contain more nutrients for soil than chemical fertilizers. They bring about improvement in soil structure, water holding capacity, microbial population and its activity, base exchange capacity and resistance to erosion.

Indravati (1970) and Laura and Idnani (1972) report that spent slurry from gobar gas plant gave better response to crop than farm yard manure. Singh (1975) and Biswas (1977) opine that the residual slurry composted with farm yard refuse, unused vegetable matter, fallen tree leaves and weeds makes an excellent manure and reduces the expenditure on chemical fertilisers.

Added to these facts, the rapid rise in the price of chemical fertilisers has doubled the importance of organic manures. Recycling waste therefore will not only provide essential nutrients at a lower price, but also improve the conditions of the soil thus enhancing the benefits from chemical fertilisers and improving the environment. Thus this is an innovation if properly exploited and extended would go a long way in meeting the domestic fuel and fertiliser needs of the population.

Considering the present shortages of commercial cooking gas and other fuels and shooting prices of fertilisers, home garden wastes can be considered as the most appropriate, economical and easily available resource material for production of fuel-gas and manures.

Therefore the objectives put forth for the present study on utilisation of Home Garden waste for Production of Biogas and Organic Manure are as follows:

1. To understand the effect of interaction of cowdung, digested cowdung slurry and home garden waste on methane gas production.
 2. To investigate the utility value of the recovery from home garden waste arising out of biological decomposition.
 3. To interpret the net return from the methane gas production as a substitute for cooking gas, and the fertiliser equivalents from the digested materials.
- and 4. To study the combination effect of organic waste in augmenting fertiliser for agriculture.

It is hoped that the findings of this pilot study would enlighten the scientists working in this field on possible use of garden waste for biogas production and follow up activities to be undertaken.

II. REVIEW OF LITERATURE

The literature pertaining to the study on the Possibilities of Utilising Home Garden Waste for Biogas Production and Organic Manure is reviewed and presented under the following heads:

- A. Energy crisis
- B. Waste recycling to meet the energy demand.
- C. Biogas plants
- D. Factors affecting gas production
- E. Organic waste as fertiliser.
- F. Influence of organic manure on the uptake of nutrients
- and G. Effect of organic manure on crop growth.

A. Energy Crisis:

Srinivasan (1978) is of the opinion that energy in diverse form is needed for accelerating economic growth and to provide a good standard of living for the people. Stout (1978) views that energy which is an essential ingredient for human existence is consumed in different forms. Fuels like coal, oil, natural gas, firewood, cowdung and vegetable wastes are primary sources of energy. The first three are of high heat value fuels, while the last three are primitive fuels of low heat value. Coal, oil, natural gas, town gas, electricity are referred to as commercial energy sources and firewood,

charcoal, cowdung and vegetable wastes as non-commercial energy sources (Venugopal, 1977; Santhianathan, 1977 and Gupta, 1977).

Sethna (1977) and Ghosh (1979) state that energy crisis is the foremost concern of today. Chandra (1978) is of the view that due to rapid industrial expansions and increasing standard of living, energy generating capacity has not been able to keep pace with the growing demand. According to Marion (1974) the energy crisis is a complex series of problems-scientific, technological, social, economic and political. Many factors conspire to produce a potential shortage of energy even though there can be plentiful supply from the varied resources particularly the renewable resources.

Kashkain (1975) remarks that "India is still heavily dependent on traditional sources of energy. Firewood contributes five times as much to her energy consumption as electricity does".

Kumar and Sampath (1976) and Adam and Tynor (1977) opine that India has large if not lavish supplies of the renewable energy sources, coal and hydro power. However as Singh (1974) and Patel (1975) state the oil crisis has brought to an end the era of cheap source of energy.

Sri khande (1976) observes that some of the factors that may have led to the development of crisis on the energy front in India is her dependence on non-commercial sources of energy in some section and insufficient attention being paid to develop all sources of commercial energy. Marion (1974) asserts that the increasing demand for energy is not only due to increasing world population but also due to the individual demand increasing for product and service.

Ramachandran (1978) and Ghosh (1979) are of the view that the role of various conventional and non conventional energy resources is rapidly expanding energy demand which is limited by major constraints such as capital intensiveness and scarcity of petroleum fuels.

Singhal (1977) and Gadgil (1978) are of the opinion that while a total energy concept is required and to be developed, the urgency for energy management is the cause of the fear that the planet may run out of fuel reserves. This is a serious thought and prompt steps need to be taken to provide the required energy for the future.

Singhal (1977) estimates that 24 per cent countries of the world containing 37 per cent of the world population have annual electrical energy consumption of about two lakh capita.

Sathianathan (1977) puts forth two estimates of future requirements of energy available for India, one made by the Fuel Policy Committee (FPC) (1976) and the other by Parikh (1976). FPC (1976) predicts an estimation of five fold increase in consumption level. Parikh (1976) predicts even higher consumption by the end of the century. He estimates an increase in consumption of 8.5 to 9 fold for coal, 6 to 9.5 fold for oil and 13.5 to 14 fold for electricity.

Scientists and technologists everywhere are engaged in experiments to mobilise solar energy, sea water energy, manure energy and so on, the oil blackmail has thus forced the world to find a substitute for oil urgently.

A part solution for India's energy crisis as recommended by Nahar (1976) Mande (1977) and Alison (1978) is biogas or 'gobar' gas.

B. Waste Recycling to Meet the Energy Demand.

The American Public Work Association (1971) and Arnold (1971) define waste as useless, unwanted or discarded material from normal community activities including solid, liquid and gaseous. According to Dhar (1976) and Clement (1976), waste is a material which is in the wrong place at the wrong time, a locational change with reference to the time frame and hence should be converted into useful material.

The solid wastes of any community which are collectively called refuse are classified by the American Public Health Association Committee (1960) and Turk et al (1972) as:

- a. Garbage-kitchen waste (animal and vegetable matter)
- b. Combustible rubbish-paper, rags and leaves
- and c. non combustible rubbish-metals, cans, glass, bottles and crockery.

Holt (1956) classified solid waste as (a) organic matter, consisting of peelings, waste food, tea leaves and clothe and inorganic matter of cinder, metals and ash. Gilbertson (1969) and Turk et al (1972) opine that the significant characteristics of solid waste are density, moisture, combustible, compostable and thermal value. Holmer and Sarag (1977) are of the opinion that the most significant characteristics of liquid waste are those of BOD.

bacteria, nitrogen, phosphoric acid, potash, suspended matters, soluble dirt and traces of food.

Vinall (1976) states that waste, if properly exploited can provide an array of useful economic products and at the same time, if neglected can be a source of great nuisance. According to Dual (1975) waste management is more than paper flying around city dumps and much attention has been focussed in recent times on recycling of waste.

Hagerty et al (1973), Arnold (1974) and Ramachandran (1977) opine that recycling is the process by which waste materials are transferred into new products in such a manner that the original products may lose their identity.

Singh and Mukerjee (1978) claim that proper recycling of waste can produce as much energy as the nation's entire consumption of oil. Stout (1979) claims that there is growing interest in the use of organic waste as fuel, the method generated by the decomposition of organic matter under anaerobic conditions. Start (1979) suggests anaerobic digestion of organic wastes including agricultural and agro-industrial waste materials with the exception of materials which are primarily cellulosic such as saw dust. By the process of pyrolysis organic materials including garbage may be converted into methane gas (Span, 1978).

Desai (1976) states that the use of rural wastes for methane generation rather than directly as fuel or fertiliser yields three direct benefits (1) the product energy resource that can be stored and used more efficiently, (2) the creation of a stabilised residue that retains the fertiliser value of original material and (3) the saving of energy required to produce an equivalent of nitrogen containing fertiliser by synthetic processes. He further states that sewage of 15.26 people when digested will satisfy the demand of an individual for his domestic fuel needs.

Chiang et al (1976) observe that waste materials from agriculture can be converted into valuable fuels. A study in Ghana demonstrated that wood, sawdust, groundnut shells and rice straw can be converted to charcoal, oil and gas by pyrolytic conversion.

Patel (1975) states that the KVIG and other organisations have estimated that the fermentation of the dung collected from 75 per cent of the country's 226 million cattle (1961 census livestock) could possibly yield about 195 million mts of energy per year (which is equivalent to about 24 million litres of kerosene).

C. Biogas Plants:

The IARI defines cowdung gas plant as a cheap and simply operated plant in which dung is digested anaerobically so as to yield sufficient quantity of combustible gas which can be utilised for cooking purposes and the

residue for manure without any loss of manurial constituents. Under anaerobic conditions the oxygen of fermentable material produces on complete oxidation, the products oxygen, methane and hydrogen (Desai and Biswas, 1945).

Anaerobic digestion is a term commonly applied in waste treatment process in which the wastes are stabilized in the absence of atmospheric oxygen with the production of methane and carbon dioxide (Gloueka, 1974).

The various uses of cowdung gas plant as listed out by Patel (1964) are as follows: It provides

- a. Fuel which is efficient
- b. Manure having high nitrogen content and
- c. Hygenic and sanitary conditions in the cooking area and around the house.

Gas as fuel: Patel and Patel and Marasimhan (1966) opine that gobar gas contains 55 per cent methane and 45 per cent carbon dioxide approximately. The calorific value of gobar gas as estimated by Patel (1974) is 550 BTU/cuft. According to Bajwa et al (1975) the heat efficiency of 'gobar' gas is about 60 per cent.

Singh (1974); KVIC (1975); Sathianathan (1975); Patel (1975); Sampath and Kumar (1976); Biswas (1977); Laura and Idnani (1977) and Adams et al (1978) state that the gaseous product of fermentation could be advantageously used for domestic and industrial purposes as a cheap source of combustible energy for lighting, heating and cooking purposes and for providing motion power to run small scale industries.

Chittaranjan (1966) and Singh (1974) opine that the gas can be utilised for pumping water for irrigation and drinking water supply, and for running agricultural industries as shelling of rice, grinding of flour, crushing seeds and cutting fodder.

Slurry as Manure:

Singh (1974); KVIC (1975) and Biswas (1977) remark that the residual slurry can be utilised in various ways. It can most profitably be applied to the farm directly by mixing with irrigation water because it is in a condition that mixes well with soil. Paul (1974), Sathianathan (1975) and Biswas (1976) report that the residual slurry composted with farm yard refuse, unused vegetables, fallen tree leaves and weeds will make an excellent manure and will reduce the expenditure of farmers on chemical fertilisers.

Fry (1974); Sathianathan (1975), Mahar (1977), Miglani and Singh (1977); Rao (1977); Singh (1978) and Mande (1978) state that the anaerobic digestion of cowdung produces manure of better quality rich in humus content. It is finely divided and gets more easily mixed with the soil. The humus helps to improve the structure of soil by increasing its capacity to retain moisture preventing water logging and by providing good aeration.

Singh (1977) and Chawla (1979) opine that the enrichment of slurry by composting with other organic matter provides agronomical manures from the limited quantity of digested slurry available from the gas plant. Verma (1978) states that digested slurry can be dehydrated quickly by absorbing it

in the leaf powder, paddy husk or in saw dust and can be further dried in the sun, and stored for use when required,

Sathianathan (1975); Ekholm (1976); Singhal (1977); Patel (1977) and Miraleedharan (1977) remark that the loss in quantity and quality of manure obtained from the gas plant is less when composted. It is found that this manure contains about 1.5 per cent of nitrogen as against only 0.75 per cent of ordinary farm compost.

Bajwa et al (1975) and Chawla (1979) state that there is only a relative increase in the concentration of total nitrogen of the residue, due to decomposition of a part of organic constituents resulting in almost its complete conservation during the process. Theoretically the increase in nitrogen content of the residual slurry will be proportional to the extent of decomposition which is about 25 to 30 per cent.

Patel (1955) is of the opinion that the nitrogen content of the digested manure from 226 million cattle would be around 3.5 tonnes which is more than the nitrogen fertiliser capacity established in the country so far.

Sanitary benefits

Sathianathan (1975); Reddy (1976); Patel (1977) and Srinivasan (1978) remark that the digestion process and the bacteria present in the digested manure prevent the breeding of flies and mosquitoes.

B. Factors Affecting Gas Production:

There are a number of environmental factors which control the evolution of gas by anaerobic fermentation in a closed system. These factors have been studied either under laboratory conditions or in working gas plants. Some of the important aspects are discussed below:

Temperature:

Singh (1974), Fleffer (1974); Munde (1978) and Stout (1979) state that the overall digestion by the bacteria^a occurs at temperature ranging from 32°F to 156°F. However the production of gas decreases rapidly below 60°F and practically stops at 50°F even though the digestion continues. Desai (1951) and Idnani and Vardarajan (1974) reveal that there is practically no gas production below 30°C, optimum temperature being 40°C and 50°C.

Idnani and Vardarajan (1974) and Bhavani (1976) observe that the gas production is optimum during summer months and lower during winter months. Adan and Tynor (1977) recommend covering the gas plant with an alkaline cloth fixed on to a wooden frame to increase gas production during winter months, Verma (1978) suggests addition of cattle urine to the dung approximately in 1:5 proportion to increase temperature, to speed up fermentation and enhance gas yield.

Srivasan (1978) is of the opinion that the detention period is directly depended upon the temperature as it would decide the state of multiplication of the methane fermenting bacteria and the velocity of fermentation. Menon (1978) reveals that the basic problem is to develop micro-organisms which can ferment dung at a temperature less than 25 celsius.

Pressure:

Acharya (1957) observed that gas production was somewhat higher when the interval gas pressure is maintained at a level of 2 to 4 (5 to 10 gms) of water below atmospheric pressure.

PH : The PH optimum has generally been found to occur between 6.7 and 7.4 according to McCarthy (1964) and between 7.2 and 8.2 according to Sharma (1974). Stout (1979) suggests checking of PH at the beginning for good results. Idani, Verkarajan and Lochr (1974) and Jewell et al (1976) state that animal wastes generate high level of ammonia, and when high loading rates are used toxicity may occur especially at high PH where ammonia is not ionised.

Patel (1968) states that methane formers thrive best in neutral to slightly alkaline media and become inactive below PH 6.0.

Microbial functions:

Fina et al (1978) state that the anaerobic utilization of benzoic acid during

fermentation was first reported by Travin and Buswel in 1934, confirmed by Clark and Fina in 1952 and later by Nottingham and Hungate in 1969. Fina and Fiskin (1960) established that carbon of the benzoic acid is converted to methane and carbon primarily to carbon-dioxide and the same may subsequently be reduced to methane.

Singh (1974); Singh and Fehr (1976), Nagar and Tietjjen (1970) and Stout (1979) observe that methane production through anaerobic digestion is a two stage biological process;

- a. The soluble carbohydrates are converted to organic acids and
- b. The organic acids are converted to methane and carbon-dioxide by methane forming bacteria.

Carbon nitrogen ratio:

Sharma (1974); Singh (1974) and Stout (1979) state that the amount of carbon and nitrogen in the material to be digested affects the nature of the process. Singh (1974) points out that the suitable C/N ratio in the raw material is about 30/1 for optimum digestion process, the other conditions being favourable. Klass et al (1976) observe that animal wastes or other substances with a C/N ratio around 30 will generally produce a mixture of gases containing 60 per cent methane.

According to Sharma (1974) very high C/N ratio will lead to early exhaustion of nitrogen with carbon left over and consequently slowing down the reaction to a stop and vice versa.

Singh (1974) points out that cowdung has a C/N ratio about 25:1 which makes it very suitable for gas production. Addition of vegetable waste will change the ratio and it must be ensured that the ratio of the mixture is not too high for gas production. Makhjan (1975) points out that the C/N ratio of crop residue with or without manure is generally too high for satisfactory biogas production. He further states that the ratio can be reduced by adding human excreta including urine or chemical nitrogen.

Chang et al (1976) state that large amount of a material with a lower C/N ratio can be mixed with dung to ensure greater gas production without exceeding the C/N limitations.

Cellulose and hemicelluloses

Swaminathan (1973), Shukula (1976) and Menon (1978) opine that the production of gas is high in the case of materials which are rich in cellulose and hemicellulose and at the same time contain some proteinaceous substances. Prasad et al (1961) point out that complex poly saccharides are more favourable for methane formation. Materials having a holo-cellulose gets decomposed into methane.

Additives for gas production:

Singh (1974) points out that substituting a portion of vegetable waste may be up to 50 per cent of the dry weight of the mixture will give more amount of gas for the same amount of fertiliser.

Arokiaswamy (1978); Menon (1978) and Majumdar (1978) state that all vegetable wastes, algae, weeds, sheep and poultry wastes, fish wastes, carcasses and vegetable wastes can be digested in proper biogas plants. Sharma (1974); Singh (1974) and Munde (1978) opine that addition of urine during winter months stimulates bacterial activity and thus increases gas production.

Chawla (1973) observes that by addition of one per cent wheat straw or bajra leaves finely powdered in combination with urea to dung at fortnightly intervals increases gas production to the extent of 30-50 per cent during winter months.

Singh (1974); Paul and Sharma (1975) and Khan (1977) suggest addition of poultry excreta to speed up and increase gas production.

E. Organic Waste as Fertiliser:

The current fertiliser shortage has prompted man to study the possibilities of producing organic manure from the many waste materials

available (Joshi, 1974). Vimal (1955) Saha (1975); Shantilal (1976) and Verma (1976) regard this possibility as a great challenge.

Pal (1962) states that conversion and utilisation of organic wastes and byproducts is an important line of activity connected with agricultural advancement.

Verma (1976) and Seminar on Complementary Use of Organic and Inorganic Fertilisers (1978) reveal that organic fertilisers keep the soil in good physical condition and supply the energy needed by the micro-organisms to help convert complex substances into simpler forms for the plants to absorb, besides supplying major nutrients in a form available to the plants and micro nutrients important for crop growth not usually available in fertilisers.

Agricultural Wastes

Stout (1979) states that agriculture is essentially an energy conversion process, the transformation of solar energy and fossil fuel products (fertilisers, Pesticides, diesel fuel etc) to food and fibre for man. Stout (1979) further affirms that the cost of collecting agricultural residues is a formidable obstacle for all processes.

Verma (1976), Invention Intelligence (1977), and Yoneyama et al (1977) opine that waste materials of various kinds such as plant residues, cereal straws, crop stubbles, cotton staples, groundnut husk farm weeds, grasses and

similar organic materials can be decomposed into rich manure through composting.

As stated by the Ministry of Agriculture, Fisheries and Food (1967) the diminishing supply of farm yard manure has caused many market gardeners to use straw as an alternate source of organic matter by ploughing directly into the soil or partly decomposing into compost.

The Ministry of Agriculture, Fishers and Food (1968) reports that fresh sea weed is similar to farm yard manure in organic matter and nitrogen content. The Ministry also remarks that the residues from the extraction of vegetable oils from seeds such as rape or castor are useful as nitrogenous fertilizers since they contain five to six per cent of nitrogen.

Vimal (1976) remarks that due to the lignocellulosic nature arecanut husk an important by product available in large quantities now practically going waste, in certain places, decomposes very slowly into soil. However it can serve as a local material for manurial purposes.

Animal wastes

Pavat (1976), Tickar (1976) and Stout (1979) opine that another major source of organic residue is animal waste. Singh (1974) states that research has been going on since 1930 in many countries to improve the composting process used extensively to convert fresh dung into farm manure.

The Ministry of Agriculture, Fisheries and Food (1978) reports that farm yard manure which is an excellent source of organic matter varies greatly in quality depending on, the kind of animal producing the manure, the nature and amount of litter used and its state of decomposition. They further state that horses produce manure that ferments quickly with considerable heating whereas dung of cattle and pigs ferment more slowly and lasts longer.

During the studies on compost making from dairy farm wastes, Paul (1976) noticed that while good quality compost can be made from cowdung, it was next to impossible to convert dry fodder waste into compost. On the other hand if fodder waste could be mixed with cowdung, both together would produce a high quality compost, in larger quantity than if only cowdung was used for compost making.

The National Commission on Agriculture (1976) states that utilisation of animal byproducts and animal wastes is vital and is used extensively for industrial purposes as a fertiliser.

Stout (1955) is of the opinion that hide waste is a useful raw material for producing nitrogen as fertiliser. Neelakantan (1974), Gomey et al (1975). Menawat (1976) and Loehr (1976) state that although poultry manure is not available in large amount as banana waste, its high nitrogen content makes it a valuable material where nitrogen is scarce.

Industrial Wastes

Verma (1976) and Shukla (1976) point out that industrial byproducts can be utilized for recycling to enrich the impoverished soils. Recycling of industrial waste depends upon the nature of the material concerned (Paul 1976). Sometimes it may be costly to recycle industrial waste in which other materials of commercial value are present.

The Ministry of Agriculture, Fisheries and Food (1968) opines that spent hops and malt culms are bulky organic manures which if used in large quantities may benefit the physical state of the soil.

Vinal (1976) Ghettiar (1978) and Patel et al (1979) point out that five to six million tonnes of dry bagasse produced every year is a valuable raw material for manure. Jadhav and Savart (1975) state that in distillery industry spent wash is one of the by products obtained from yeast fermented maltose after removal of rectified spirit. The wash may be used as a manure.

Town and Municipal Wastes

Banagaopadhyay (1976) and Ramachandran (1976) remark that in India more than 75 per cent of the urban wastes remain unutilised for any profitable purpose.

The Ministry of Agriculture, Fisheries and Food (1968) and Paul (1976) state that people living in towns and cities produce large amounts of garbage

and sewage everyday which can be easily decomposed into compost after removing the nondecomposable materials.

Singh (1973) claims that the availability of manurial constituents from waste alone amounts to 2,12,450 tonnes of nitrogen, 1,37,965 tonnes of phosphoric acid and 1,81,785 tonnes of potash. It is estimated that 15 million tonnes of urban compost of good quality containing about 1:5 per cent nitrogen and one per cent phosphoric acid which is superior to cowdung and farm yard manure can be prepared every year from urban waste available in the country.

Paul (1976) holds the view that sewage sludge can be processed to give sewage gas and the waste sludge can be utilized for compost making along with garbage.

F. Influence of Organic Manure on the Uptake of Nutrients:

Naik and Ballal (1968) reported that except for nitrogen, the uptake of other nutrients was not very much improved by the application of manures or fertilizers. Hortenstine and Rothwell (1969) stated that in oats, nitrogen uptake was greatly increased by the application of compost. Stump and Kolbe (1968) observed that there was ^{an} increase in yield of root crops by 10 per cent due to application of organic manures over the control.

Hortenstine and Rothwell (1973) further state that the uptake of all nutrients except Magnesium was increased by the application of compost.

Nishita et al (1973) state that application of organic matter increased the nitrogen and potassium in plants.

Pooma and Humbla (1973) observe that application of farmyard manure caused gradual increase in the dry weight of dhaincha top and it also caused a gradual increase in the content of Magnesium and Potassium and decrease in the content of Ca, Na, N and P. Purves and Jean Mackenzie (1973) report that the application of compost increased the uptake of Ca, Zn and B for lettuce and beans.

The results from the co-ordinated project on Assessment on the Effect of Fertiliser use and Pest Management In Changing Environment Under Intensive Cropping reveal that the uptake values of N, P, K, Ca and Mg by ragi crop from NPK and farm yard manure plots were significantly superior to other treatments. No significant difference in the nutrient content of amaranthus could be observed except in Nitrogen and Calcium which were high in pots treated with cowdung slurry. (Philomena 1978).

Effect of Organic Manure on crop Growth:

Garg et al (1971) observe that compost and farm yard manure had the same effect upon crop growth. It was observed that application of farm yard manure and compost significantly increased the yield of rice, wheat and sugarcane over control.

Rebein et al (1972) observe that application of cattle slurry plus straw increased the yields of maize and potato crops. Sharda and Koula (1973) observe that organic fertilisers were more effective with cereals and root crops. Lah (1974) reports that in a long term trial conducted at Thaivan from 1926 to 1957 on rice, organic manuring was found better than inorganic on the basis of equal amounts of nitrogen.

Laura and Indnani (1971-72) report that spent slurry and sundried slurry were superior to farmyard manure and compost and they also stated that spent slurry gave better response than sundried slurry in respect of wheat grain. They further state that sundried slurry with urea gave better response than urea alone in respect of the yield of wheat grain and straw.

Kutzenke et al (1973) report that in a long term experiment, application of farm yard manure plus NPK fertilisers increased the yield more than that with ammonium sulphate, superphosphate, potassium chloride.



III. EXPERIMENTAL PROCEDURE

The experimental procedure for the study on the Possibilities of Utilising Home Garden Waste for Production of Biogas and Organic Manure consisted of the following aspects:

A Utilisation of selected waste from home garden for biogas production
and B. Preparation and evaluation of organic manure

A. Utilisation of Selected Waste from Home Garden for Biogas Production

This aspect of the study consisted of the following steps:

1. Selection of organic materials for gas production
2. Selection of test cans for anaerobic fermentation of organic materials
3. Determining the proportion of components to be used for gas production
4. Experimental set up
5. Assessing the volume and composition of gas produced
- and 6. Analysing the manurial value of digested residue

1. Selection of organic materials for gas production

Loehr (1975) remarks that leaves of various shrubs and plants like banana which can be grown without much attention, utilising waste from the kitchen, give substantial amount of renewable waste which can be recycled for gas production.

In larger villages, towns and cities not served by modern sewage facilities, provision is usually made to lead the discharge from the house drains to the backyards where a kitchen garden with a few clumps of banana plants can be raised to avoid slush (National Commission of Agriculture, 1976). Various parts of plantain plant are utilised to serve a variety of purposes. Plantains, ^cpsudostem and inflorescence can be consumed while the unbroken leaves are used mainly for serving meals. The remaining parts considered as waste are often discarded in the absence of cattle in the house.

Similarly neem trees are common in the backyard of many households in Coimbatore and the fallen leaves are often dumped into pits though considered valuable in the medical fields

Hence, waste portions from banana plant viz, stem, leaves and peels and fallen neem leaves along with fresh cowdung and spent cowdung slurry were considered for the experiment involving production of biogas.

2. Selection of test cans for anaerobic fermentation of the organic materials:

Since the experiment was planned to be conducted on laboratory basis utilising waste from home garden, oil cans of five litre capacity were selected as test cans (Figure 1). A total number of 20 cans were required for the experiment and these were purchased from the local market.

3. Determining the proportion of components to be used for gas production:

Since the experiment was designed to study the possibilities of utilising organic waste material from home garden, the proportion of cowdung,

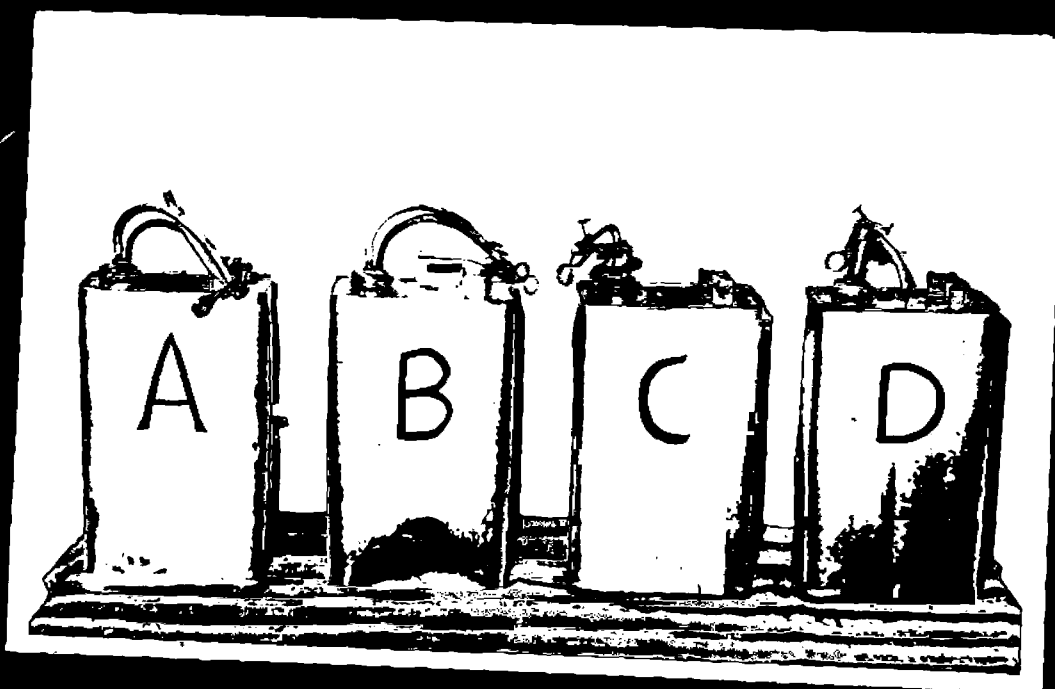


FIGURE - 1
SELECTED TEST CONTAINERS

slurry and water were maintained in the same proportion for all, with a variation in the proportion of waste material added.

Table I presents the various proportions of selected materials utilised for the experiment.

TABLE - I

SELECTED PROPORTIONS OF ORGANIC MATERIALS FOR BIOGAS PRODUCTION

S. No.	Test material (gm)	Cowdung (gm)	Spent cowdung slurry (gm)	Water ml	Proportion
1.	666	666	666	1000	1:1:1
2.	1000	500	500	1000	2:1:1
3.	1200	400	400	1000	3:1:1
4.	1333	333	333	1000	4:1:1
5.	1426	286	286	1000	5:1:1

The total weight of all the components together in each of the test can was maintained as two kg. The same proportions were followed for all organic materials such as banana stem, peels, and leaves of banana and neem.

4. Experimental set up:

Cowdung, spent cowdung slurry and the test material were gathered first and weighed as per Table 1. The garden waste material was cut into bits of one cm size for easy and quick decomposition.

The cut pieces were then mixed thoroughly with cowdung, spent cowdung slurry and water in a plastic basin and later the mixture was poured into the test can through the opening on top to fill $\frac{2}{3}$ of its volume. The contents of the test can were then shaken thoroughly. The opening was closed with the help of a nipple soldered on to it.

Rubber tubing of length ten cms was passed through the nipple and the tube was clipped with a pinch clip to prevent the escape of gas. The atmosphere inside was thus rendered anaerobic. They were then placed under direct sunlight for production of gas, which could be recognized by the bulge on the surface of the container. Gas thus produced for the first three days was released as it generally contains a mixture of gases. Later the test cans were kept for a period of eight weeks to record the volume of gas produced.

5. Assessing the volume and composition of gas produced:

The total volume of gas produced daily from the fourth day was measured quantitatively using the Gas Flow Meter Model IR 18 of recording type having one litre capacity shown in Figure (2). The gas production was

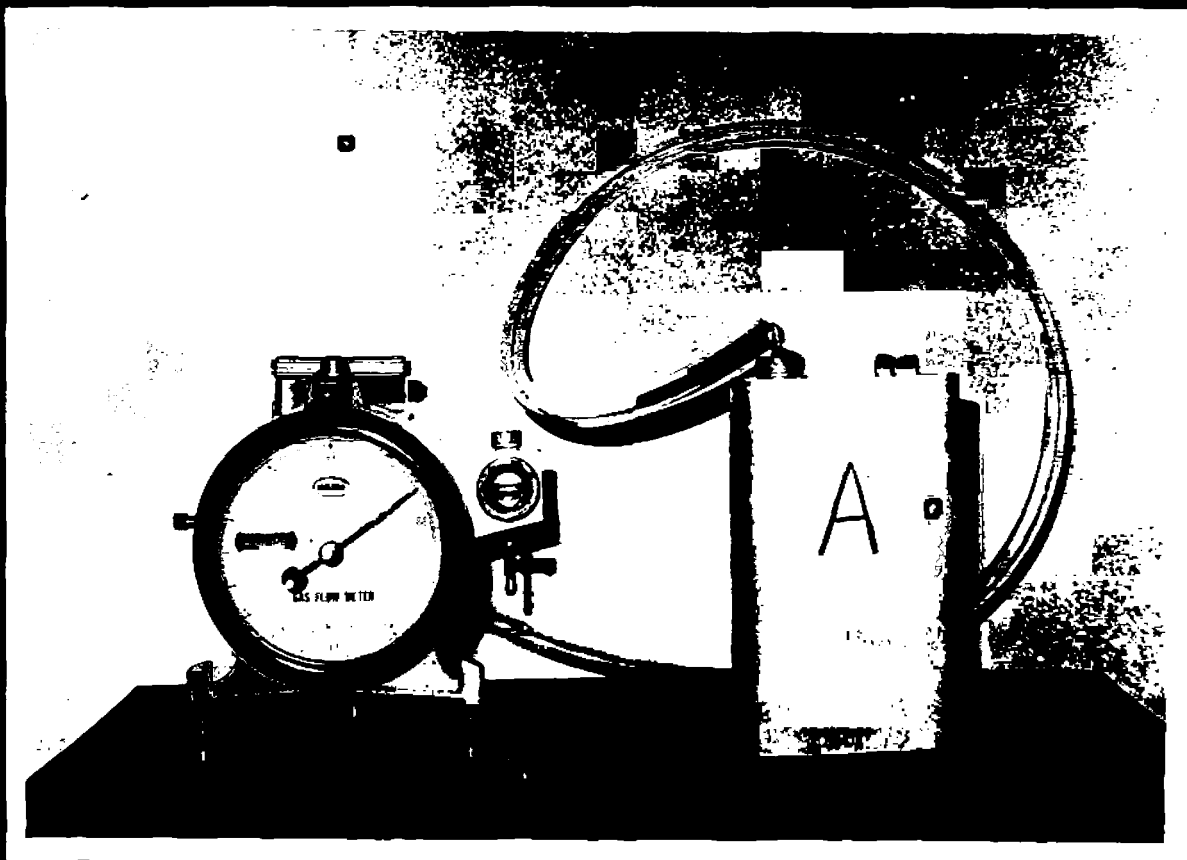


FIGURE - 2
GAS FLOW METER

recorded for a period of eight weeks in the case of neem leaves and for four weeks (from fourth to eight week) in the case of banana refuse.

The Gas Flow Meter was placed on a horizontal plane and the tripod screws were adjusted for levelling the instrument. The experimental test can was then placed on the same horizontal plane and was connected to the Gas Flow Meter with the help of a rubber tubing fixed on to the nipple. The pinch clip was then released to allow the gas to flow through the rubber tube into the Gas Flow Meter and the reading as indicated on the Meter was recorded. The same procedure was followed for all the test cans to record the daily production of gas from which the total volume of gas produced during a week was calculated.

The percentage of methane in the gas produced was estimated by using the Gas Chromatograph Model Perkin Elmer F11 Flame Ionizing Detector. The poropak column 80-100 mesh was used. The column temperature was adjusted to 150°C.

The gas sample of 0.5 ml. was collected from the test can and was injected into the injection front of Gas Chromatograph, the retention time of gas being one minute. The percentage of methane present in the sample was calculated by using the formula given below:

Peak height x attution x range.

The methane content of biogas generated from selected test samples were tested for a three week period in the case of sample A (neem leaves) and samples B, C and D (Banana refuse) at the end of the eighth week. Since standard Methane was not available, 'gobar' gas was considered as standard to find out the methane content of the samples .

6. Analysing the manurial value of digested residues:

On completion of eight weeks, the test cans were opened and the contents were dried under shade on polythene sheets for two days. On drying it was powdered thoroughly using a mortar and pestle. Roughly about ten gms. of the sample was used to estimate the nitrogen, phosphorus and potassium content (NPK) of the residue on dry weight basis, following the procedure given in Appendix I

B. Preparation and Evaluation of Test Manures:

The procedure for the preparation and evaluation of organic manure comprised the following steps:

1. Selection of treatments.
 2. Preparation of compost
 3. Estimation of NPK in selected organic manures
 4. Growing plants utilising selected organic and inorganic manures
- and
5. Comparing 'amaranthus' grown using selected manures.

1. Selection of treatments

Ten treatments with three replications were selected, Randomised Block Design was selected for the experiment. The details regarding the treatments are furnished in Table II.

TABLE - II

SELECTED TREATMENTS FOR MANURIAL APPLICATION

S.No.	Treatment	Symbol
1.	Control (no manure)	T ₁
2.	Fresh spent cowdung slurry	T ₂
3.	Dried spent cowdung slurry	T ₃
4.	Dried cowdung	T ₄
5.	Compost (a) (Spent cowdung slurry + garbage)	T ₅
6.	Compost (b) (Cowdung + garbage)	T ₆
7.	Inorganic	T ₇
8.	Inorganic + dried spent cowdung slurry	T ₈
9.	Inorganic + fresh spent cowdung slurry	T ₉
10.	Inorganic + dried cowdung	T ₁₀

The three manures selected for the treatments included inorganic fertiliser (urea, separate of potash and super phosphate) and compost prepared from

- a. Fresh cowdung, dry leaves and cereal stalk and
- b. Spent cowdung slurry, dry leaves and cereal stalk.

Organic fertilisers were selected due to its high nitrogen content and richness in humus as compared to farm yard manure (Tanhane, 1970; Singh, 1973; and Biswas, 1974).

2. Preparation of compost:

The pit system commonly considered as the best method was adopted for preparation of compost.

This involved the following operations:

- a. Selection of materials
- b. Selection of site
- c. Preparation of compost

a. Selection of materials:

As suggested by Tanhane (1970) fallen leaves and waste cereal stalk from cattle shed were chosen for compost preparation.

b. Selection of site:

The site selected for the pits for preparing the compost was near the existing gobar gas plant in Sri Avinashilingam Home Science College campus.

The nearness to the gas plant facilitated filling the pits.

G. Preparation of compost:

Two pits of 1 x 1.5 metres each were dug, Cowdung, fallen leaves from garden and cereal stalks were added alternatively in one pit for a period of two weeks until it was filled. In the second pit, spent cowdung slurry, fallen leaves from garden and cereal stalks were added. The pits were later covered with soil and allowed to decompose for a period of two months.

3. Estimation of NPK in selected organic manures:

To estimate the NPK content, two gms of each of the manure was dried in an oven at 100°C, cooled and weighed and analysed following the procedure given in Appendix I.

4. Growing plants utilizing selected organic and inorganic manures:

The experiment was conducted with the objective of studying the comparative efficacy of different sources of organic manure in relation to the available nutrients. Pot experiments were conducted in the following order.

- a. Preparation of pots for cultivation.
- b. Sowing seeds
- c. Plant protection
- d. Maintaining growth record of the plant
- and e. Harvest

a. Preparation of pots for cultivation:

Thirty earthen pots were purchased and marked T₁ R₁ - T₁₀ R₃ for the ten different treatments with three replications. Since red soil is light textured, well drained and good for cultivation (Thomas, 1975) this was selected for the experiment. One cart load of soil was purchased. The holes in the pots were closed with stones to prevent leaching. Five Kg. soil was used to fill each of the pots. Organic manure of 100 gms was added to the soil in each the pots T₂, T₃, T₄, T₅, T₆, T₈, T₉, T₁₀ as per the schedule presented in Table II. Calculated quantities of inorganic fertiliser (Table II) in the order of 20:50:20 kg/hectare were added to treatments T₇, T₈, T₉, and T₁₀. The contents of the pots were mixed well and left for a week for proper distribution of manure in soil.

b. Sowing seeds:

Amaranthus seed of Co Variety was selected for conducting the experiment because of their suitability to season and short duration. Few seeds were sown in each of the pot and a thin layer of soil was spread over to cover the surface. The pots were watered daily using a water can taking care to use the same quantity of water in each pot.

c. Plant protection:

BHC ten per cent was applied around the pots to guard against ants and insects.

d. Maintaining the growth record of the plants:

The record of growth of the plants was studied under the following heads:

- i. Time taken for germination of seeds
- and ii. Time taken for the third leaf to appear.

The above data were recorded. After the seventh day of germination each pot was thinned to six plants per pot to facilitate proper growth.

e. Harvest:

'Amaranthus' thus grown was harvested after 25 days from the date of sowing. The six plants from each pot were taken for further analysis.

5. Comparing 'amaranthus' grown using selected manures:

To compare the greens grown using different treatments of manure, the following two steps were undertaken:

- a. Biometrical observation
- and b. Chemical analysis of plant material.

a. Biometrical observations:

Biometrical observation was done as follows:

- i. Height of 'amaranthus' in relation to manurial treatments.
- ii. Yield of the 'amaranthus' in relation to manurial treatments.
- and iii. Thickness of plant stem in relation to manurial treatments.

i. Height of 'amaranthus' in relation to manurial treatments:

The height of the plant was measured with the help of a scale after harvesting and recorded.

ii. Yield of 'amaranthus' in relation to manurial treatments:

The yield in relation to manurial treatments was assessed by taking both the wet and dry weights of 'amaranthus'.

Wet weight:

The plants on harvesting were washed with water to remove soil. The weight was then determined using a balance. Thus the wet weight from each set of six plants from each pot was determined and recorded for comparison.

Dry weight:

The different sets of plants were dried in an oven at 100° c for 24 hours. The dried material was then weighed using a balance and recorded for comparison.

iii. Thickness of plant stem in relation to manurial treatments:

The thickness of the stem of six plants from each pot was found out with the help of a Screw Gauge at the first node of the plant and recorded. The mean thickness was calculated for comparison.

b. Chemical analysis of plant material:

The chemical analysis was done for total nitrogen, phosphoric acid, potassium, calcium and magnesium following the procedures given in Appendix II.

IV. RESULTS AND DISCUSSIONS

The results of the study on the Possibilities of Utilising Home Garden Waste for Production of Biogas and Organic Manure are discussed under the following headings:

- A. Use of home garden waste for biogas production:
- and B. Evaluation of manurial value of organic and inorganic manures.

A. Utilisation of Home Garden Waste for Biogas Production:

This aspect of the study is discussed under:

- 1. Volume of biogas produced from selected garden refuse
- 2. Percentage of methane in biogas produced
- and 3. Nutrient analysis of digested residues.

1. Volume of biogas produced from selected garden refuse:

The volume of biogas produced from selected refuse is discussed under

- a. Volume of biogas produced from neem leaves base
- b. Volume of biogas produced from banana refuse and
- c. Total volume of gas produced from the selected samples during the test period.

a. Volume of biogas produced from neem leaves base:

The data on the volume of biogas produced are presented in Table III and Figure 3 in terms of the average gas produced during each week and the total volume produced during the eight week test period.

TABLE - III

VOLUME OF BIOGAS PRODUCED FROM NEEM LEAVES BASE (SAMPLE 'A')

Sl. No.	Proportion		Slurry	Biogas production/week in c.c								Total during test period(L)
	Waste	Dung		1st	2nd	3rd	4th	5th	6th	7th	8th	
1	1	1	1	525	815	680	592	525	842	538	560	35.539
2	2	1	1	675	817	870	892	758	625	432	294	37.541
3	3	1	1	783	817	820	1083	1168	1108	375	242	44.758
4	4	1	1	858	800	690	592	1375	608	375	140	37.435
5	5	1	1	780	1208	1350	1375	1166	1333	670	510	58.744

The general pattern showed an increased production of gas during the fourth, fifth and sixth weeks, while the following weeks recorded decreased quantities. The gas production during the eighth week was comparatively low, only 27-48 per cent of the volume produced during the peak production period except in proportion (1) which generated 68.7 per cent.

The data on the total volume of gas produced during the test period of eight weeks indicate that proportion (5) yielded the maximum of 58.7 litres. The next best result (44.1 litres) was obtained from proportion (3) while proportion (1) yielded the lowest amount.

b. Volume of biogas produced from banana refuse base:

The data on the volume of biogas produced from banana refuse base per week and that of the total volume produced during the eight week period are discussed as gas produced from

- i. Banana stem - Sample B
- ii. Banana leaves - Sample C
- and iii. Banana Peels - Sample D

i. Biogas produced from Banana stem (Sample A):

The average weekly production of biogas from banana stem and the total volume of gas produced from fourth to eighth week are presented in Table IV. and Figure (4).

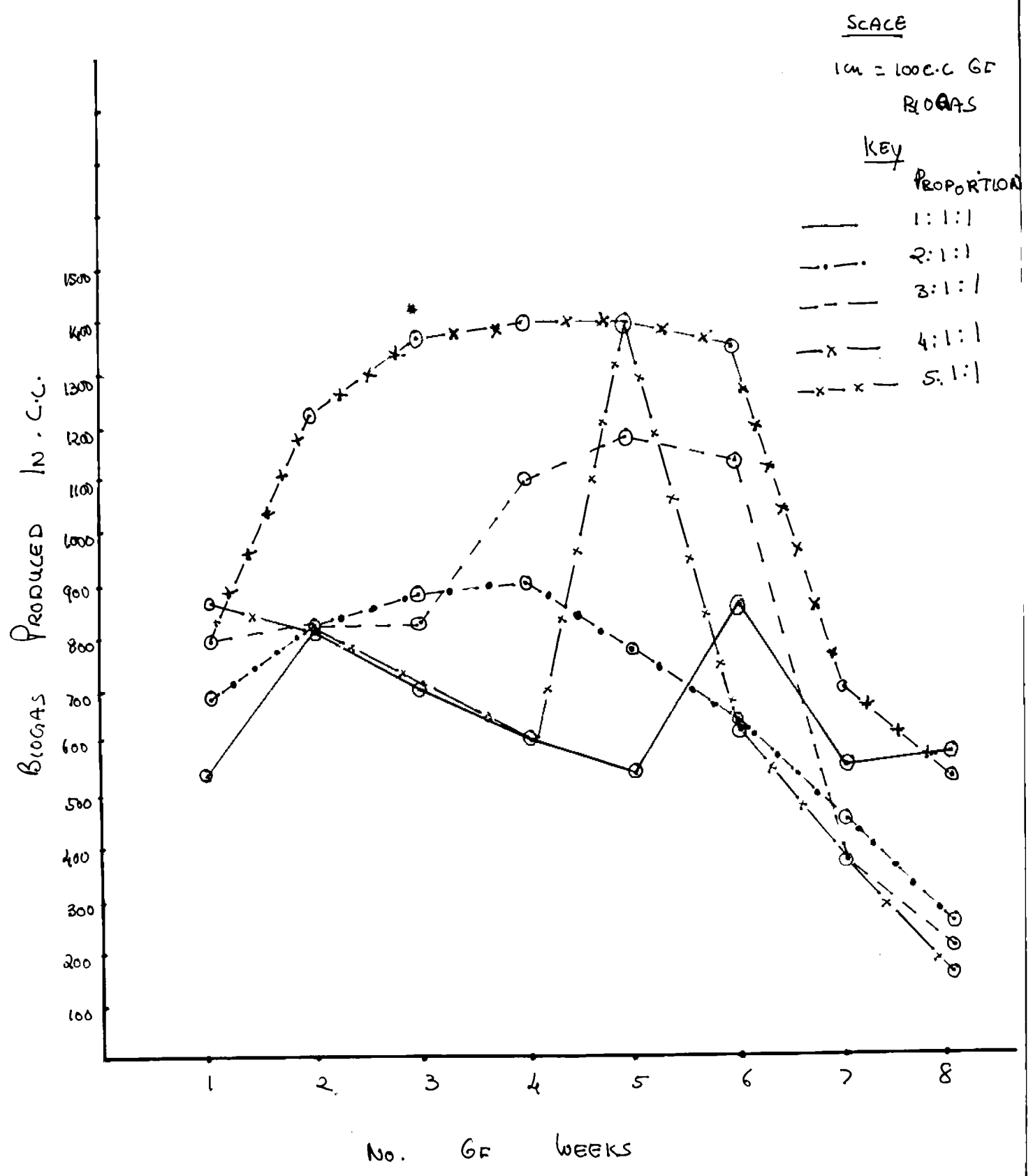


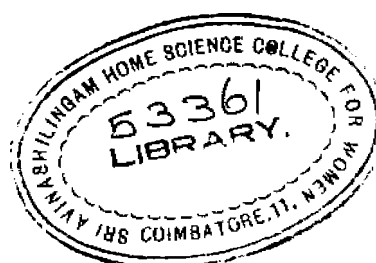
FIGURE - 3.

VOLUME GF BIOGAS PRODUCED
FROM NEEM LEAVES BASE.

TABLE - IV

VOLUME OF BIOGAS PRODUCED FROM BANANA STEM BASE (SAMPLE B)

S.No.	Proportion			Gas production/week in c.c					Total during test period(1)
	Waste	Dung	slurry	4th	5th	6th	7th	8th	
1	1	1	1	615	1150	1350	1142	240	39.074
2	2	1	1	570	750	1000	800	360	24.360
3	3	1	1	660	700	1100	438	205	21.721
4	4	1	1	750	850	1000	445	323	23.576
5	5	1	1	820	900	990	750	360	26.740



The gas production was recorded to be the maximum during the sixth week in all the proportions excepting in proportion (1) in which the fourth week was the peak production period. During the eighth week the generation of gas was the minimum when compared to that of the previous weeks. Proportions(1) and (2) registered the lowest production being 17 and 19 per cent respectively while in proportions (2), (4) and (5) about 32-36 per cent of the maximum was recorded.

Proportion (1) yielded the maximum volume of gas during the total period of five weeks. Not much of a variation was observed in the total volume of gas produced during the test period in the other proportions.

11. Biogas produced from banana leaves base (Sample-c):

The biogas production from banana leaves in terms of average weekly production and total volume of gas produced from fourth to eighth week is presented in Table V. and Figure (5).

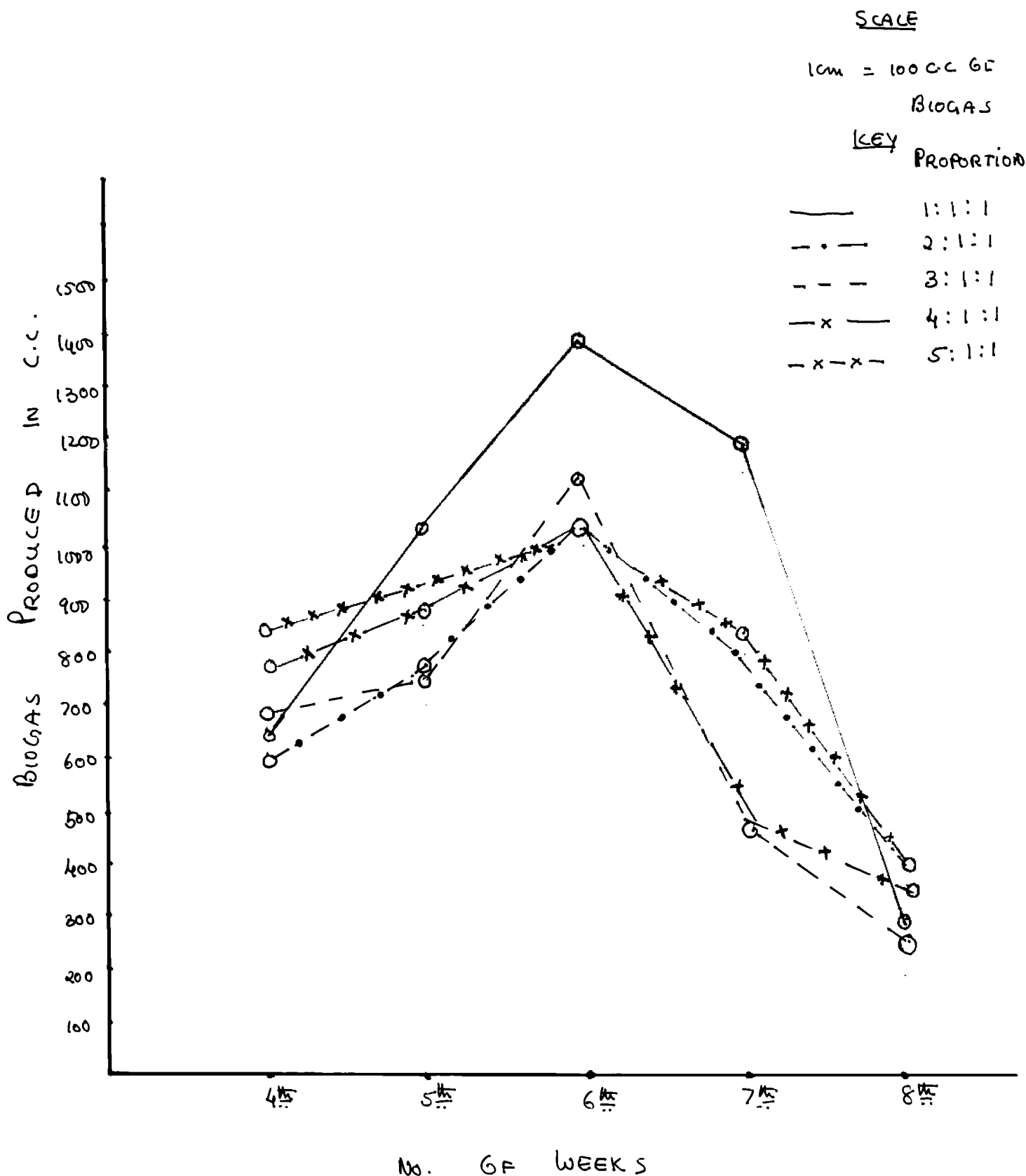


FIGURE - 4 .

VOLUME GF BIOGAS PRODUCED FROM BANANA STEM BASE.

TABLE - V

VOLUME OF BIOGAS PRODUCED FROM BANANA LEAVES BASE (SAMPLE C)

S.No.	Proportion			Gas production/week in ccc					Total during test period (1)		
	Waste	Dung	Slurry	4th	5th	6th	7th	8th			
1	1	:	1	:	1	400	375	300	275	175	10.535
2	2	:	1	:	1	200	180	150	116	135	5.474
3	3	:	1	:	1	500	350	400	236	145	11.472
4	4	:	1	:	1	1100	800	750	639	118	23.849
5	5	:	1	:	1	1200	990	800	766	628	30.688

The fourth week recorded the maximum production of gas in all the proportions with a steady decline during the following weeks. During the eighth week the production of gas was lowest almost about 11 per cent of the maximum production in proportion (4) and highest (68 per cent) in proportion (2).

Considering the total volume of gas produced during the five week period, a maximum of about 31 litres was observed in proportion (5). Proportion (4) also

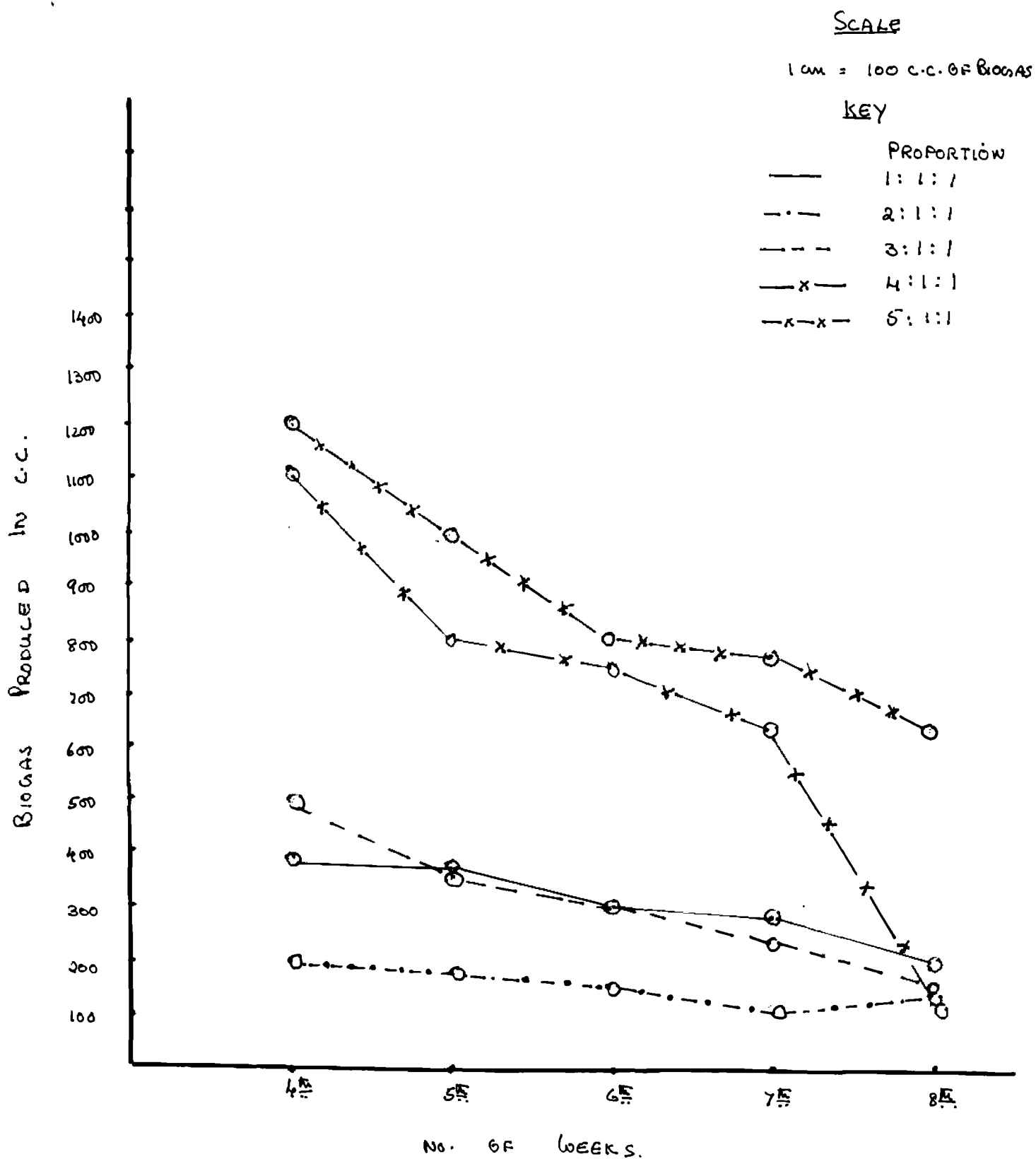


FIGURE - 5.

VOLUME OF BIOGAS PRODUCED FROM BANANA LEAVES BASE.

indicated gas production to the tune of 24 litres, while the remaining three compositions gave a very meagre quantity between 5 and 11 litres.

iii. Biogas produced from banana peels bast: (Sample D):

The weekly average and the total volume of biogas produced from banana peels during the fourth to the eighth week are presented in Table VI and Figure (6).

TABLE - VI

VOLUME OF BIOGAS PRODUCED FROM BANANA PEELS BASE (SAMPLE D)

S.No	Proportion			Gas production/week in c.c.					Total volume during test period (L)
	Waste	Dung	Slurry	4th	5th	6th	7th	8th	
1	1	1	1	400	312	176	100	122	8,190
2	2	1	1	550	258	522	437	102	13,053
3	3	1	1	530	410	198	224	168	10,710
4	4	1	1	410	366	300	274	147	10,479
5	5	1	1	535	400	550	332	212	14,203

As seen in sample D, the production of biogas was at the maximum level during the fourth week followed by a gradual decline during the succeeding weeks except in proportions 2 and 5 which registered an increase during the sixth week. Low gas production was evident during the eighth week, which ranged between 18 and 38 per cent of the maximum during the peak period.

It was observed that the proportions (2) and (5) yielded the maximum quantity of 13-14 litres during the test period, the minimum being eight litres from proportion (1).

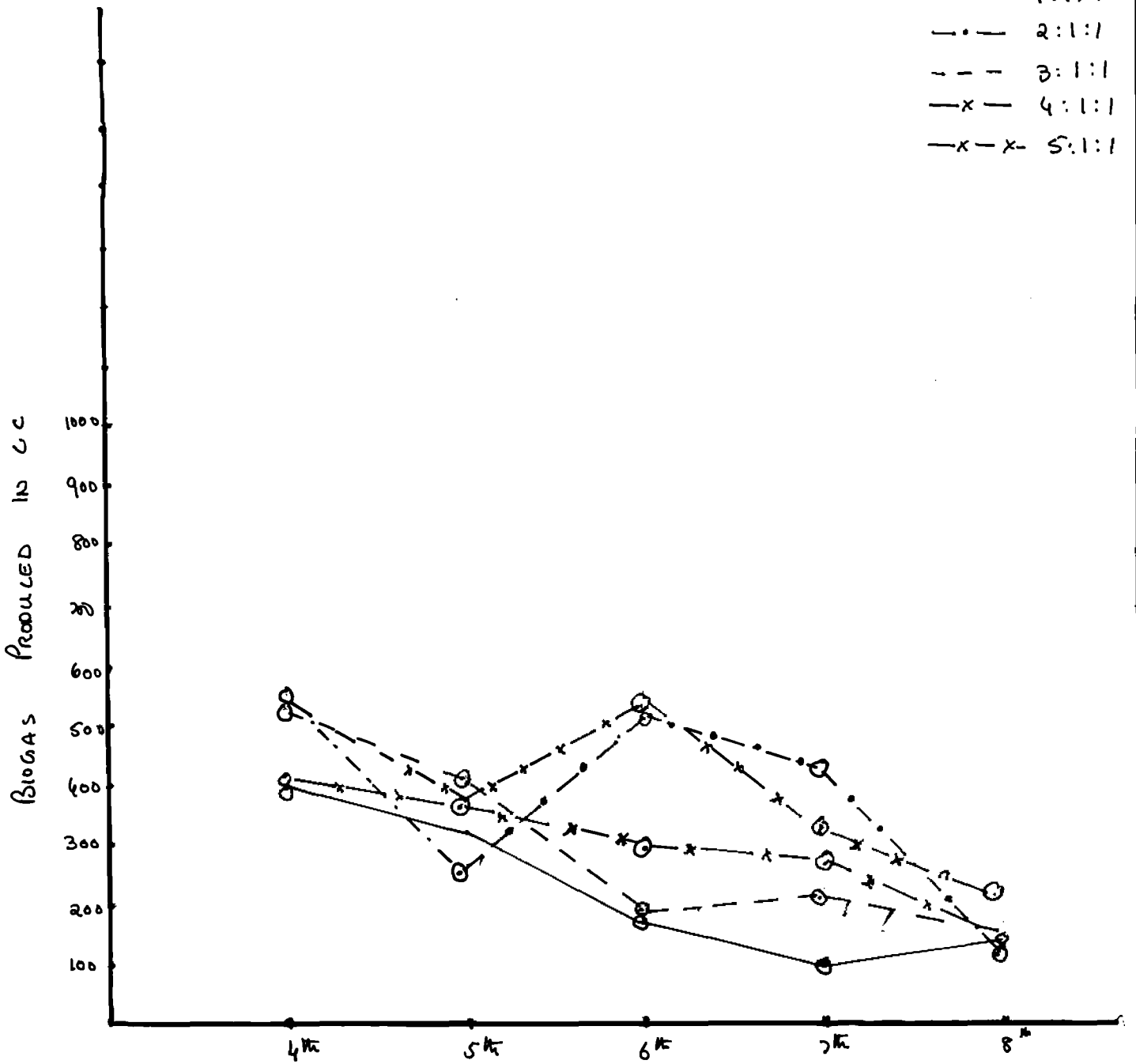
SCALE

1cm = 100 C.C OF BIOGAS

KEY

PROPORTION

- 1:1:1
- o- 2:1:1
- - - 3:1:1
- x- 4:1:1
- x-x- 5:1:1



No. GF TREATMENTS

FIGURE - 6

VOLUME GF BIOGAS PRODUCED FROM BANANA PEELS BASE.

C. Total volume of biogas produced from selected samples during the test period:

Table VII ^{and figure-7} presents the total volume of gas produced during fourth to eighth week from the selected samples- neem leaves base and banana refuse base.

TABLE - VII

TOTAL VOLUME OF BIOGAS PRODUCED FROM SELECTED SAMPLES

S.No.	Proportion			Gas production/week in litres			
	Waste	Dung	Slurry	Neem leaves sample A	Banana stem sample B	Banana leaves sample C	Banana peels sample D
1	1	1	1	21.399	39.074	10.535	8.190
2	2	1	1	21.077	24.360	5.474	13.083
3	3	1	1	27.832	21.721	11.417	10.710
4	4	1	1	22.050	23.576	23.849	10.479
5	5	1	1	35.378	26.140	30.688	14.203

From the data recorded it was observed that banana stem registered the maximum gas production followed by that of neem leaves. While proportion (1) generated a maximum of 39 litres of biogas from banana stem, proportion (5) in neem leaves evolved a maximum of 35 litres. A fairly good volume of gas was generated in the case of banana leaves, only 23-31 litres in proportions (4) and (5). The gas production was considerably poor eight to 14 litres in the case of banana peels.

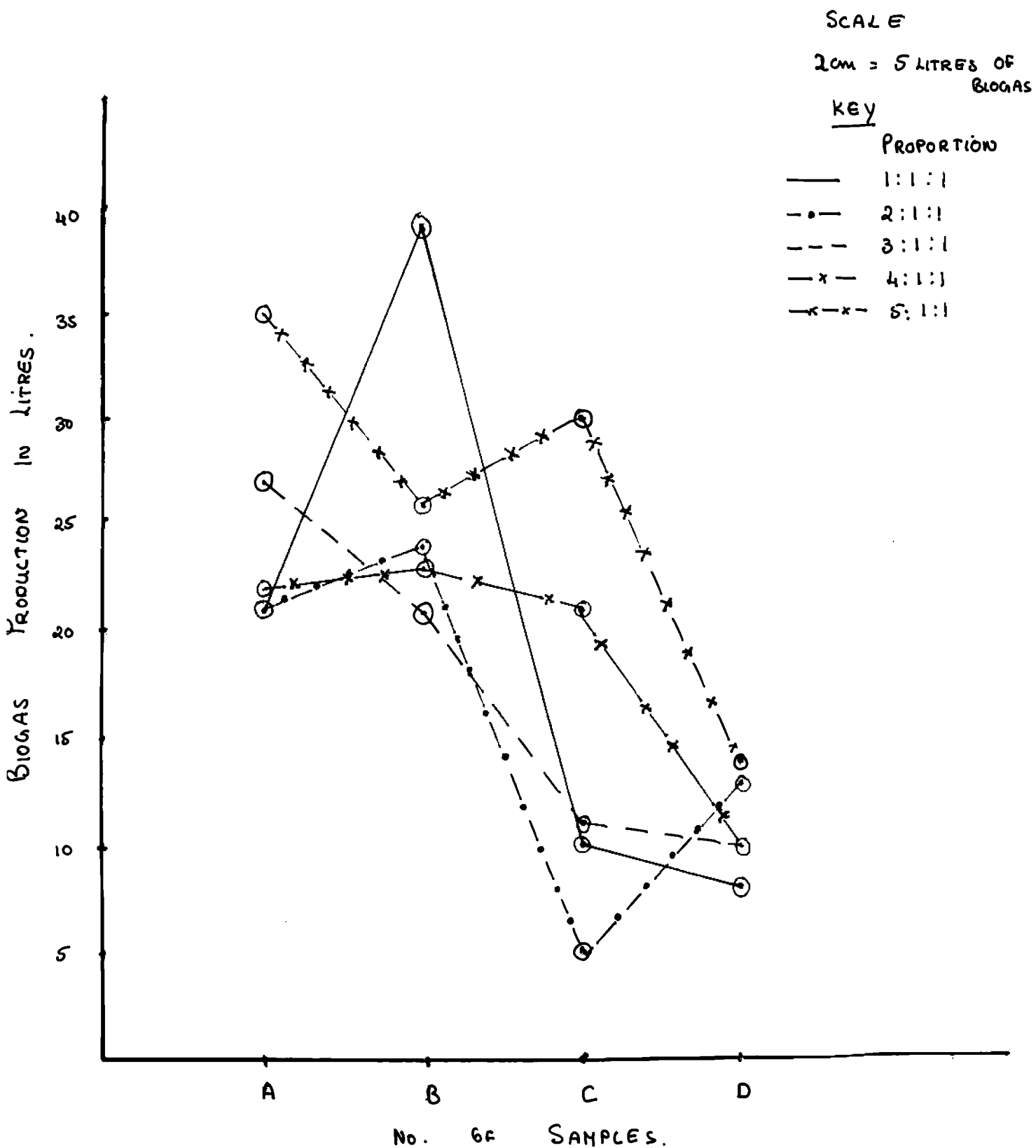


FIGURE - 7.

TOTAL VOLUME OF BIOGAS PRODUCED FROM SELECTED SAMPLES.

The data thus reveal that a combination of neem leaves, dung and spent slurry may be used advantageously for biogas production in two proportions as 5:1:1 and 3:1:1 Banana stem, dung and spent slurry in equal proportions and in proportions 5:1:1 also, may be effective for biogas production. Only 5:1:1 proportion was found suitable with banana leaves, dung and slurry.

2. The percentage of methane in biogas produced:

The percentage of methane in biogas produced from the selected materials was estimated during the first, second and fifth week of gas production in neem leaves (Sample A) and for the eighth week in banana stem (Sample B), banana leaves (Sample C) and banana peels (Sample D). The percentage of methane present in sample A and samples B, C and D is depicted in Tables VIII and IX respectively.

TABLE - VIII

PERCENTAGE OF METHANE IN BIOGAS FROM NEEM LEAVES BASE

Sl.No.	Proportion			Percentage of methane in weeks					
	Waste	Dung	Slurry	1st		2nd		5th	
				G.U *	%	G.U	%	G.U	%
1	1	1	1	1.8	372.42	0.013	2.834	6.5	672.41
2	2	1	1	1.85	382.75	1.5	310.00	3.8	393.0
3	3	1	1	0.9	186.20	3.38	699.0	5.1	527.5
4	4	1	1	1.3	268.98	1.6	331.03	2.5	258.6
5	5	1	1	1.5	310.34	1.5	310.34	4.6	478.5

* Chart Unit

The various proportions of neem leaves in combination with dung and slurry yielded higher percentage of methane than that of 'gobar' gas during the first, second and fifth weeks except in proportion (1) during the second week which indicated only a very small percentage of methane (2.8 per cent).

The higher percentage of methane in neem leaves in various combinations with dung and slurry indicates the definite possible new avenue of utilizing this waste material found in abundance in many parts of the country for producing methane for fuel needs.

b. Percentage of methane in banana refuse:

The percentage of methane present in the digested banana refuse at the end of the eighth week is presented in the Table below:

TABLE IX

PERCENTAGE OF METHANE IN BIOGAS FROM BANANA REFUSE BASE

Sl.No	Proportion			Banana stem Sample B		Banana leaves Sample C		Banana peels Sample D	
	Waste	Dung	Slurry	C.U ^m	%	C.U	%	C.U	%
1	1	1	1	5.8	600	4.1	424.13	0.1	10.34
2	2	1	1	1.4	144.8	2.0	206.89	0.97	100.34
3	3	1	1	4.1	424.14	5.8	600	0.1	10.34
4	4	1	1	2.0	206.89	3.5	362.06	0.17	17.58
5	5	1	1	4.8	496.55	6.2	641.37	0.025	2.58

* CHART UNIT

On analysis for methane content at the end of the eighth week it was observed that banana leaves in combination with dung and slurry generated a

very high percentage of methane when compared to that of 'gobar' gas. Banana stem also showed similar results. The highest percentage of methane gas was observed in proportion (5) using banana leaves. The next two best combinations were banana stem with dung and slurry in equal proportions and banana leaves with dung and slurry in proportion (3). Since the percentage of methane generated from banana peels was considerably low in all proportions, this can be claimed unfit for ^{fuel gas} generation.

Thus the data reveal the possibility of high percentage of methane gas generation from banana leaves and stem in combination with dung and spent slurry mainly in three proportions 1:1:1, 3:1:1 and 5:1:1.

3. Nutrient analysis of digested residues:

The nutrient analysis of digested test sample A and that of samples B, C and D are presented in Tables I and II respectively (Figure 2) illustrates the Nitrogen and Potassium content of digested test samples A, B, C and D.

TABLE I

NUTRIENT ANALYSIS OF DIGESTED RESIDUE FROM A NEEM LEAVES BASE

Sl.No	Proportion			Percentage		
	Waste	Dung	Slurry	Nitrogen	Phosphorus	Potassium
1	1	1	1	2.30	0.19	0.90
2	2	1	1	2.24	0.17	0.90
3	3	1	1	2.29	0.14	0.90
4	4	1	1	2.21	0.15	1.10
5	5	1	1	2.10	0.13	0.70

Sizeable difference in nitrogen, phosphorus and potash content could not be observed within the selected proportions. However proportion (1) appeared to be a better source of nitrogen and phosphorus while proportion (4) in potassium content,

TABLE - XI



NUTRIENT ANALYSIS OF DIGESTED RESIDUE FROM BANANA REFUSE BASE

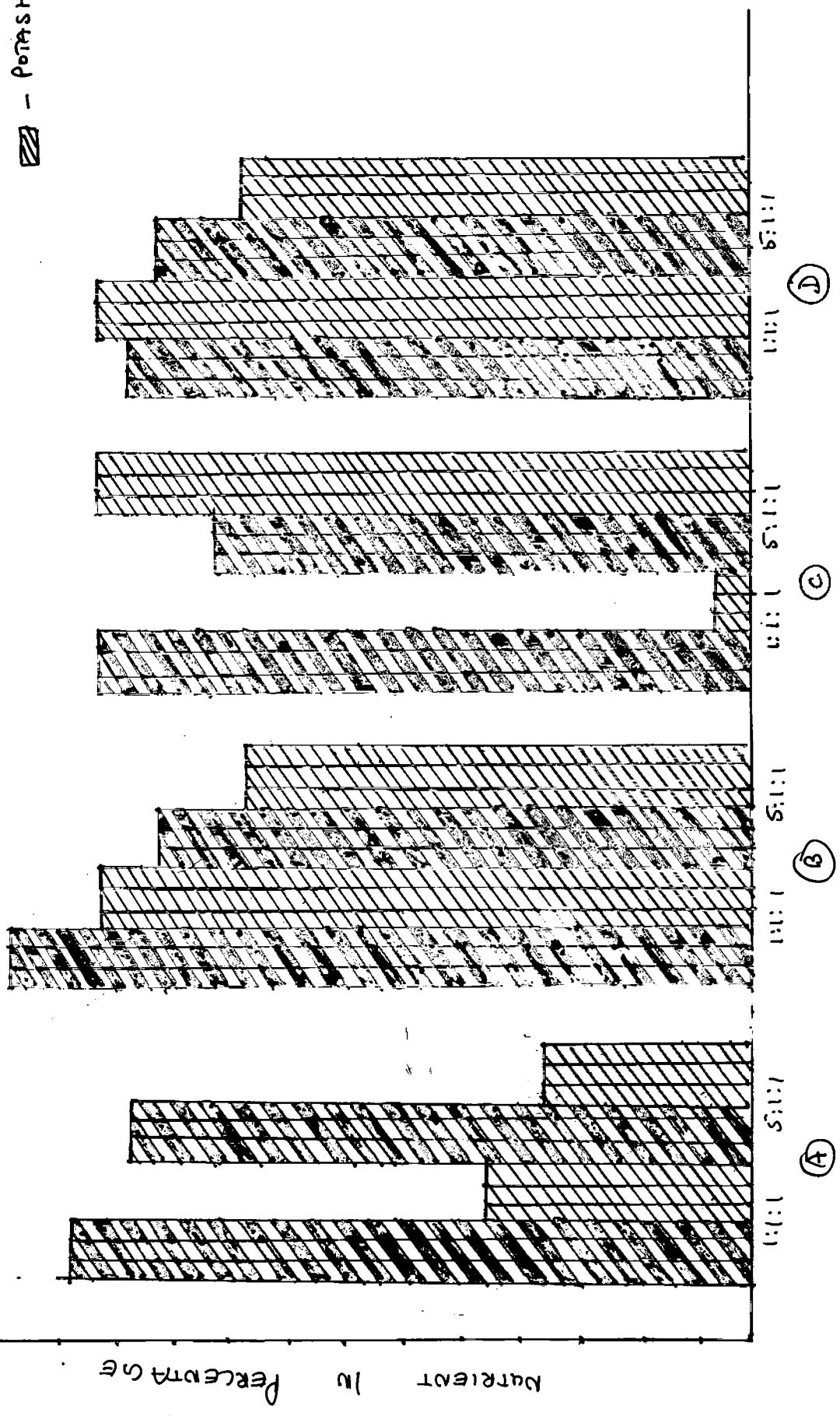
S, No.	Waste	Dung	Slurry	Sample B			Sample C Percentage of			Sample D		
				N	P	K	N	P	K	N	P	K
1	1	1	1	2.54	0.30	2.20	2.26	0.27	0.10	2.18	0.21	2.20
2	2	1	1	2.57	0.26	2.85	2.52	0.26	4.80	2.10	0.19	2.85
3	3	1	1	2.38	0.27	4.00	2.57	0.36	2.90	2.24	0.16	4.00
4	4	1	1	2.57	0.20	3.60	2.15	0.22	2.20	2.24	0.19	3.60
5	5	1	1	2.04	0.13	1.70	1.84	0.11	2.95	2.00	0.13	1.70

The nitrogen, phosphorus and potash content of the digested residue of the selected samples was more or less similar in all the proportions. However proportion (3) resulted in maximum potassium content, in Sample B and maximum phosphorus content in Sample C. Hence it can be concluded that the percentage of NPK of digested residue from banana refuse is more or less similar when any of the above proportions are selected.

LOW = 2 PERCENT

KEY

-  - NITROGEN
-  - POTASH



No. OF SAMPLES

FIGURE - 8

NUTRIENT ANALYSIS OF DIGESTED RESIDUE IN PROPORTION

B. Evaluation of the Manurial Value of Organic and Inorganic Manures:

The results of the study on the manurial value of organic and inorganic manures using digested slurry from the 'gobar' gas plant are presented and discussed under the following heads:

1. Nutrient content of selected manures
2. Effect of selected manures on growth of 'amaranthus'
3. Height of 'amaranthus' in relation to manurial treatments
4. Thickness of stem of 'amaranthus' in relation to manurial treatments
5. Yield of 'amaranthus' in relation to manurial treatments
- and 6. Nutrient content of 'amaranthus' treated with selected manures

1. Nutrient content of selected manures:

The nutrient analysis of selected manures viz., fresh spent cowdung slurry, dried spent cowdung slurry, dried cowdung, compost prepared using (a) fresh slurry+garbage and (b) fresh cowdung and garbage and that of inorganic manures used for the pot experiments is presented in Table XII.

TABLE XII

NUTRIENT CONTENT OF SELECTED MANURES

Sl.No.	Manures	Percentage of		
		Nitrogen	Phosphorous	Potassium
A. Organic manures				
1.	Fresh spent cowdung slurry	2.0	0.17	0.65
2.	Dried spent cowdung slurry	1.7	0.17	0.65
3.	Dried cowdung	1.6	0.17	0.65
4.	Compost (a) cowdung slurry garbage	1.09	0.08	0.07
5.	Compost (b) Cowdung garbage	1.06	0.1	0.5
B. Inorganic				
1.	Urea	46.00	-	-
2.	Superphosphate	-	18.00	-
3.	Mirate of potash	-	-	60.00

The organic and inorganic manures selected for the experiment on analysis for their chemical composition showed the following results: Inorganic manure registered maximum percentage of nutrients in terms of nitrogen, phosphorous and potassium when compared to organic manures. Fresh spent cowdung slurry, dried spent cowdung slurry and dried cowdung, were found to be rich in nitrogen and potassium though not in phosphorous content.

2. Effect of selected manures on growth of 'amaranthus':

The effect of selected manures on the growth of 'amaranthus' was evaluated in terms of

- a. Time taken for germination of seeds
and b. time taken for arrival of third leaf

a. Time taken for germination of seeds:

The time taken for germination of seeds in the three replicated pots treated with selected manures is given in Table XIII and Figure(9).

TABLE - XIII

TIME TAKEN FOR GERMINATION OF 'AMARANTHUS' SEEDS

S.No.	Treatments	Time taken in hours			
		R ₁	R ₂	R ₃	Mean
1	T ₁	98	90	98	95.3
2	T ₂	60	72	72	68.3
3	T ₃	60	72	60	64.0
4	T ₄	72	72	80	74.6
5	T ₅	72	80	60	70.6
6	T ₆	80	72	72	74.6
7	T ₇	60	72	90	74.0
8	T ₈	60	98	72	76.3
9	T ₉	80	72	98	83.3
10	T ₁₀	80	98	90	89.3

The variation in mean time taken for germination of seeds as seen from the Table indicates that in control pot (T_1) the seeds took a maximum of 95 hours whereas treatment (T_3) with dried spent cowdung slurry took a minimum of 64 hours and treatment (T_2) with fresh spent cowdung slurry took 68 hours thus indicating that addition of organic manure in the form of spent slurry hastens the germination process. Soil treated with compost using a combination of spent cowdung slurry + garbage (T_8) and cowdung + garbage (T_6) germinated faster when compared to that of inorganic fertilisers which required 83 and 89 hours in (T_9) and (T_{10}) respectively.

When statistically analysed the treatments were found to be significant at 5 per cent level. The treatments T_1 , T_{10} and T_9 were found to be on par as is denoted by the critical difference = 24.13 (Appendix III A).

The above results indicated the beneficial influence of organic manures over the combination of organic and inorganic fertilisers particularly with reference to germination of seeds.

b. Time taken for the arrival of third leaf:

The effects of treatments with physiological activity was also evaluated in terms of time taken for the third leaf to appear and the data are presented in Table XIV.

SCALE

1cm = 10 Hours

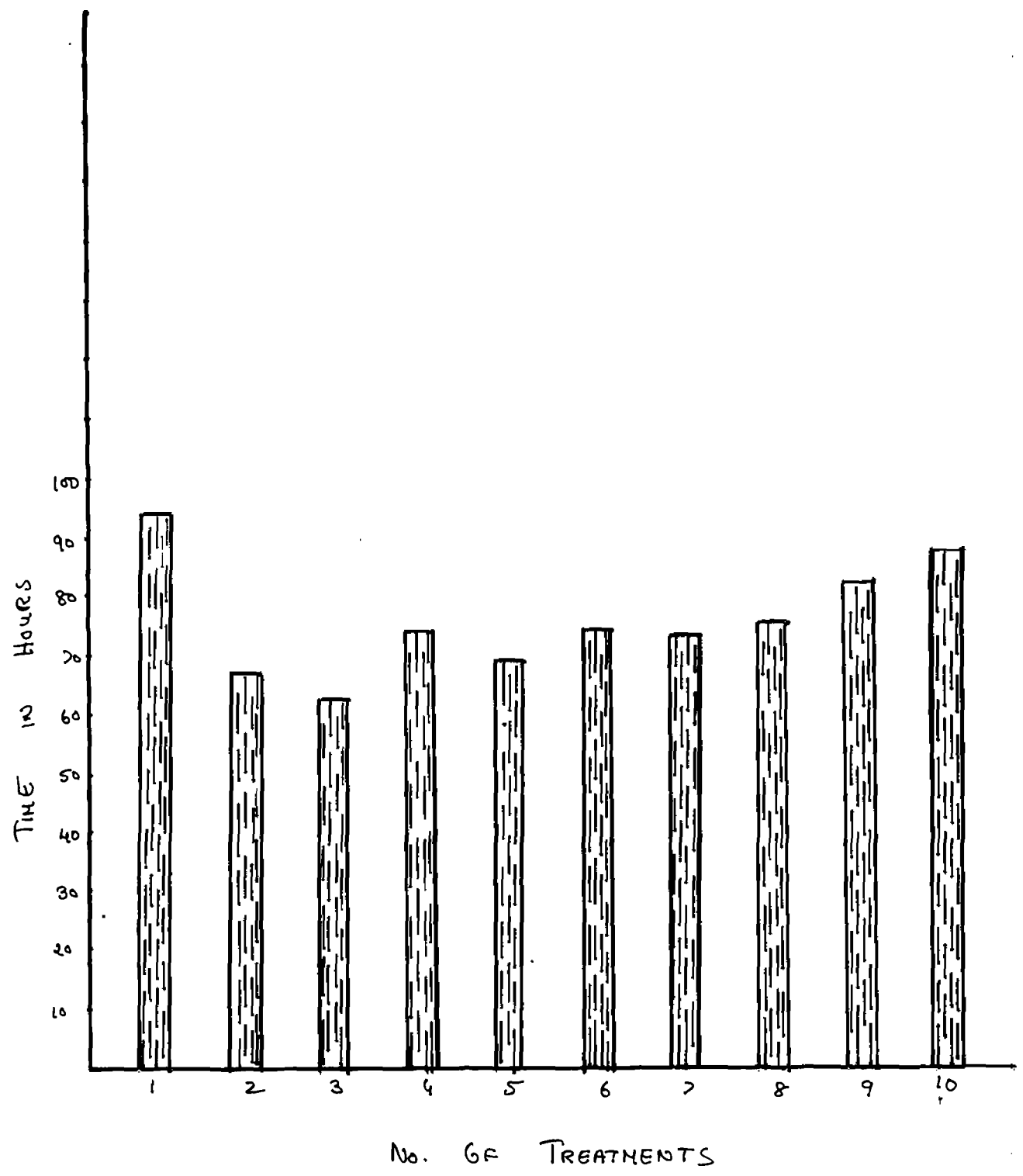


FIGURE - 9

TIME TAKEN FOR GERMINATION GF
'AMARANTHUS' SEEDS

TABLE - XIV

TIME TAKEN FOR EMERGENCE OF THIRD LEAF IN 'AMARANTHUS'

S.No.	Treatments	Time taken in hours			
		R ₁	R ₂	R ₃	Mean
1	T ₁	168	168	160	165.3
2	T ₂	144	160	144	149.3
3	T ₃	104	120	104	109.3
4	T ₄	144	120	144	136.0
5	T ₅	144	144	120	136.0
6	T ₆	160	144	168	157.0
7	T ₇	120	144	168	144.0
8	T ₈	120	144	120	128.0
9	T ₉	144	168	160	157.3
10	T ₁₀	168	144	168	160.0

Considering the growth of plant with regard to time taken for emergence of third leaf, it was observed that treatment (T₃) using dried spent cowdung slurry as manure took a minimum of 10.9 hours compared to that of control (T₁) which took a maximum of 165 hours. Both the treatments using dried cowdung

(T₄) and the compost using slurry +garbage (T₅) took 136 hours each whereas treatment (T₃) using a combination of dried spent cowdung slurry and inorganic manure took only 128 hours (Appendix III B).

Statistical analysis showed that the difference in treatments were significant. The favourable influence of spent cowdung slurry on time taken for the emergence of the third leaf indicates the role of digested dung in hastening the physiological activity of the plant.

3. Height of 'amaranthus' in relation to manurial treatments:

The height of 'amaranthus' in relation to manurial treatments is presented in Table IV and portrayed in Figure (10) and (11).

TABLE - XI

HEIGHT OF AMARANTHUS IN DIFFERENT TREATMENTS

S.No.	Treatments	Height in cms.			
		R ₁	R ₂	R ₃	Mean
1	T ₁	6.6	4.35	6.1	5.68
2	T ₂	14.3	10.75	15.0	13.35
3	T ₃	13.0	10.60	16.75	13.45
4	T ₄	16.1	16.40	7.80	13.43
5	T ₅	14.93	14.60	12.50	14.01
6	T ₆	14.90	12.83	13.80	13.84
7	T ₇	8.6	9.25	18.30	12.05
8	T ₈	11.30	7.80	11.25	10.11
9	T ₉	9.0	10.60	9.90	9.83
10	T ₁₀	8.16	8.8	9.66	8.87

'Amaranthus' grown in soil treated with compost prepared from spent cowdung slurry+garbage (T₅) showed a maximum growth in terms of height.

Treatments T₂, T₃, T₄ and T₆ using fresh spent cowdung slurry, dried spent cowdung slurry, dried cowdung and compost prepared from cowdung + garbage respectively recorded a height varying between 13.3 and 15.8 cm. The shortest growth (5.60 cm.) was observed in the case of control (T₁).

Eventhough profound differences were not observed among the organic and inorganic manurial treatments, they recorded higher value for the treatments height of plant compared to the control and the difference in the above treatments also attained the level of significance.

4. Thickness of stem of 'amaranthus' in terms of manurial treatments:

The thickness of 'amaranthus' stem in relation to manurial treatments is depicted in Table XVI.

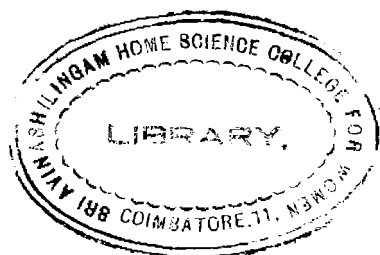
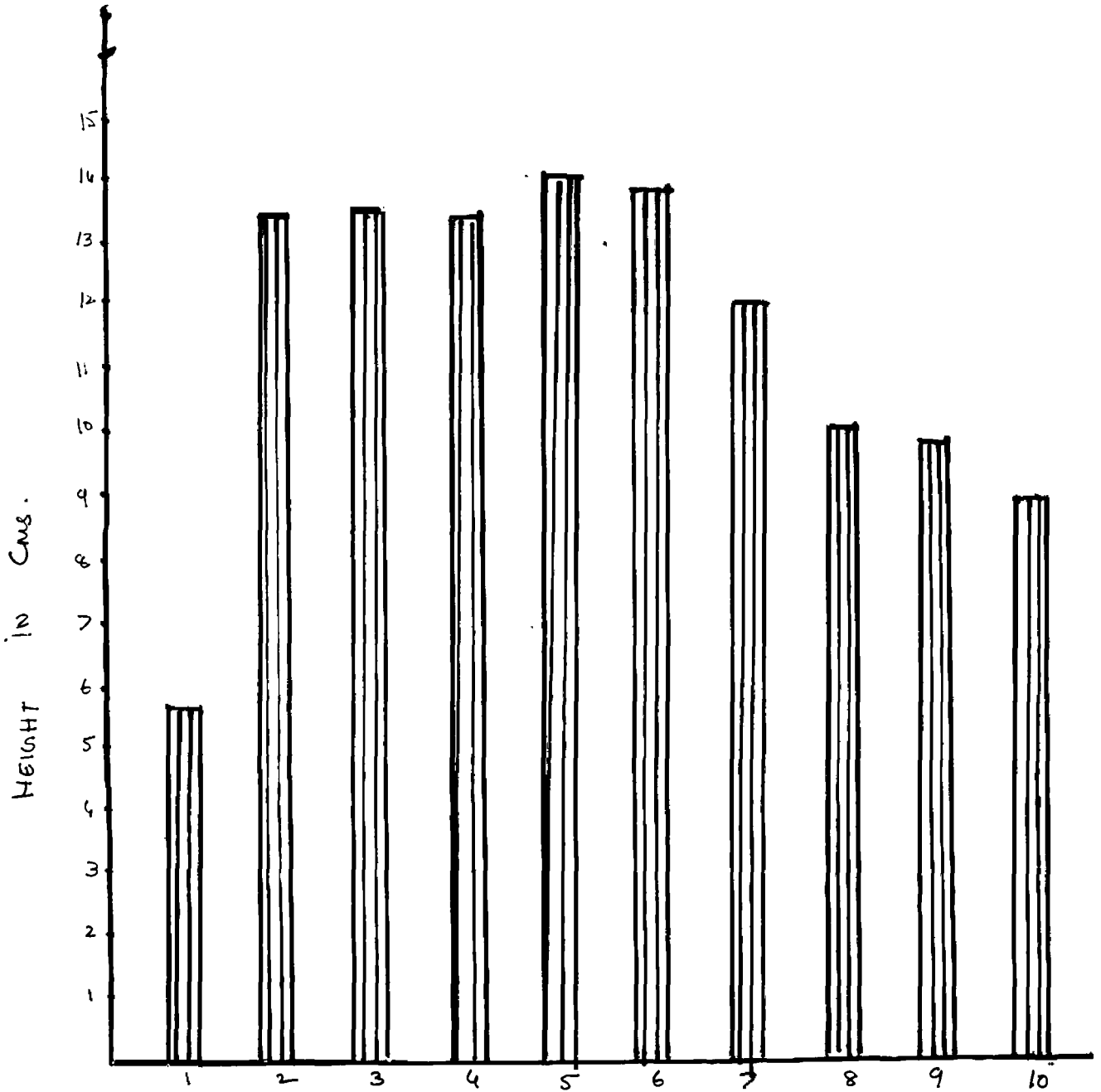




FIGURE - 10
GROWTH OF 'AMARANTHUS' PLANT.

SCALE

1 CM = 1 CM HEIGHT



No. OF TREATMENTS

FIGURE - II

HEIGHT OF 'ANARANTHUS' PLANT

TABLE - XVI

THICKNESS OF 'AMARANTHUS' STEM IN DIFFERENT TREATMENTS

S. No.	Treatments	Thickness in cms.			
		R ₁	R ₂	R ₃	Mean
1	T ₁	1.05	1.14	1.10	1.1
2	T ₂	1.77	1.90	1.94	1.87
3	T ₃	2.23	1.97	2.50	2.23
4	T ₄	2.39	2.42	1.55	2.12
5	T ₅	2.48	2.35	2.12	2.30
6	T ₆	2.39	2.22	2.06	2.22
7	T ₇	1.18	1.47	2.03	1.56
8	T ₈	1.80	1.60	1.83	1.78
9	T ₉	1.43	1.93	1.94	1.73
10	T ₁₀	2.16	1.90	2.30	1.85

The mean thickness of the stem in treatments T₃, T₄ and T₆ was found to be greatest ranging from 2.12-2.30 cm. as compared to treatments T₇, T₈, T₉ and T₁₀ which recorded a thickness between 1.56 and 1.85 cm. The thickness of stem had shown an increase when inorganic fertiliser was used in combination with organic manures as indicated by treatments (T₈, T₉ and T₁₀).

The thickness of stem in treatment (T₁) was found to be the minimum.

Statistically the differences observed among the treatments were found to non-significant (Appendix III D)

4. Yield of 'amaranthus' in relation to manurial treatments:

The effect of different manures on the yield was assessed by taking

a. Wet weight soon after harvest:

and b. Dry weight on oven dry basis

a. Wet weights:

The total yield obtained from the three replicates receiving the different treatments is given in Table; XVII and Figure 13.

TABLE XVII

WET WEIGHT OF AMARANTHUS GROWN USING SELECTED MANURIAL TREATMENTS

S.No.	Treatments	Wet weight in gm.			
		R ₁	R ₂	R ₃	Mean
1	T ₁	1.2	1.2	1.4	1.23
2	T ₂	8.9	12.7	7.0	9.53
3	T ₃	8.9	6.2	15.9	10.33
4	T ₄	12.4	12.3	3.4	9.33
5	T ₅	12.3	9.2	7.6	10.03
6	T ₆	4.3	6.9	9.0	6.73
7	T ₇	2.0	2.2	3.0	2.43
8	T ₈	6.0	5.6	4.2	5.26
9	T ₉	2.8	6.0	6.9	5.23
10	T ₁₀	6.9	4.5	6.0	5.80

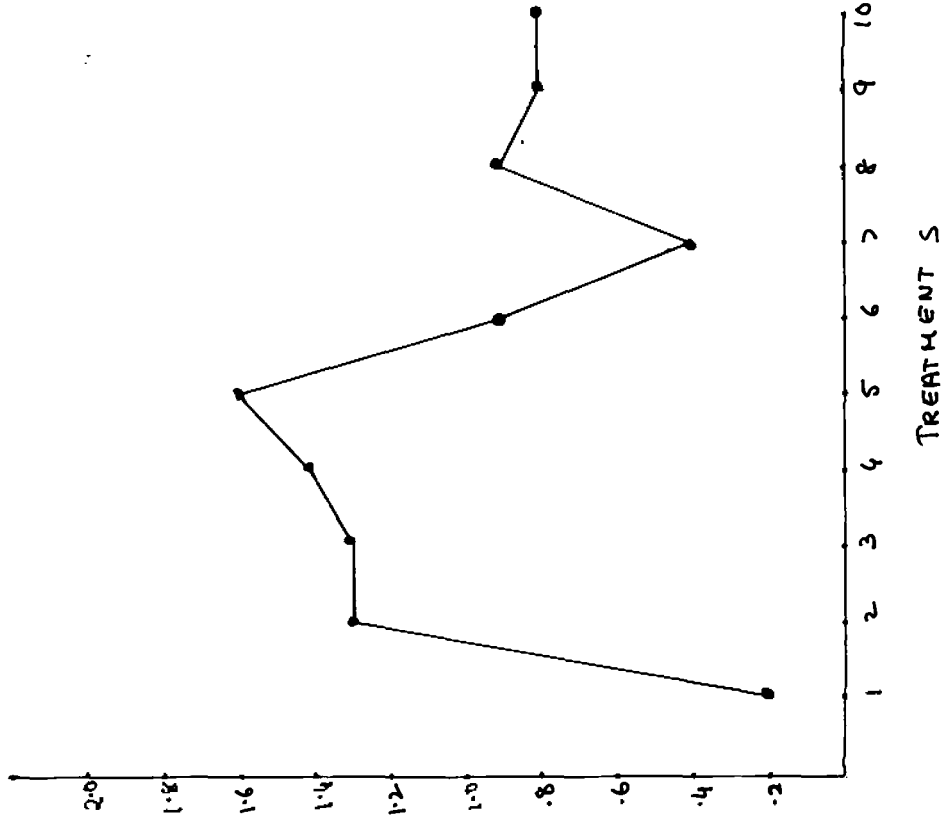
The treatment (T₃) using dried slurry as manure recorded the highest yield of 10.33g followed by treatment (T₄) using slurry + garbage compost. The treatment using fresh spent cowdung slurry (T₂) and dried cowdung (T₄) registered an approximate yield of 9.5g., while the control treatment registered the lowest yield of 1.23 g.

Statistically it was found that the treatments were significantly different from control (T₁). The treatments T₂, T₃, T₄, T₅, T₆, and T₇ were found to be on par. As observed in the biometric observation, the above results also clearly indicate the beneficial influence of organic manuring on growth of 'amaranthus' (Appendix III D).

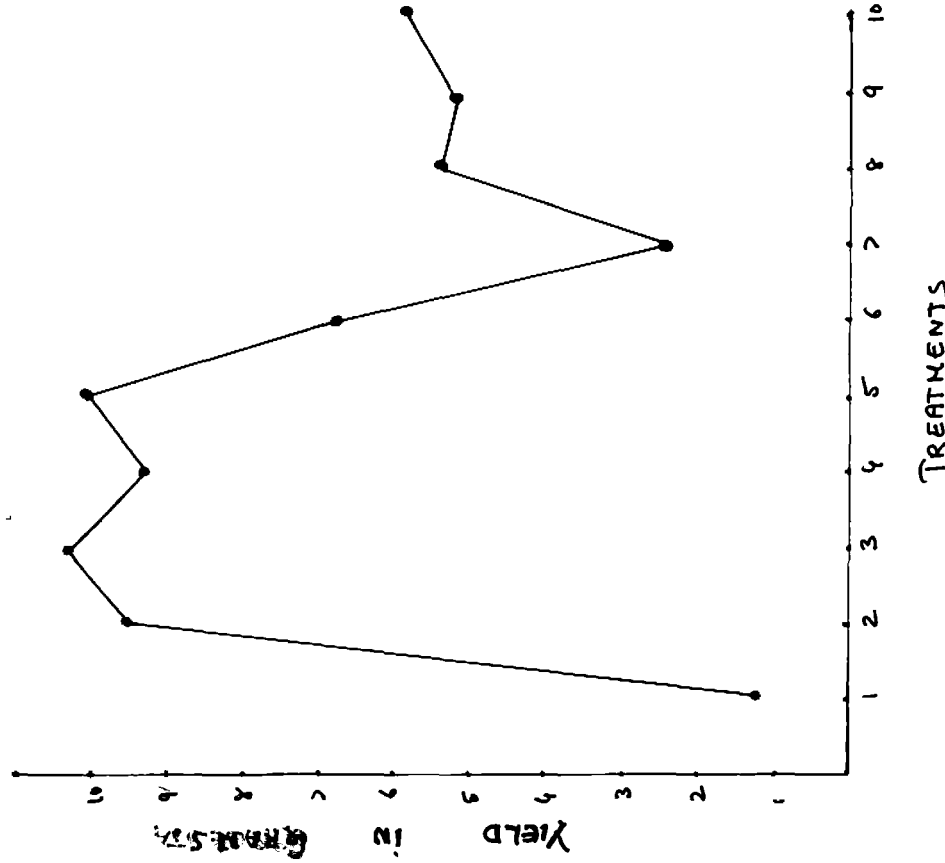
b. Dry weight

The mean dry weight of 'amaranthus' is given in the following Table ^{vii} and Figure (IX)

- A) 1cm = 1g.
- B) 1cm = .2g.



(B) Dry Weight



(A) Wet Weight

FIGURE-12
YIELD OF 'AHARANTHUS'

TABLE XVIII

DRY WEIGHT OF 'AMARANTHUS' GROWN USING SELECTED MANURIAL TREATMENTS

S.No.	Treatments	Dry weight in gm.			
		R ₁	R ₂	R ₃	Mean
1	T ₁	0.2	0.2	0.2	0.2
2	T ₂	1.4	1.6	1.0	1.3
3	T ₃	1.2	0.8	2.4	1.3
4	T ₄	2.1	1.8	0.3	1.4
5	T ₅	2.3	1.4	1.1	1.6
6	T ₆	0.5	1.0	1.1	0.9
7	T ₇	0.2	0.3	0.7	0.8
8	T ₈	0.8	1.0	0.9	0.9
9	T ₉	0.5	1.0	1.0	0.8
10	T ₁₀	1.0	1.0	0.4	0.8

The mean dry weight of the yield obtained from the various treatments indicated that an approximate yield of 1.3 - 1.6 g., on dry weight basis was obtained from T₂, T₃, T₄ and T₅. The yield from control(T₁) was found to be the least.

Statistically the treatments were found to be non significant.
(Appendix III E)

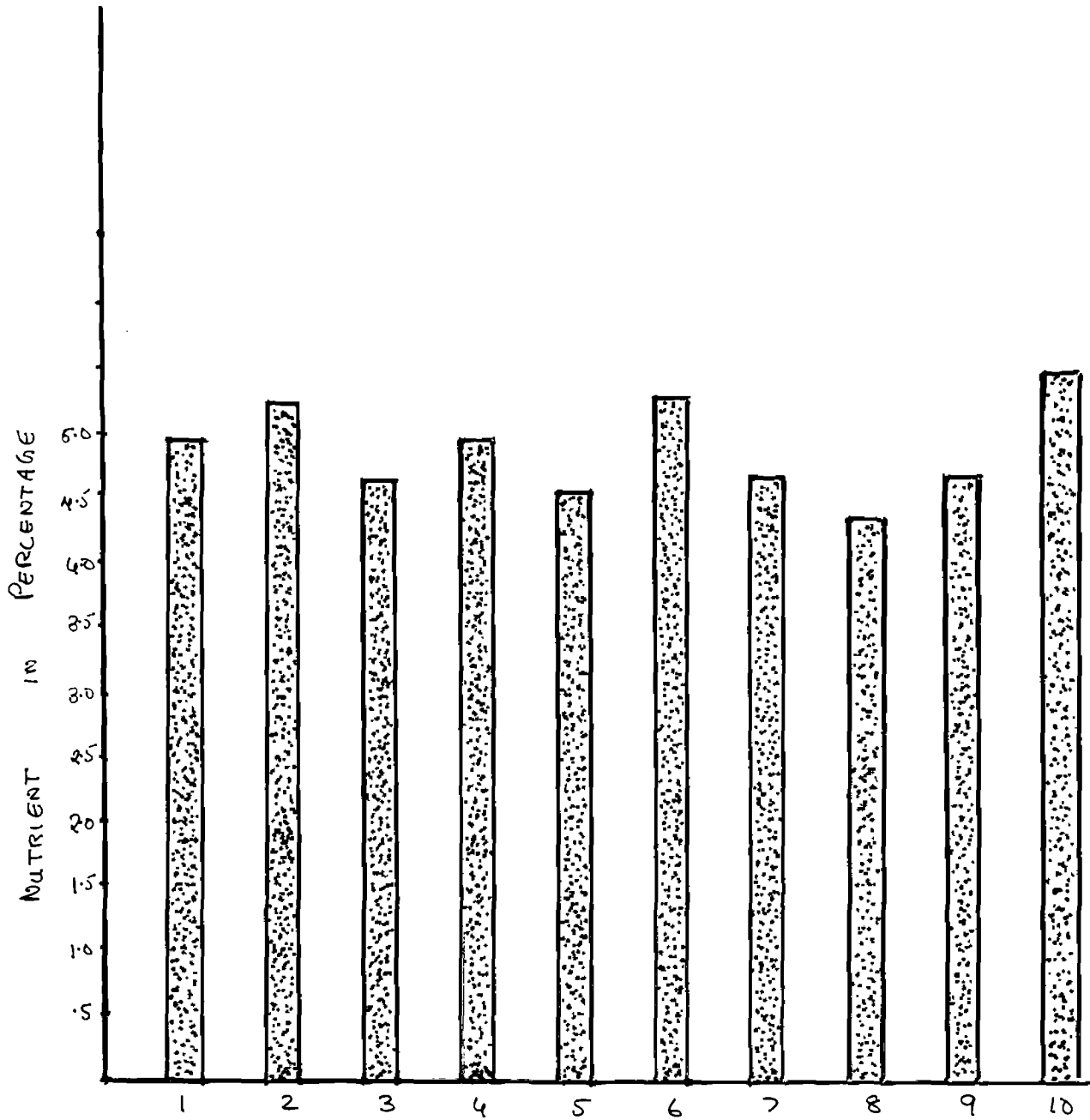
TABLE IX

NITROGEN, PHOSPHORUS AND POTASSIUM CONTENT OF 'AMARANTHUS' GROWN ^{USING} SELECTED MANURIAL TREATMENTS

S.No.	Treatment	Percentage of		
		Nitrogen	Phosphorus	Potassium
1	T ₁	4.9	0.15	4.3
2	T ₂	5.2	0.15	3.9
3	T ₃	4.6	0.20	4.5
4	T ₄	4.9	0.15	4.9
5	T ₅	4.5	0.15	4.5
6	T ₆	5.2	0.17	4.9
7	T ₇	4.6	0.15	4.1
8	T ₈	4.3	0.20	4.3
9	T ₉	4.6	0.20	4.3
10	T ₁₀	5.4	0.25	4.6

On analysis it was observed that plants grown in treatment (T₉) using cowdung and inorganic had the highest percentage of 5.4 nitrogen followed by plants treated using fresh spent cowdung slurry (T₂) and compost prepared from cowdung+garbage (T₆). The treatments T₃, T₄ and T₇ were also

SCALE
1cm = .5 PER CENT



No. OF TREATMENTS

FIGURE - 13

NITROGEN CONTENT OF 'AMARANTHUS' PLANT.

SCALE

1 cm = .5 PERCENT

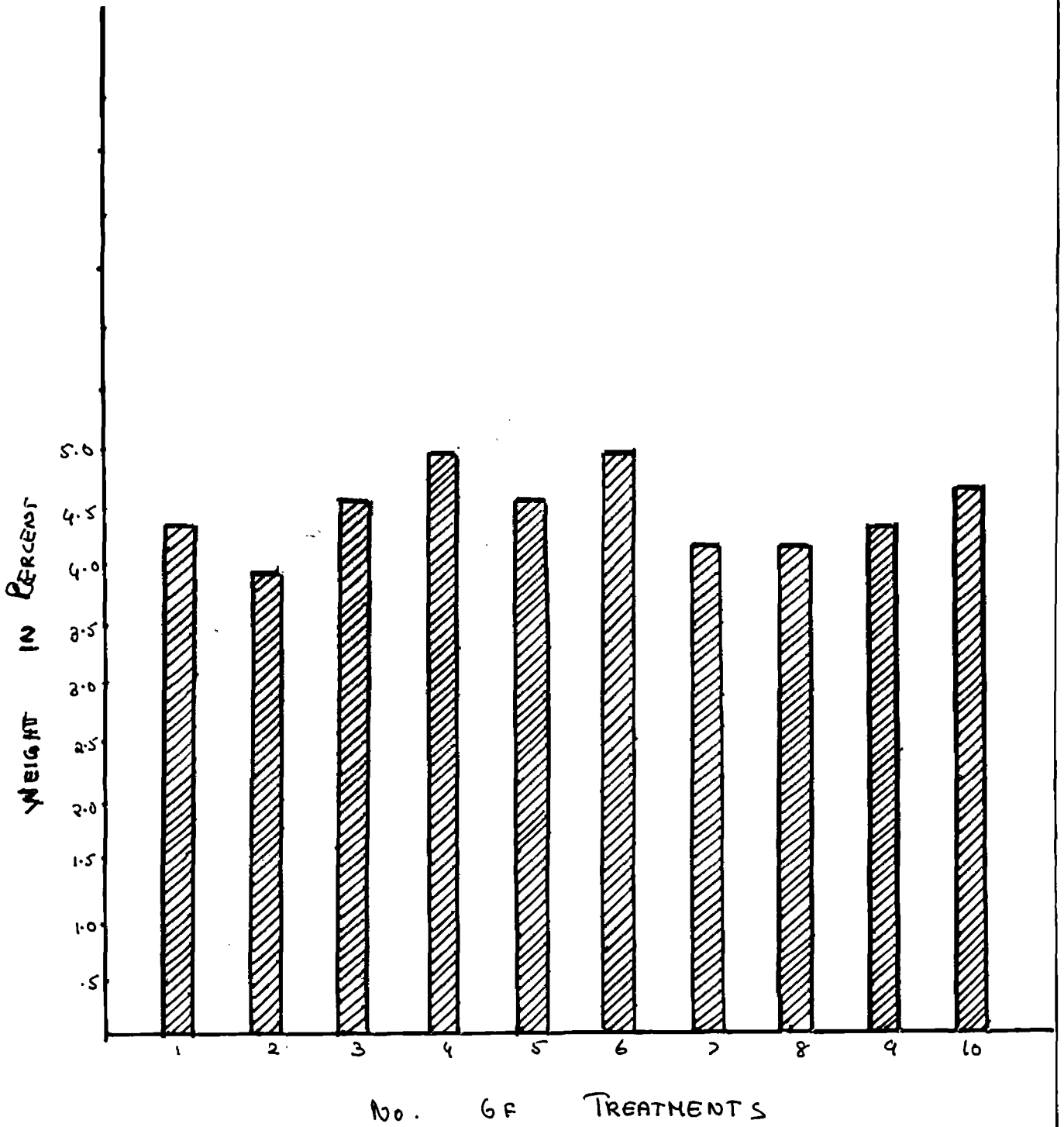


FIGURE - 14 .

POTASSIUM CONTENT OF 'ANARANTHUS'.

found to be rich in nitrogen content, ^(figure-13) In the case of phosphorus, plants grown using inorganic manures recorded a higher percentage. Potassium content was recorded to be high in the case of treatments T₁ (control), T₄ (dried spent slurry) and T₆ (compost from cowdung + garbage). (figure-14).

Thus it can be stated that application of organic manure enhanced the nutrient quality of the plant, since nitrogen constitutes the various amino acids, which in turn is the building block of proteins. The application of organic or inorganic manures did not have any profound influence on the potassium content of the plant.

The statistical scrutiny of the data pertaining to the study indicated that fertiliser application alone promoted the nitrogen and phosphorus content of 'amaranthus' (Appendices - III G, H F and I) .

b. Calcium and magnesium content of 'amaranthus'

The following data presented in Table XI and Figure (15) reveal the calcium and magnesium content of the selected plant samples.

TABLE - XI

CALCIUM AND MAGNESIUM CONTENT OF 'AMARANTHUS' GROWN USING SELECTED MANURIAL TREATMENTS.

S. No.	Treatments	Nutrients in percentage	
		Calcium	Magnesium
1	T	2.8	3.12
2	T	2.8	2.88
3	T	2.8	2.88
4	T	2.0	2.88
5	T	2.0	3.12
6	T	2.4	3.12
7	T	2.0	2.16
8	T	2.8	2.64
9	T	2.0	3.12
10	T	2.8	2.64

The calcium content was found to be the highest in the case of treatments T₁, T₂, T₃, T₈ and T₁₀, Substantial variation was not observed in between the treatments in the case of calcium content.

SCALE

1 CM = 2 PERCENT

KEY

xx - CALCIUM

■ - MAGNESIUM

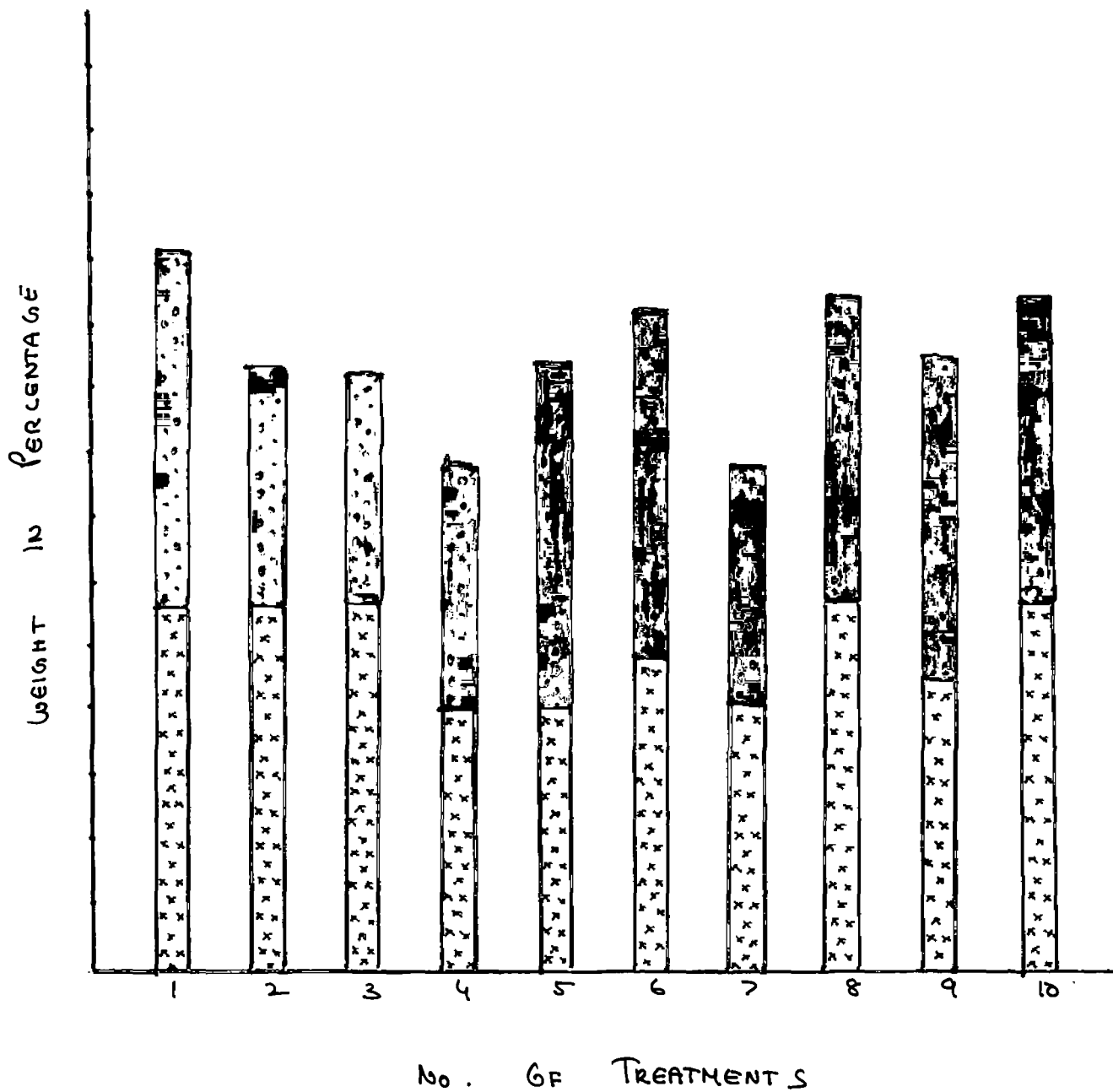


FIGURE - 15

CALCIUM AND MAGNESIUM CONTENT OF
 'AMARANTHUS'

Similar to calcium content of the plant material, appreciable variations were not observed in the case of magnesium content of different samples. The statistical analysis of the data pertaining to magnesium content was found to be significant. [APPENDIX III. k.].

It can thus be concluded that organic manures of spent cowdung slurry, compost prepared from spent cowdung slurry+garbage and cowdung+garbage improved the nitrogen content of the plant, and inorganic manure influenced the phosphorus content of the plant while the remaining nutrients were not influenced by any of the treatments.

V. SUMMARY AND CONCLUSION

The investigation on the Possibilities Of Utilising Home Garden Waste for Biogas Production and Organic Manure comprised the following major aspects.

- A. Utilisation of home garden waste for biogas production.
- B. Evaluation of manurial value of organic and inorganic manures.

A. Utilisation of Home Garden Waste For Biogas Production:

Four samples of waste such as neem leaves, banana stem, banana leaves and banana peels in combination with digested spent cowdung slurry and fresh cowdung to form proportions as 1:1:1, 2:1:1, 3:1:1, 4:1:1 and 5:1:1 were selected for biogas production.

The gas production was recorded for eight weeks in case of neem leaves base and from the fifth to the eighth week in the case of banana refuse base. The percentage of methane was estimated for the first, second and fifth weeks in neem leaves base and at the end of the eighth week in banana refuse base.

The nutrient analysis for nitrogen, phosphorus and potassium content in the digested residues was carried out towards the end of the study.

B. Evaluation of Manurial Value of Organic and Inorganic Manures:

Ten treatments as T₁ - control, T₂ - fresh spent cowdung slurry
 T₃ - dried spent cowdung slurry, T₄ - dried cowdung, T₅ - fresh spent
 cowdung slurry+garbage, T₆ - fresh cowdung+garbage, T₇ Inorganic, T₈ dried
 spent cowdung slurry+ Inorganic, T₉ fresh slurry + Inorganic and T₁₀ dried
 cowdung+ Inorganic were selected for pot experiment using red soil and co-
 variety 'amaranthus' seeds.

Urea, super phosphate, murate of potash, fresh and dried spent cowdung
 slurry, dried cowdung and compost

- a. Prepared with a combination of spent cowdung slurry+garbage and
- b. With a combination of cowdung+garbage were selected to study the
 effect of these manures on plant growth in terms of yield and
 nutrient content.

Biometric and chemical analyses were done for plant samples collected
 on the 25th day.

The findings of the various aspects of the study are as given below:.

1. Banana stem in combination with cowdung and spent cowdung slurry in
 equal proportion generated a maximum amount of 39 litres of gas.
2. Both neem leaves and banana leaves generated approximately 31 litres
 of gas when used in the proportion 5:1:1 with fresh cowdung and spent
 cowdung slurry.

3. Banana peels as base in the five proportions produced only a negligible amount of gas varying between 8-14 litres.
4. Biogas generated from neem leaves, banana stem and banana leaves had a high percentage of methane ranging between 189 and 699 percent being 12 times greater than gobar gas considered as standard.
5. A high percentage of methane about 262 litres was generated in proportion (3) of neem leaves.
6. Similarly a high percentage ranging between 600-650 percent was registered in proportion (1) in banana stem and in proportion (5) of banana leaves being 10 times greater than that of gobar gas.
7. Percentage of methane was low in biogas produced from banana peels compared to other waste proportions selected.
8. In the digested residues ^{of} the selected samples, sizable difference could not be noted in terms of nitrogen, phosphorus and potassium.
9. The digested residues of the samples registered a higher percentage of NPK compared to that of spent cowdung slurry from gobar gas plant.
10. Nitrogen content in slurry and compost was 2.1 percent and 1.6 percent respectively which indicated the richness of slurry in terms of nitrogen content.

11. Early germination of seeds was noted in pots treated with cowdung slurry.
12. Plants registered a maximum height of 143 cms during the 25 days study period when treated with compost prepared from cowdung + garbage (T₅) and that of fresh spent cowdung slurry (T₂) and dried spent cowdung slurry (T₃).
13. A higher yield in terms of weight was registered from a combination of organic and inorganic fertilisers.
14. There was no significant difference in the nutrient content of 'amaranthus' in different treatments except in nitrogen and calcium which were considerably high in treatments using cowdung slurry as manure.

Hence it can be concluded that neem leaves and banana refuse often dumped into pits can well be utilised for optimising production of biogas with higher percentage of methane, which can thereby reduce the expenditure on fuels. The efficient recycling of these garden wastes in an anaerobic digestion unit may not only result in saving of fuel money, but also in increased production of crops by utilising the rich manure left as digested residue as plant food.

The present study, a humble effort to utilise selected waste for biogas production, throws light on the possibility of recycling several other organic waste materials considered as pollutants harmful to human existence.

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APPENDICES

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APPENDIX - I

PROCEDURE FOR ANALYSIS OF DIGESTED TEST RESIDUE

Analysis of Compost for Nitrogen, Phosphoric Acid and Potash.

Procedures:

Nitrogen was estimated by Kjeldahl's method and Phosphoric acid and Potash were estimated by precipitating them as phospho ammonium molybdate and sodium potassium cobalt nitrate from the Hcl extract.

The estimations were carried out as detailed—Nitrogen was estimated by Kjeldahl's method, Hcl extract was taken and from that Phosphoric acid and potash were estimated volumetrically, by precipitating as ammonium phosphomolybdate and sodium, potassium cobalt nitrate respectively.

A. Estimation of Nitrogen:

About 2.0 gms of the sample was digested with concentrated ^{rat} H₂SO₄, Potassium sulphate and copper sulphate and distilled. The distillation was carried out with conc. 40% NaOH. The evolved ammonia was treated in a known excess of N/10 H₂SO₄ taken in a ice tumbler. When the evolution was over the excess of N/10 H₂SO₄ left over was back titrated against N/10 KOH, using methyl red as indicator from the titre value the amount of nitrogen was calculated.

B. Phosphoric Acid:

5.0 gms of the material was digested with Conc. Hcl (30 c.c) for eight times. The extract was collected in a 500ml volumetric flask.

The volume was made upto 50ml with distilled water. From the extract 20ml of the liquid was taken and P_2O_5 was precipitated in acid media with precipitating mixture (20ml of ammonium molybdate and 7:3 HNO_3 and H_2O). The precipitate was washed free of acid and dissolved in a known excess of 0.1619 N, KOH. The excess of 0.1619 N was back titrated against 0.1619 N HNO_3 using Phenolphthalin as indicator. From the titre value, the amount of phosphoric acid was calculated.

C. Potassium:

From the Hol extract 50ml was pipetted out into a silica dish and evaporated to dryness. It was cooled and with the addition of and vigorous stirring with 1.5ml of glacial acetic acid, 10ml of sodium chloride, .5ml of $NaNO_2$ and 5ml of cobalt intrate, potash was precipitated. The precipitate was left overnight and then filtered using good crucible with asbestos. First, the precipitate was washed with 35 percent alcohol and then with distilled water 3 or 4 times. The precipitate was dissolved in a known quantity of 0.1N $KMnO_4$. The contents was then titrated against N/10 oxalic acid. From the titre value, the amount of Potassium was calculated.

APPENDIX - II

PROCEDURE FOR PLANT MATERIAL ANALYSIS

A. For Nitrogen

0.2gm well powdered plant material was taken and digested with Sulphuric acid using, Potassium Sulphate and Copper sulphate as catalyst. The digested material was made up to known volume, A known aliquote was distilled after adding excess alkali. The distillate was collected in boric acid and it was titrated against N/50 H_2SO_4 . The indicator used was the double indicator (Bromocrysol green and methyl red). From the titre value nitrogen percent was calculated.

B. Phosphoric Acid

0.5g of the material was subjected to wet digestion (Sulphuric acid, perchloric acid and Nitric acid mixture). The digested material was made up to known volume. .5ml of the liquid was taken and Ammonium meta borate was added and the Vanade molybdo phosphoric yellow colour was developed and it was read in the calorimeter. From the reading, the phosphoric acid content was calculated.

C. Potassium

The aliquote mentioned under phosphoric was directly fed into the flame photometer and from the reading the potassium content was calculated.

D. Calcium and Magnesium

Known aliquots from the material mentioned under P was taken and titrated against 0.02 N EDTA using erichrom blackdate as indicator. This gives the titre value for Calcium and Magnesium. Moreover for this titration the buffer solution was also added before starting the titration. For estimating Calcium alone, known aliquots was taken and titrated against 0.2 N EDTA using murexide as indicators. Here before starting the titration excess amount of 10N NaOH was added. This gives the titre value for Calcium alone.

By subtracting Calcium value from Calcium + Magnesium, the titre value for Magnesium was arrived and the content of Calcium and Magnesium were worked out.

APPENDIX - III

ANALYSIS OF VARIANCE FOR BIOMETRIC OBSERVATION
THE 'F' RATIO FOR GERMINATION OF SEEDS.

COMPARISON OF TREATMENTS:

S. No.	Source of Variance	D.F	S.S	M.S	F
1	Treatments	9	2515.2	279.466	2.656 *
2	Replications	2	357.07	178.535	
3	Error	18	1893.6	105.2	
Total		29			

Means

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	S.E	C.D
95.6	68.0	64.0	74.6	70.6	74.6	74.0	76.3	83.3	89.3	8.37	17.5

Conclusions:

T₁ T₁₀ T₉ T₈ T₇ T₆ T₅ T₄ T₃ T₂

Notes

S.E. : Standard error difference

C.D. : Critical difference

* : Significant at 5 percent level

*(Any two means differing, greater than the C.D. are said to be significant)

B. The 'F' Ratio for the Arrival of the Third Leaf: Comparison of Treatments:

S. No.	Source of variance	D.F	S.S	M.S	F
1	Treatment	9	8040.53	893.39	4.5 **
2	Replication	2	106.67	53.33	
3	Error	18	3562.67	197.92	
Total		29			

Mean:

T ₁	T ₂	T ₄	T ₅	T ₇	T ₈	T ₉	T ₁₀	S.E	C.D
165.3	149.3	109.3	136.0	144.0	128.0	157.3	160.0	11.48	24.13

Conclusion

T₁ T₁₀ T₉ T₇ T₅ T₄ T₂ T₈ T₃

Notes

** Significant at 1 percent level

G. The 'F' Ratio for the Length of Amaranth Plant: Comparison of Treatments:

S. No.	Source of Variance	D.F	S.S	M.S	F
1.	Treatment	9	205.4046	22.823	2.88 *
2	Replication	2	12.1275	6.0638	
3	Error	18	142.8074	7.934	

Means

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	S.E.	C.D
5.68	13.35	13.45	13.43	14.00	13.84	12.05	10.11	9.83	8.87	4.75	2.685

Conclusion:

T ₁	T ₁₀	T ₉	T ₈	T ₇	T ₆	T ₅	T ₄	T ₃	T ₂
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Notes:

* Significant at 5 per cent level.

D. THE 'F' RATIO FOR THE THICKNESS OF AMARANTHUS STEM: COMPARISON OF TREATMENTS

S.No	Source of Variance	D.F	S.S	M.S	F
1	Treatments	9	3.8707	0.4300	0.35 *
2	Replication	2	0.01613	0.008	
3.	Error	18	1.41007	0.0783	
	Total	29			

Conclusions: N.S.

Notes:

* N.S. Non Significant

THE 'F' RATIO FOR THE WET WEIGHT OF AMARANTHUS YIELD: COMPARISON OF TREATMENTS

S. No.	Source of Variance	D.F	S.S	M.S	F
1	Treatments	9	277.1163	30.79.7	4.01 **
2	Replication	2	25.1687	12.584	
3	Error	18	138.1847	7.677	
Total		29			

Means

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	S.E	C.D
1.23	9.53	10.33	9.33	10.13	6.73	2.43	5.60	5.23	5.60	0.26	4.01

Conclusions

T₂ T₃ T₄ T₅ T₉ T₁₀ T₈ T₇ T₆ T₁

Notes:

** Significant of 1 per cent level.

F. THE 'F' RATIO FOR THE DRY WEIGHT OF AMARANTHUS YIELD: COMPARISON OF TREATMENTS

S. No.	Source of Variance	D.F	S.S	M.S	F
1	Treatment	9	5.8213	0.6468	0.35 *
2	Replication	2	0.074	0.037	
3	Error	18	4.9127	0.272	
Total		29			

Conclusion:

N.S.

Note:

* N.S: Non Significant.

6) THE 'F' RATIO FOR NITROGEN CONTENT OF PLANT MATERIAL

S. No.	Treatments	Replications			Total	Mean
		R ₁	R ₂	R ₃		
1	T ₁	4.7	5.1	4.9	4.9	4.9
2	T ₂	4.9	5.3	5.4	15.6	5.2
3	T ₃	4.6	4.7	4.5	13.8	4.6
4	T ₄	5.0	4.9	4.8	14.7	4.9
5	T ₅	4.5	4.6	4.4	13.5	4.5
6	T ₆	9.2	4.9	5.5	19.6	6.5
7	T ₇	4.6	4.6	4.6	13.8	4.6
8	T ₈	4.4	4.3	4.2	12.9	4.3
9	T ₉	4.7	4.5	4.6	13.8	4.6
10	T ₁₀	5.5	5.4	5.5	16.4	5.4
Total		48.1	48.3	48.4	144.8	

COMPARISON OF TREATMENTS

S. No.	Source of Variance	D.F	S.S	M.S	F
1	Treatments	9	3.713	0.4125	14.8 **
2	Replications	2	0.606	0.003	
3	Error	18	0.501	0.0278	

Means

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	S.E	C.D
4.9	5.2	4.6	4.9	4.5	5.2	4.6	4.3	4.6	5.4	0.04	0.093

Conclusion:

$\overline{T_2 T_6}$ $\overline{T_1 T_4}$ $\overline{T_3 T_7 T_9}$ $T_5 T_8 T_{10}$

Note

** Significant at 1 percent level

H)

THE 'P' RATIO FOR PHOSPHORUS CONTENT OF PLANT

S.No	Treatment	Replications			Total	Mean
		R ₁	R ₂	R ₃		
1	T ₁	0.16	0.15	0.14	0.45	0.15
2	T ₂	0.14	0.16	0.15	0.45	0.15
3	T ₃	0.19	0.19	0.22	0.60	0.20
4	T ₄	0.15	0.15	0.15	0.45	0.15
5	T ₅	0.16	0.16	0.13	0.45	0.15
6	T ₆	0.18	0.16	0.17	0.51	0.17
7	T ₇	0.16	0.15	0.14	0.45	0.15
8	T ₈	0.22	0.24	0.20	0.66	0.22
9	T ₉	0.19	0.21	0.60	0.20	0.20
10	T ₁₀	0.26	0.24	0.25	0.75	0.25
T _{total}		1.82	1.79	1.76	5.37	

COMPARISON OF TREATMENTS

S. No.	Source of Variance	D.F	S.S	M.S	F
1	Treatments	9	0.0357	.00397	23.9 **
2	Replications	2	0.00021	0.00015	
3	Error	18	0.00299	.000166	
Total		29			

Mean:

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	S.E	S.D
0.15	0.15	0.20	0.15	0.15	0.17	0.15	0.22	0.20	0.25	0.003	0.007

Conclusion:

$\overline{T_1 T_2 T_4 T_5}$	$\overline{T_3 T_9}$	T_6	T_8	T_{10}
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Note:

** Significant at 1 per cent level

1) THE 'F' RATIO FOR POTASSIUM CONTENT OF PLANT MATERIAL

S. No.	Treatments	Replications			Total	Mean
		R ₁	R ₂	R ₃		
1	T ₁	4.4	4.2	4.2	12.9	4.3
2	T ₂	4.0	3.9	3.8	11.7	3.9
3	T ₃	4.6	4.6	4.3	13.5	4.5
4	T ₄	4.9	4.9	4.9	14.7	4.9
5	T ₅	4.5	5.3	4.7	13.5	4.5
6	T ₆	4.8	5.0	4.9	14.7	4.9
7	T ₇	4.1	4.2	4.0	12.3	4.1
8	T ₈	4.2	4.2	3.9	12.3	4.1
9	T ₉	4.2	4.2	4.5	12.9	4.3
10	T ₁₀	4.2	4.2	4.5	13.8	4.3
Total		44.4	44.2	43.7	132.3	

COMPARISON OF TREATMENT

S. No.	Source of Variance	D.F	S.S	M.S	F
1	Treatments	9	2.150	.239	13.27 **
2	Replications	2	0.029		
3	Error	18	0.331		
Total		29			

Mean :

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀
4.3	3.9	4.5	4.9	4.5	4.9	4.1	4.1	4.3	4.6

S.E C.D
0.10 0.23

Conclusions:

T₄ T₆ T₁₀ T₃ T₅ T₉ T₈ T₇ T₂ T₁

Notes:

** Significant at 1 per cent level

APPENDIX VII

J) THE 'F' RATIO FOR CALCIUM CONTENT OF PLANT MATERIAL

S. No.	Treatments	Replications			Total	Mean
		R ₁	R ₂	R ₃		
1	T ₁	2.7	2.9	2.8	8.4	2.8
2	T ₂	2.8	2.8	2.8	8.4	2.8
3	T ₃	2.6	2.8	3.0	8.4	2.8
4	T ₄	1.9	2.1	2.0	6.0	2.0
5	T ₅	2.0	2.1	1.9	6.0	2.0
6	T ₆	2.6	2.2	2.4	7.2	2.4
7	T ₇	2.0	2.0	2.0	6.0	2.0
8	T ₈	2.8	2.9	2.7	8.4	2.8
9	T ₉	1.9	1.9	2.2	6.0	2.0
10	T ₁₀	2.7	2.8	2.9	8.4	2.8
Total		24.0	24.5	24.7	73.2	

COMPARISON OF TREATMENTS

S.No.	Source of Variance	D.F	S.S	M.S	F
1	Treatments	9	4.272	0.4746	2.409 **
2	Replications	2	0.026		
3	Error	18	3.546		
Total		29			

Mean:

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀	S.E	C.D
2.8	2.8	2.8	2.0	2.0	2.4	2.0	2.8	2.0	2.8	0.19	0.4

Conclusions

T₁ T₂ T₃ T₆ T₁₀ T₄ T₅ T₇ T₈ T₉

Notes

** Significant at 5 percent level

THE 'F' RATIO FOR MAGNESIUM CONTENT OF PLANT MATERIAL

S. No.	Treatments	Replications			Total	Mean
		R ₁	R ₂	R ₃		
1	T ₁	3.11	3.12	3.13	9.36	3.12
2	T ₂	2.89	2.87	2.88	8.64	2.88
3	T ₃	2.88	2.76	3.00	8.64	2.88
4	T ₄	2.88	2.87	2.89	8.64	2.88
5	T ₅	3.11	3.13	3.12	9.36	3.12
6	T ₆	3.13	3.11	3.12	9.36	3.12
7	T ₇	2.13	2.18	2.17	6.48	2.16
8	T ₈	2.64	2.65	2.63	7.92	2.64
9	T ₉	3.11	3.11	3.14	9.36	3.12
10.	T ₁₀	2.64	2.64	2.64	7.92	2.64
Total		28.52	28.44	28.72	85.62	

COMPARISON OF TREATMENTS:

S. No.	Source of Variance	D.F	S.S	M.S	F
1	Treatments	9	2.578	0.286	258.011 **
2	Replications	2	0.0613		
3	Error	18	0.0325	0.00181	
Total		29			

Mean:

T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	T ₇	T ₈	T ₉	T ₁₀
3.12	2.88	2.88	2.88	3.12	3.12	2.16	2.64	3.12	2.64

Conclusion:

T₁ T₂ T₃ T₄ T₅ T₆ T₇ T₈ T₉ T₁₀

Note:

** Significant at 1 per cent level.

