THE EFFECTS OF AMENDED MOLASSES WASTEWATER ON THE GROWTH PROGRESS, NUTRITION AND YIELD OF *Capsicuum annuum* ON ACIDIC SOILS OF KENYA

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A THESIS SUBMITTED TO THE SCHOOL OF SCIENCE, DEPARTMENT OF CHEMISTRY AND BIOCHEMISTRY IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE IN CHEMISTRY, UNIVERSITY OF ELDORET, KENYA.

NOVEMBER, 2015

DECLARATION

Declaration by the Candidate

This thesis is my own original work and has not been presented for the award of any degree in any institution.

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DEDICATION

To God who is the source of life, knowledge, inspiration and the witty inventions being made daily in the world be all the glory, honour and majesty forever and ever.

ABSTRACT

Little research work has been done especially on increasing effects of soil acidity on crop production due to long periods of chemical fertilizer use in North Rift region especially Uasin Gishu and Nandi Counties. Moreover, very little published data on fertilizer requirements is available to the farmers.The wastewater produced by Muhoroni Agro-Chemicals Company is 1.2 litres a day and is causing environmental pollution in the area thus requiring a safer way of disposal. Field and greenhouse experiments were conducted for two seasons at the two different locations that is Kaiboi in Nandi County and University of Eldoret in Uasin Gishu to study the effects of the amended molasses waste water fertilizer on the growth, nutrition and yields of *Capsicuum annum*.The seeds of the crop were obtained from the Kenya Seed company distributer in Eldoret. The crop was chosen because it has certified seeds in the market; the cultivar produces harvestable fruits within a measureable time and is sensitive to acidic soils. The wastewater was obtained from Muhoroni Agro-chemicals and Food Company, while biogas effluent was from University of Eldoret and were analyzed using atomic absorption spectrophotometer, colorimetry and flame photometer for anions such as phosphates,nitrate and cations such as Na^{+},K^{+},Mg^{2+},Ca^{2+},Fe^{3+},Zu^{2+},Cu^{2+},including heavy metals such as Cd^{2+},Pb^{2+} and Cr^{3+}.Lime was obtained from Koru, Kisumu County is 49% CaO.Soil samples taken during cropping seasons were used to determine soil chemical properties changes .Ascorbic acid was determined by redox titration while solubility was done by electrical conductivity .The soil pH had 1.51 units increase in the greenhouse experiments while the field experiments change was 0.94 units for biogas effluent, lime and wastewater treatment. Also, organic carbon, Olsen Phosphorous and extractable calcium increased in all treatments except DAP which showed remarkable decrease in pH of 0.48 units.Economic analysis of treatments showed waste water, biogas efficient and lime treatment with the highest yields of 18.998 tonnes per hectare and net profit of about US$ 2,700 per hectare.Two way analysis of variance indicated that treatment effects were significant but season (season I and II) in location effects (green house or field) was not significant.The studyrecommends land use of waste water as fertilizer for economic agricultural production and reversal of increasing soil acidity.

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ACKNOWLEDGEMENT

I acknowledge with gratitude the scientific assistance offered by my Supervisors Dr. Arusei M.K and ProfessorNdalutP.K. I acknowledge the effort of all these who contributed to the success of this thesis especially my colleague Ezekiel Bore of Chemistry department Mr. Rotich of Mathematics department and the staff of soil science department, University of Eldoret who assisted in the technical analysis of the various samples.

Special thanks go to my parents especially my late mother for their spiritual, moral and financial support which laid the strong foundation for my education in life

CHAPTER ONE

INTRODUCTION

1.1 General Introduction

The bell pepper genotype used in this experiment is *Capsicuumannuum* L with the common name California wonder.Peppers Capsicum exhibit a wide variety of shapes, sizes, colours and tastes than most garden vegetables .They can be classified into three categories, hot, mild and sweet-tasting fruits .They produce a large yield in a small amount of space, making them suited for even small gardens. Their popularity with gardeners also can be attributed to their unique taste and visual attractiveness Dickerson, (2002). Pepper pungency is determined by the amount, location and types of the compound Capsicuum (Capsaicinoids) which vary from sweet to hot and are generally produced in the fruit .They are produced by the glands associated with the placenta in the centre of the pod where the seeds are produced .The source of the pungency are not the seeds although they may absorb some of the Capsaicinoids when cooked .Cool growing conditions decreases pungency while water stress increases it Salunke, (1998).

This bell pepper is a rich source of alkaloids (Capsaicin) fatty acids, flavonoids volatile oil and carotene pigment. It is rich in vitamin C and Zinc; two nutrients which are vital for strong and healthy immune system. It also contains iron, calcium,potassium,magnesium,phosphorous,sulphur,B-complex vitamins, sodium and selenium.It is eaten raw and can be cooked both as mature and immature fruits insalsas,salads,stuffing,roasting and cooked vegetable dishes. Acidic soils, poor in organic matter and water logged are not suitable for the pepper Dickerson, (2002). The study was carried out to monitor the effect and nutritional implications of the amended waste water fertilizer on both the growth and yields of California wonder and the study area soils.Mugambi, (1975) observed a decline in soil pH, organic Carbon, total and extractable P to plants when working with most Kenyan soils. This poses a threat to food production in the nation .Hence use of industrial waste such as molasses fermentation waste water which has a high organic carbon matter content can be used to enhance growth of food crops,improvement of soil pH which contributes in improving food security both locally and regionally.Poor diets are a characteristic of most households in the rural settings.There is need to improve on this aspect by ensuring production of crops that improve on human health like this California wonder and other vegetable .Food security is an important aspect in all life studies on how to improve yields and nutrition value of crops or plants will go a long way in minimizing food insecurity in Kenya and healthy risks in most people.

1.2 Statement of the problem

Decreasing soil pH,organic carbon and extractable soil phosphorus results in low yields of crops which are of poor nutritional value.California wonder for instance, has a production of 2.5tonnes per hectare.The prices of imported inorganic fertilizers have gone up and are unaffordable to most farmers. This has led to a decline in food production locally and has led to escalation of food prices.The molasses fermentation waste water produced by Agro-Chemical and Food Company is in large quantity that is about 1.2 million liters daily with brown color and bad oduor. This is acting as an environmental pollutant affecting both human and aquatic life that depends on water of River Nyando where the water is discharged to. The waste water has a pH of 9.12 and hence a better substance to neutralize acidic soils and can be used to improve the poor soils.Prolonged use of chemical fertilizer increases soil acidity which results in declining crop production due to low soil extractable phosphorous, nitrogen, calcium and organic carbon which are essential elements for good plant establishment.

1.3 Justification

Muhoroni Agro-chemicals and food company produces about 1.2 litres of molasses fermentation wastewater daily which is discharged to River Nyando. This causes both air and water pollution. The management of the company asked Prof.P.K.Ndalut of University of Eldoret to propose a technology to purify the waste water because of the environmental concerns. The luxurious growth of vegetation and grasses hinted an idea this could be used as an organic fertilizer since it was basic. Due to perennial chemical fertilizer use over the years in the region there has been depletion of organic carbon in the soils which in essential for plant because these fertilizers lack elemental carbon.

1.4 Objectives

(i) To determine the effects of molasses fermentation waste water on the acidic and infertile soils nutrient composition.

(ii) To determine the solubility of lime in waste water

(iii) To evaluate the growth performance nutrition and yields of California wonder fruits when treated with amended waste water fertilizer.

(iv) To determine the effects of the organic fertilizer across season and location.

1.5 Specific Objectives

(i) To determine the effects of molasses fermentation waste water on the decreasing soil pH.

(ii) To investigate the effect of the amended waste water fertilizer in the soil chemical properties specifically Olsen phosphorous,extractable calcium, organic carbon and available nitrogen which are essential for plant growth.

(iii) Assess fertility of amended waste water fertilizer on the nutrition of fruits specifically the protein and ascorbic acid content

(iv) Assess effects of amended waste water on plant height, average fresh fruit size fresh fruit and yields of California wonder plants.

1.6 Hypothesis

(i) Molasses fermentation waste water reverses increasing soil acidity.

(ii) The amended fertilizer improves the nutrient status of the soil.

(iii) Amended waste water improves the protein and ascorbic acid content of California wonder fruit.

CHAPTER TWO

LITERATURE REVIEW

2.1 General introduction to Uasin Gishu County soils

The soils in UasinGishu County are of the igneous type and acidic (pH 4.5-5.0) with low fertility and poor moisture storage. They are well drained, non-humic and shallow underlain with murram over petrifferic phase and classified as rhodic feralsol Birech (2000). They have brownish yellow colour and are characterized by high iron, aluminium and manganese ions solubility and inadequacy of key elements particularly Ca, P, N and Mo. Mugambi, (1975) observed a decline in soil pH, organic carbon, total and extractable P to plants when working with most Kenyan soils. He noted a shift from available P to sparingly available P forms where P is bound to Al or Fe complexes as weathering intensified. Improved cropping systems, involving major crops that rely on the very high rates of inorganic fertilizers continuously for many years often lead to unsustainability in production and also pose threat to the environment Patra*et al*, (2000). In review of the potential of organic manure on African Agriculture, Ofori and Santana (1990), Schleich, (1985) noted that, cow dung which is the most studied waste product improves productivity of soils more than inorganic fertilizers due to its slow nutrient release. There is a concerted effort worldwide to use green manure, legumes and organic manure to produce the same amount of food with less fossil fuel based inorganic fertilizer Pastra*et al*, (2000). Organic manures provide a means of recycling nutrients for plant growth and to counteract the declining organic moisture content of most agriculture soils (Wong *et al*(1998).Continuous use of inorganic fertilizers in UasinGishu County in large scale production of cereals especially maize and wheat, extensive growing up of wattle trees in the region, soil processes such as nitrate leaching, ammonium nitrification and to a less extent the effect of acidic rains in the region and surface run-offs have contributed to the soil infertility and acidication.

2.2 General introduction to NandiNorth Soils.

The field experiments were done in Kaiboi .Here the annual rainfall is about 1200mm and 66% reliability with at least 400mm in the first season during the period 190-200 days with warm temperatures of (17.5 -20^{0}C).The top-soil is non-humic, well drained, moderately deep and inherent fertility. The soil is non-saline, non-rocky and non sodic. The parent rock is of rich biotite gneisses and prevalently classified as rhodic ferralsols and ferralochromic acrisols which developed on granites. The base saturation of the profile indicates a moderate leaching intensity of mineral-N applications during planting time through denitrification. During high rainfall period when soil erosion is not restricted, high N losses occurs through NO_3being higher than NH_4^+. Due to long periods of chemical fertilizer use, there has been increasing soil acidity over the area. Where lime was applied Zn, S, Cu and Mn become low for plant uptake .The soil reaction of the upper horizon down to 50cm shows increasing H^+ and Al^{3+} =0.86 me/100g and about 10.05% of exchangeable bases plus Al in the top soil which may even affect sensitive crops .The K saturation of the exchange complex is high (0.7 me/100gm) in the top soil to very low range (0.09-0.25 me/100g) in underlying horizons while Mg saturation is ranging between (0.9-1.28 me/100g compared to other bases .The soil has high Fe saturation (5.5-11.5 me/100g) and varying OC (3.8 -0.6%) on the top horizons .The N content is (0.36-0.39%)though the soil is non humic. Available P shows low range values < 5.5ppm which is not adequate for plant growth. The available N supplying capacity of the soil is inadequate while S values are also low < 6ppm.The soil pH ranges from 4-5 -6.5 with consistent decline over the years (Anonymous, 1987).The land has a rolling topography. This pH of the soil solution controls the form and solubility of many plant nutrients.

2.3 Wastewater treatment at Agro-chemicals and Food Company

The Agro-Chemicals and food company (A.C.F.C) was incorporated in 1978 with main objective of producing alcohol and baker's yeast from cane molasses. The effluent has levels of biological oxygen demand (BOD), chemical oxygen demand (COD), Fe, Zn, Na and Gallic acid.The Agro-chemicals and Food Company has been able to reduce the pollution load by 90% in terms of COD by converting the waste generated to biogas. The waste water from the factory having a COD of 800mg/L and BOD of 450mg/L is allowed to flow to two cooling settling ponds with an average dimension of 40m by 20m by 15m at the outlet. The outlet of the settling pond, the effluent is pumped to the bulk volume fermented (BVF) at a rate of 60cm^3 per hour. At the BVF, the effluent is anaerobically digested and then allowsto flow to the secondary aeration tank where it is aerated using four blowers each having a power rating of 90kw. The effluent flows to the tertiary clarifier then to four polishing lagoons where further digestion takes place then released to R.Nyando. Essential information of the effluent include organic molasses, Gallic acid, Zn, Fe, Cu, Organic carbon and Chromium, Cadmium and Lead, (Anonymous, 1999).

2.3.1 Organic Molasses

Molasses is made from sugar cane, sugar beet and citrus. It is mostly made from sugar cane. There are three types of sugar cane molasses; unsulphured, sulphured and black strap molasses. When new sugar cane is harvested, the leaves are stripped and the juice extracted by crushing or mashing and processed to extract sugar. The result of the first boiling and processing is the first molasses which has the highest content of sugar. The result of the second boiling is the second molasses which is darker in color and has slightly bitter test. Black strap molasses is from the third boiling. Unsulphured molasses is the finest quality and is made from the juice of sun-ripened cane and the juice is clarified and concentrated. Sulphured molasses is made from green sugar cane that has not matured long enough and is treated with Sulphur fumes during the sugarextracting process. There are a number of different types of molasses and some have already had the maximum sugar content removed and therefore not sweet. There are two main types of organic molasses; Highest Testing Molasses (HTM) which is a sweet syrup and is used as a sweetener. Black strap molasses which is rich full bodied flavor that adds natural colour to food which is the end product of the production sugar and contains vitamins, minerals and trace elements naturally found in sugar cane and is a good source of iron, vitamin B_6, potassium, Magnesium and calcium. It has the following composition, 55% sucrose and other sugars, 15% organic non-sugars and 10% ash (Unpublished work, 1999)

2.3.2 Zinc.

Zinc ranks fourth among metals in a consumption being surpassed only by iron, aluminium and copper. The chief source of zinc in municipal sewage, waste water and the waste generated in plants that manufacture consumer and industrial products that utilize zinc. Background levels of zinc in natural inland surface water vary from 0.001 to 0.2mg/l or higher Hodgson, (1987). Waste water containing zinc is often acidic and may also have high content of copper iron and cadmium Moore and Remorthy, (1984). Zinc deficiency manifests itself in growth retardation, lesions of the skin and appendages, impaired development and functionality of reproduction organs Fredrick, (1980).

2.3.3 Iron

The chief Iron ores are haematite (Fe_2O_3) brown and Magnetite (Fe_3O_4) Silicate or Spathic iron ore (FeS_2)) and chalcopyrites ($CuFeS_2$). It is also found in most clay, sand stones and granites. Meteorites iron contains cobalt and nickel. Industrial and domestic effluent discharges are other sources of iron. The metal could originate from its natural deposits and the use of iron materials in the factory. Soils are usually rich in iron and hence there are high chances of transfer of iron from the soil to the waste water directly or indirectly.It is the most useful metal in the modern times in manufacture of implements, tools, machinery, spare parts and other necessary products. In animals it is involved in the transport of oxygen, oxygen storage, and transfer in muscles (myoglobin).Chronic iron poisoning leads to deposition in the lungs causing chronic bronchitis and tracheobronchial disorders. The recommended normal iron intake of children is 10-20 mg/kg. Signs of iron poisoning may be noticeable within 30 minutes or may be delayed for hours after ingestion. Symptoms initially include irritation and hecrosis. Sometimes, there may be pallor or cyanosis, diarrhea may follow and cardiovascular collapse. Death has been known to occur within six hours Fredrick, (1980).

2.3.4 Copper

Natural sources of copper include windblown dust, forest fires and decaying vegetation. This metal is widely distributed in Free State in sulphides, arsenide chlorides and carbonates Johnson and Eaton,(1980). Anthropogenic emissions of copper originate from smelters, iron foundries, power stations and combustion sources such as municipal incinerators. The major source of copper is mines and sewage sludge. It is also commonly present in natural surface water in trace amounts. Soil solutions and river water contain copper at a level of about 0.01 mg/ml. Copper may be released to water as a result of natural weathering of soils and discharges from industries and sewage treatments, plants (WHO, 1992). The metal could originate from its natural deposits and the use of copper based fungicides in the area. This observation suggests a possibility of contamination of waste water.Copper is used in the manufacture of alloys such as cupronickel, Aluminum, bronze and silicon bronze. It is also used in making copper wire, sheet and in standard electrolyte copper electrode. Other uses of copper include use in electrical industries for making generators light bulbs, telephone wires, telegraph cables, rods, cooking utensils and wires for light and power lines Fredrick,(1980). Copper is also used in making agricultural chemicals such as fungicides, algaecides, fertilizers, bactericides, animal feed additives and growth promoters as well for disease control in livestock and poultry. Agriculture use of copper products account for only 2% copper release to the soil (WHO and FAO, 1998).

2.3.5 Chromium

Chromium is widely dispersed in natural deposits. Chromate ($FeOCrO_4$) is the only important compound of Chromium. Chromate is used as source of chromium and its compounds. Chromium could be released to the environment from natural deposits, use of chromium based fungicides, seed protectants and wood preservatives. Chromium is widely used for electroplating and as an additive for steel. Chromium compounds such as Cr_2O_3 and Chromate (IV) are used as pigments for colouring glass and leather tanning textile, as oxidizing agents and in refrigerators Fredrick,(1980). Trivalent chromium (Cr^{3+}) is an essential animal nutrient and is a necessary compound for the metabolism of glucose and lipids. Chromium deficiency mimics diabetes mellitus because it is essential for proper functioning of insulin in sugar metabolism and induces the atherosclerotic plaque in rats. There is no evidence of chromium ions toxicity and it is poorly absorbed from digestive system though its deficiency increases the toxicity of Lead. Chromium (VI) compounds are irritating and corrosive. They are absorbed through the digestive tract, skin or alveoli of the lungs. Body deposits of Chromium are principally the lungs, muscles, fat and skin. Cell function studies reveal that about half of the body Chromium is within the cell nucleus. Inhalation of dusts or mists of hexavalent Chromium is irritating to upper respiratory parts and causes sneezing, nasal discharge and vascular congestion. Bronchospasm resembling an asthmatic attack may occur and could cause death if its exposure is prolonged. It is a chemical carcinogenic connected with long term occupation exposure that produces bronchogenic carcinomous.

2.3.6 Cadmium

Cadmium is a very toxic element. Its major source is volcanic eruptions. Other sources of Cadmium include forest fires and the release of metal enrichment particles from terrestrial vegetation. The human activity associated with the release of cadmium to the environment include non-ferrous mining, metal smelting and refinery together with the industrial involved in the manufacture of cadmium containing compounds. Other sources of cadmium include coal production, refuse incineration, sewage and waste water discharge, iron and steel industries More and Remorthy, (1984). Uptake of cadmium by plant is the pathway of human exposure from agriculturalcrops. The cadmium uptake is greater at low pH. Application of phosphate fertilizer is a significant source of cadmium input in the soils in some areas of the world. Cadmium is a natural constituent of rock phosphate deposits and use of rocks phosphate fertilizer leads to evaluated levels of cadmium in the soil and hence in the crops Johnson and Eaton, (1980). However, the mobility of cadmium in the environment and its effects on the ecosystem depends on the nature of its compounds.

2.3.7 Lead

Lead is soft pale grey metal occurring naturally. It is the heaviest metal known. The global production of lead from both smelter and mining operations has been relatively high throughout this century and will continue slowly in the near future. Lead is one of the metal wide spread in the environment, largely because of human activities when released into the environment, lead has long residence time compared to other pollutants. As a result, lead and its compounds tend to accumulate in the soil sediments and due to their solubility and relative freedom from microbial degradation they remain accessible to the food chain and human metabolism far into the future, Davies,(1990). Other sources of lead include smelting and burning petroleum containing tetra ethyl lead and tri methyl lead. Tri alkyl lead compounds are formed in the environment due to the breakdown of tetra alkyl lead. Tri alkyl lead is less volatile and more readily soluble in water. This species may also be lost to environment as emissions and remain available to organisms Anonymous, (1999).Lead may be introduced to a terrestrial environment by atmospheric deposition onto exposed surfaces. Some lead taken by plants may be passed onto to the animals. The availability of lead in organisms in the environment is limited by its strong absorption to environmental substances such as soil sediments, organic matter and biota.

However environmental contamination with lead is wide spread and organisms are known to accumulate high body burdens of lead.Lead and inorganic lead compound are now being used in a variety of commercial products and industrial materials including plastics, storage batteries, bearing alloys, ceramics, cable sheathing, radiation shield and even in some paints (Fredrick, 1980). Other compounds still in use include red lead triplumbic tetra oxide (Pb_3O_4),Calcium plumbate ($CaPbO_4$) and lead chromate (Pb**Cr**O_4). Erosion of these lead pigmented paints must still be regarded as major source of environmental pollution. Compounds of lead like lead bisilicate are used in ceramic glazing Hodgson, (1987).

2.4 Effects of exchangeable acidity on soil

In soils of low pH (<5.5) it is not the hydrogen ions (H^+) that operate as a direct constrain to plant productivity but rather the abundance of toxic cations primarily Al^{3+} and to a lesser extent Mn^{2+}.This causes deficiencies in plant nutrients due to unfavourable rooting environment Marschner,(1986):Russel,(1973).In most mineral soils of the tropics, the exchangeable acidity in soils between pH=3 and pH=5.5 is comprised almost entirely of exchangeable aluminium, which has become an important soil chemical parameter for highly weathered soils of the tropics. Aluminum ions in soil solution exist in a variety of pH dependent forms. At pH=3, aluminium species are dominated by Al $(OH)_2^+$up to pH=5.5.Because of this pH dependency on aluminium activities ,extractable acidity is determined using unbuffered neutral salts such as KCL Mclean,(1965).When the pH is below 5, phosphorous is less available and at high pH levels, its availability increases to harmful levels which interferes with normal growth of plants .At low pH the concentration of available iron and aluminium in the soil solution may increase to harmful levels. This low pH also inhibit the activity of soil micro-organisms such as nitrifying and nitrogen fixing bacteria and encourages outbreak of soil-borne fungal diseases which affects crops .Useful soil micro-organism thrive well within pH = 5.5 - 8.0 and also most plant nutrients are available at the range.

2.4.1 Solubility of lime

Lime is only slightly soluble in water. Quick lime reacts with water to form hydrated lime (calcium hydroxide) which has solubility of 0.165g at 20^0 C per 100 g of water. Despite this low solubility in water , it is effective as a base because of the smallness of the hydrated lime particle size and the double hydroxyl groups that result from each molecule of lime that does goes in to solution Thus due to small size ,these particles have high surface area which enables them to dissolve in to solution quickly as lime in solution is used up in reaction due to granary explosion thus provides plentiful supply of neutralizing power.Lime is partially soluble and establishes an equilibrium which obeys Le Chatelier' principles. Quick lime has cubic crystal structure while calcium by dioxide has hexagonal crystal structure due to interaction with water molecules.

2.4.2 Effect of phosphorous fertilization on soil fertility and Plant growth:

Phosphorous fertilization in acid soils is important to overcome acidity induced nutrient deficiencies. Phosphorous is one of the major plant nutrients and it is a component of every living cell as part of nucleic acids. It is also vital in energy transfer needed by plants for metabolism. Phosphorous application promotes dry matter production, nodule development, dinitrogen fixation, Phosphorous uptake and tissue nitrogen (N) yield and yield components (fruit plant and size/fruit) are affected unfavorably by phosphorus deficient soils Phosphorous is important for good root development and fruit production of Peppers Dickerson,(2002).

2.4.3 Effect of phosphorus and lime on fruit quality.

Applied P and seed P concentration affect the field performance of the sown seed and the quality of the harvested fruit. P application also increased fruit vigour by reducing hollow heat and increasing the germination of deteriorated seed. Liming plays a role in improving seed germination and 1,000 seed weight for crops grown in acid soils. SeedCa was shown in soybean Keiser and Mullen, (1993) to contribute positively to seed quality. In the later case, peanuts sown in acid sandy soils with low cation exchange capacity and low soil Ca benefited from gypsum supplementation which significantly increased seed Ca concentration. Seed Ca content was highly correlated with both germination percentage and seedling survival. Adam *et al*, (1993) concluded that soils used for seed production needs higher levels of available Calcium than those used for general production. Application of lime to Mung bean at rate of 10 tonnes / ha significantly increased seed yield, seed vigour and the longevity of stored seeds. The positive correlation between liming and seed N, P, Ca, S, Mg and seed protein concentration as observed in cowpeas grown on an oxicaplustalf in the semi-arid tropics Parvatheppa*et al*,(1995).

2.5 Bell Pepper

Latin Name	:	*Capsicuumannuum*
Common Name	:	California Wonder
Family	:	Solanaceae
Genus	:	*Capsicuum*
Species	:	*Annuum*

2.5.1 Origin and climatic requirements

This crop is native to tropical South America (Brazil) because warm and humid climates of the tropics favour it. It is top selling and grown widely as a spice and medical crop. In Kenya, this vegetable is grown successfully in varied climate and soils of Kenya where the annual rainfall exceeds 1100mm. It is grown in large quantities in dry low altitudes in the coastal regions Waithaka (1971). Because it is of tropical origin they thrive well in warmer conditions and very sensitive to cold and frost. The optimum temperatures for growth, over 4-5 months growing seasons, are 20-27˚C, At temperatures below 15^0C degrees growth becomes progressively poorer and maturity of fruits delayed. At temperatures above 32˚ C, excessive flower drop may be a problem especially when coupled with dry winds. Prolonged cloudy weather retards and reduce fruit bearing. Blossoms may not set fruit if temperatures are below these ranges or if soil is too dry or they may even fail to blossom. Other environmental conditions that cause an extreme lose of water result in the dropping of flowers and small fruits. Even though there may be adequate moisture available in the soil, a dry and windy day will cause rapid, excessive transpiration that the plant can't tolerate Salunke, (1998). Soil moisture can cause buds and blossoms to drop. Heavy rainfall during flowering and fruiting causes flower drop and fruit rotting. Moisture stress during flowering favours flower and bud abscission, causing heavy flower drop and low yields. Higher light intensities increase yields.

2.5.2 Soil Conditions and Preparation.

Pepper plants grow best in warm, well – drained clay loam or sandy loam soils of moderate fertility and good tilt with a pH of 7.0-8.5 range. These soils tend to warm up more rapidly than heavier soils and yet have good water holding capacity. Soils with high humic content are ideal. Acid soils, poor in organic matter and water logged are not suitable for peppers. Cultivation done should mix crop residues and organic matter in the top 7 to 8 inches of the soil during preparation for planting Salunke, (1998). The soil should be worked over to break up large clods and any hard pan that prevents good drainage. Over-cultivated soils become powdery and have a tendency to crust. Adding ample quantities of compost will improve the quality of soil by increasing water-holding capacity, nutrient retention aeration and drainage.

2.5.3 Fertilization.

Phosphorus is important for good root development and fruit production. P induces this type of pepper to make good early growth which results in larger crops with fruits that are less exposed to sunlight. A minimum of 40kg per hectare should be incorporated into the soil before planting. Total Nitrogen requirements is about 150-180kg N per hectare and about 30kg Potassium per hectare side dressing usually of Lime Ammonium Nitrate, 4 to 5 weeks after transplanting should be followed by two more other dressing of about 150 – 200kg Lime Ammonium Nitrate or Calcium Ammonium Nitrate or Ammonium sulphate. This stimulates vegetative growth in peppers and if added after the fruit harvest, it will improve fruit size and vigour. For the seed bed, a fresh layer of rich compost in the top soil was added, then tilted to loosen the soil and mixed with the compost. Rake level must be done. Germination is between 14 - 21 days if soil temperature is between 20 - 30˚C. Starting two weeks after germination, seedlings can be fertilized preferably with a water-soluble fertilizer in 1 gallon of water until the seedlings are ready for transplanting in about 6-8 weeks Dickerson (2002).

2.5.4 Planting, Population and Spacing:

They are usually transplanted rather than seeded directly into the garden, from seedlings raised under warm, protected conditions. Early planting is preferred to later plantings because the plants are severely affected by viral diseases. The transplants should be stocky and healthy for best results and the soils should be fertilized before Desai, (2004). Because of the sensitivity of these fruits to sunburn, the seedlings are usually planted out in double rows, sometimes two or four rows with picking pathways of about 50 cm in between. The space of plants is 8-14 inches apart, 3-4 inches deep and 30-36 inches wide. Transplanting should be done in the evening or on a cloudy day to avoid wilting. Water the plants after planting. Peppers should start growing quickly after planting and maintain a rapid growth rate. If they start blooming and set fruit while they are too small, they will be stunted and fail to mature to the plant size necessary for a good yield. Such premature fruit should be removed. Populations generally vary from a minimum of 40,000 plants per hectare to plant densities in the range of 100,000-120,000 plants/ha yielding optimally and fruits of good quality Desai (2004).

2.5.5 Cultivation, Watering and Mulching

Two to three shallow hoeing to keep weeds under control should be done. Deep cultivation of the plants will destroy much of the root system and reduce yields and quality. Because of the softer growth, the requirement for large fruit and the susceptibility to sunburn of the fruits when they are more exposed due to temporary wilting, California wonder has a higher water requirement than other types of peppers. The soil should be thoroughly wet to a depth of at least 400mm at planting. For the first two weeks after transplanting, they are irrigated twice a week 10-15mm at a time in order for the transplants to become well established. They are then irrigated with a 15-20mm, once or twice a week for further two or three weeks depending on climatic conditions. During the next eight weeks, 35mm should be applied weekly, followed by approximately 30mm per week for the rest of the season. Dry conditions from flowering onwards can cause a significant reduction in yields Waithaka (1971). The goal of the irrigation programme is to maintain a uniform soil moisture level that promotes uniform growth and fruit set. Under-watering a crop can cause blossoms-end rot diseases, a dry rot on the tips of peppers. Over-watering a crop can cause phytophthora root rot which causes the plant to wilt and die suddenly. Drip irrigation techniques are the most efficient way to water plants. Combined with either plastic or organic mulch, water conservation can be considerable while providing sufficient water for maximum crop production. Gardens can also use sprinkler or furrow irrigation techniques but water and diseases management are more difficult. After plants are well established, mulching can be applied to conserve soil moisture and to help suppress weed growth. Peppers respond favourably to both plastic mulch and row covers. Black plastic mulches help to warm the soil early in the season and control weeds and can be replaced with organic mulches like straw dry grass chippings and leaves to help cool the soil during the hot weather and are effective in controlling weeds Dickerson, (2002).

2.5.6 Harvesting, Storage and Yields

Crop time for bell peppers is about 80 days after transplanting. They are harvested green when the fruits are fully developed, firm and crisp with the skin looking shiny and waxy having 3-4 lobes. When harvested too young, they will wilt and shrivel and when left to mature on the vine to full maturity, they may reduce yields Desai (2004). Picking of the fruits in the green stage induces further flowering and yields. The bulk of the crop is usually harvested over about 2 months, after which the crop is generally too small to warrant the cost of further picking. The later-developing fruits become too small and tend to have a poorer shape and may continue for several months later. When harvested green, it should average 25-30 tons/hectare with good crops yielding in excess of 40 tonnes per hectare. When harvested red average yields are only 8-12tons/hectare partly due to losses from sunburn. The harvesting should be 7-14 day interval when they attain their full size Desai (2004).

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Before packing, they are graded according to size and shape. The diseased, wilted or damaged fruit should be discarded. The large blocky fruits, four-lobed and fully sized are graded first; the late-maturing fruits are smaller, more pointed, three-lobed or malformed and may change to purple in coo conditions. In general, fresh peppers have a shorter storage life, 1-2 weeks. Cool, moist conditions of 45-50^{o}F and up to 90% relative humidity make for ideal storage. They can be freezed whole or in slices. Branched peppers are easier to pack and are best in cooked food Salunke (1998).

2.6 Vitamin C

Vitamins are a group of small molecular compounds that are essential nutrients in many multi-cellular organisms. Vitamin C in particular, is a water soluble anti-oxidant that is essential for human nutrition. Deficiency lead to a disease called scurvy which is characterized by abnormalities in the bones and teeth. Many fruits and vegetables contain vitamin C and are destroyed by cooking.The U.S Recommended Daily Allowance (RDA) for ascorbic acid is 60 mg. A one cup (240 g) serving as green peppers (105 mg/100 g) would furnish 4.2 times the RDA. A 57 g serving would furnish the 60 mg RDA. It is the best known of all vitamins. Over 80 million pounds of vitamin C are now synthesized worldwide each year; more than the total amount of all other vitamins combined. In addition to its use as a vitamin supplement, vitamin C is used as a food preservative a "flower improver" in bakeries and an animal food additive.It is famous for its anti-scorbutic properties meaning that it prevents the onset of scurvy, a bleeding disease affecting those with a deficiency of fresh vegetables and citrus fruits in their diet. In more recent times, larger doses of vitamin C have been claimed to prevent the common cold, cure infertility, delay the onset of symptoms in AIDS, and inhibit the development of gastric and cervical cancers. Proof is still lacking for most of these claims, but a recent study in Europe did find statistical evidence for an inhibitory effect against gastoric cancers .Although large daily doses of vitamin C are probably not warranted, the harmful side effects of vitamin C appear minimal.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

Greenhouse and field experiments were conducted with California Wonder Bell-genotype in two cropping seasons 2006/2007 and 2007/2008.The greenhouse experiments were conducted in University of Eldoret farm while the field experiments were done in Kaiboi North ,Nandi district of Nandi County, where the soils are classified as rhodic ferralsols and ferralo-chromic acrisols while of University of Eldoret is classified as rhodic ferralsols .There were a total of ten treatments laid out in Randomized complete block design(RCBD) in the greenhouse with three replications while complete block design was used in the field(CBD). In the greenhouse experiments, there were ten experiments with three replications each were set for each treatment. Then 10 kg of dried and crushed soil were packed in (50 cm by 30 cm) plastic pots with three holes in the bottom for percolating water. The soil was then mixed with the weighed fertilizers and transplants were then planted in each pot and watered. They were then mulched to conserve moisture.

3.2 Materials

Waste water and biogas efficient was obtained in University of Eldoret farm. The waste water was obtained from Muhoroni agro-chemicals and Food Company. About 0.5ml of waste water 0.3g of biogas effluent was oven dried,grounded and placed in clean digestion tubes.Digestion mixture was prepared by adding 0.42g selenium powder, 14g of lithium sulphate to 350ml of 30% hydrogen peroxide followed by 420ml of concentrated sulphuric acid while cooling in an ice bath.About 4.4ml of the digestion mixture was added to the sample tubes and also to two reagent blanks and digestion was done at 360^{o} C for two hours until the solution were colourless and sand remaining was white and the contents were made upto 50ml mark and mixed well ,allowed to settle and a clear solution from the top of the tube was taken for analysis for K^{+} and $Na^{+}$where flame photometer was used, Atomic absorption spectrophotometer was used to analyze Mg^{2+} Ca^{2+}, Fe^{3+}, Zu^{2+}, Cu^{2+}, Cd^{2+}, Pb^{2+} and Cr^{3+} while colorimetry was used to determine nitrates and phosphorous and redox reaction was used to determine organic carbon in the sample. Lime was obtained from Koru, Kisumu which had a composition of 49% CaO. Diammonium phosphate (DAP -46% P_2O_s) was used as a source of P. Biogas effluent rate of 10 tonnes per hectare was maintained for all treatments. The factors levels were, factor A-lime (10tonnes per hectare) factor B-phosphorous 40kg P per hectare and factor C-bell genotype (Capsicum annum)

3.2.1 Soil Sampling

100g of soil samples were taken from each plot (systematic quadrate method)to a depth of 20cm,using a soil auger before the start of the experiment .Another soil sampling from each plot was done to the same depth during the cropping seasons at intervals of three weeks for 6 times in the greenhouse experiments and three times in the field experienced.The soil was air dried in a well ventilated room for 7 days and then gently crushed to break soil lumps and sieved through 2mm mesh. The soils needed for the total N, extractable P, exchangeable acidity and organic carbon was further grounded in a mortarin order to pass through a 60 mesh screen to obtain 0.3mm soil particles. Another soil sampling from each plot was done to the same depth during the cropping season at intervals of three weeks and pH in water was taken and the pH meter was calibrated using pH=4 and pH=7 buffer solutions and the readings recorded.

3.3 Treatments

In both the field and green house experiments there were experiments with three replications

Diammonium phosphate	(DAP)
Waste Water	(WW)
Waste water + lime	(WWL)
Biogas effluent	(BE)
Biogas effluent + Lime	(BEL)
Waste water +Biogas Effluent	(WBE)
Biogas effluent + waste water +Lime	(BLW)
Biogas effluent + waste water +Lime + Urea	(BLWU)
Lime	(LM)
Control	(Nil)

3.4 Analytical methods

All the reagents used were of analytical grade.

3.4.1 Determination of solubility and the quantity that gives the optimum pH.

The solubility of lime was determined by electrical method according to the procedures described by (Hicks, 1986). Lime was transferred into 100ml of wastewater, biogas effluent and distilled water in the following increments 5 g,10g,15 g,25 g,30 g,35 g,40 g,45 g and 50 g, then shaken for 30 minutes using a mechanical shaker 2.6g of urea were dissolved in waste water and used to dissolve lime and the solution were mixed with biogas effluent and optimum pH obtained and the solubility of lime calculated. It was then allowed to stand for 30 minutes and then shaken for 2 minutes before measurement of pH of various solutions was done. The pH meter was calibrated using pH = 7 and pH = 9 buffer solutions. Then the pH of the solution was taken .The suspension with optimum pH was then filtered through the whatman N0.5 filter paper into a crucible whose weight had been taken .The quantity of solvent that contained the lime water that dissolved from the weight of the filtrate in both respectively .Solubility of lime was given by the following expression.

$$\text{Solubility} = \frac{\text{mass of lime x 100 g solvent dissolved}}{\text{Mass of solvent that contained the dissolved lime.}}$$

$$\text{Solubility (g/dm3)} = \frac{1000 \times c \times 10.6 \times 0.74}{\Lambda}$$

Where C is the electrical conductivity and $\Lambda$is the sum of the molar conductivity of calcium ion and hydroxide ion.

3.4.2 Extractable Soil Phosporous Determination

The soil was extracted with 0.5m solution of sodium bicarbonate at pH = 8.5 which was the Olsen extracting solution Okalebo (1985).

Phosphate standard stock solution of 250ppm was prepared by weighing 1.098g of dry $KH_2PO_4$and dissolved in distilled water to a 100ml mark. About 25g of air –dried soil was weighed out and placed in a 250ml beaker and 50ml of the Olsen's extracting solution was added, then stoppered well and shaken on a mechanical shaker for 30 minutes. The suspension was then filtered through the whatman no.42 paper to obtain a clear filtrate which was used for colorimetric phosphorous measurements .The phosphate stock solution, 1,2, 2.5, 5, 10,15,20 and 25ml was each pipetted into clean 500ml volumetric. The 100 ml of the Olsen extracting solution was added to each flask filled to the mark with distilled water to make phosphate standard solution of 0.5,1,1.25,5, 7.5,10 and 12.5 ppm P respectively. For colorimetric P measurements, 10ml of each P standard solution, 10ml of the sample filtrate and two reagent blanks were pipetted into50 ml volumetric flasks followed by 5ml of 0.8 M boric acid and 10ml of the ascorbic acid and each flask filled to the mark with distilled waterand then stirred for further two minutes. The contents were stoppered and shaken well. After 1 hour, the absorbance of each solution was measured at a wavelength setting of 880nm, and then phosphorous calibration curve was obtained.

The concentration of phosphorus using the sample expressed in P mg kg -1 was calculated as follows:

$$P(mg/kg) = \frac{(a-b) \times v \times f \times 100}{1000 \times w} \quad \text{.......Equation 1}$$

Where

a = concentrated of P in the sample

b = the concentration of P in the blank

v = volume of the extracting solution

f = dilution factor

w = weight of the sample

3.4.3 Determination of exchangeable cations in soils

Ten grams of air dried soil after 2 mm sieving were weighed and placed in a clean stoppered container and then 100 ml 1M ammonium acetate was then added and shaken for 30 minutes and filtered through whatman filter paper No 42 and dispensed

.This soil extract was then used for Na, K ,Ca and Mg determination. An internal standard and a reagent sample were kept for each batch of test soils. The soil extract used for K, Na and Ca was diluted 10 times and then 5ml of each soil extract was pipetted into a 50 ml volumetric flask and 1 ml of 26.8 % lanthanum chloride solution was added and each solution diluted to a 50 ml mark with 1M ammonium acetate extraction solution .For analysis of Na and K, the solution were then sprayed into the flame of photometer at a wavelength of 766 nm.

Magnesium standard solution were made by pippeting into each 100 ml volumetric flask 0,1.0, 2.0, 3.0 and 5.0 ml. of magnesium stock solution (100 ppm Mg) then 20 ml of 1 ml ammonium acetate extract solution was added and filled to 100 ml mark with distilled water. The soil extract was then diluted 25 times for the determination of magnesium .The solution was made by pipetting 2 ml of the soil extract solution into 50 ml volumetric flask, then 5ml of strontium chloride was added and filled to the 50 ml mark with IM ammonium acetate. The solution was then sprayed into the flame of the atomic absorption spectrophotometer for Mg analysis.

The standard solutions were first measured to calibrate the elements. The concentration of K, Na, Ca and Mg/kg were calculated as follows;

$$\text{mg/Kg K, Ca, Na and Mg in soil.} = \frac{(a-b) \times v \times f \times 10}{1000 \times w}$$ …**Equation 2**

Where;

a = concentration of K, Na, Ca and Mg in the sample extract.

b = Concentrations of the elements in the blank extract

v = volume of the extract solution

w = weight of the soil sample

f = dilution factor

3.4.4 Determination of exchangeable acidity and aluminum in soils

The method used was the alteration method described by Anderson and Ingram (1993). Ten grams of air –dry (2 mm) soil was placed in 50 ml beaker and 25 ml of 1M KCL was added and the contents stirred with a glass rod. The contents were left standing for 30 minutes and then transferred to a buchner funnel fitted with a whatman No.5 filter paper and mounted on a 250 ml flask. Filteration of contents was followed by leaching with 5 successive 25 ml aliquots of 1M KCl .To obtain KCl acidity, 5 drops of phenolphthalein indicator was added to the filtrate and titrated with KCL to pink colour end point. A blank of titration of 150 ml KCl solution was used to correct titration readings and Calculation done as follows;

Exchangeable acidity (AL^{3+}+ H^{+})= (ml NaOH sample – ml NaOH) x 10 (Mol/kg).

$$\text{Me KCl acidity} = \frac{(1\text{mlNaOHsample} - \text{mlNaOHblank})\text{xNlx100}}{\text{Weight of sample (\%)}} \quad \text{…………} \textbf{Equation 3}$$

To estimate the amount of Al^{3+} and H^{+}, 10ml of 1Mpotassium fluoridewas added to a 150 ml filtrate and titrated with 0.1 M HCl until the pink colour disappeared .The contents were left to stand for 30 minutes and additional HCl was added to clear and Aluminum and hydrogen were calculated as;

$$\text{Me KCl exchangeable Al} = \frac{\text{mlHClxNx100}}{\text{Weight of sample}} \quad \text{……………..} \textbf{Equation 4}$$

Me H = KCl acidity – KCl exchangeable Al.

3.4.5 Total organic carbon in soil, wastewater, fruits and biogas effluent.

About 0.5 g of ground (60 mesh=0.3 mm) soil was weighed and placed into a block digester tube.(0.5 ml of waste water ,0.5 ml of fruit juice and 0.5 g of biogas affluent)were used as sample weights.Then 5 ml of potassium dichromate and 7.5ml concentrated sulphuric acid was added to the tube and two blank reagents .The block digester was placed in a pre-heated block at 145-155˚c for exactly 30 minutes .After this period ,the digest was removed and cooled and transferred to 100 ml where 0.3 ml of the ferroin indicator solution was added and mixed thoroughly using magnetic stirrer. The reagent blanks and the digest were titrated with 0.2 ferrous ammonium sulphatesolution to a brown end point. The titre was recorded and corrected for the mean of 2 reagent blanks (T) where T = titre value (difference between reagent blank and sample solution.

Calculation of organic carbon (%) $= \frac{Tx0.5x0.2}{\text{Sample weight}}$ ………………....**Equation 5**

(Vb-Vs) ml of 0.2MFe^{2+}vsolution = 12/4000 x 0.2 x (vb-vs) g C

where;

(vb-Vs) = T (the titration volume)

The amount of C in a 0.5g soil sample (w) is,

Organic C (%) $= \frac{0.005x0.2(vb-vs) x 100}{\text{Sample weight}}$ ……………....**Equation 6**

where;

Vb = Volume in ml of 0.2 M ferrous ammonium sulphate used to titrate the reagent blank solution.

Vs = volume in ml of 0.2 M ferrous ammonium sulphate used to titrate sample solution.

12/4000 is the milliequavalent weight of C in grams.

3.4.6 Determination of total Nitrogen in soil, California Wonder fruits, wastewater and biogas efficient.

Total N in soil, fruits, waste water and biogas effluent samples was extracted by colorimetric method described by Okalebo et al, (1993). Included in the digestion were concentrated sulphuric acid and hydrogen peroxide which served as strong oxidants. Lithium sulphate was used to raise the boiling point of the mixture and selenium powder acted as catalyst. About 3.5g of selenium powder was dissolved in 1 litre of concentrated sulphuric acid and heated to 300 ˚C until a light yellow suspension was formed. The digestive mixture was prepared by dissolving 3.2 g salicylic acid in 100 ml of the above mixture .Wastewater 0.3 ml, 0.5 ml biogas effluent, 0.5 ml fruit juice and 0.5 g of soil samples (<0.25 ml, 60mesh) oven dried was transferred to the labeled digestion tubes followed by 2.5 ml of the digestion mixture to each tube and the reagent blanks for each batch of samples and digested at 110˚C for 1 hour . The samples were then removed, cooled and three successive 1 ml portion of hydrogen peroxide were added and heated to a temperature of 330˚C until the solution was colourless and any remaining sand white. Then 25ml of distilled water was added and mixed well and until no more sediment dissolves. After cooling ,water was added to a 50 ml mark, allowed to settle and a clear solution from the top was taken for analysis of total N, Ca, Mg, Na, P, Zn, Cu,Fe and Mn in the digests.

The absorbancy was measured at 650 nm setting of the colorimeter. A calibration curve was plotted and the concentration of N in the solution was read off.

The N (%) in the sample was calculated as follows.

$$N(\%) = \frac{(a-b) \times V \times 100}{1000 \times w \times al \times 1000} \quad \textbf{Equation 7}$$

where

a	=	Concentration of N in the solution
b	=	Concentration of N in the blank
v	=	total volume at the end of the analysis
w	=	weight of the sample
al	=	aliquot of the solution taken.

3.4.7 Determination of the total P in fruits, wastewater and biogas effluent

The ascorbic acid procedure with no pH adjustment was used. About 5 ml of the supernatant clear wet-washed solution from digests prepared in determination of nitrogen of each sample was pipetted into 50 ml volumetric flask and 20 ml of distilled water was added followed by 10 ml of the ascorbic acid to each flask beginning with the standards and the solutions made upto 50 ml mark, stoppered and shaken well then left for 1 hour standing for full blue colour development .The absorbance of the standard and samples was measured at 880 nm wave length setting in a spectrophotometer. For the standard solutions, 0,1,2,3,4,5 and 6 ml of the 10 ppm, P working solution was pipetted into 50 ml volumetric flasks and 10 ml of the ascorbic acid reducing solution was added to each flask and made to the mark with distilled water and left for one hour standing and then absorbance was read. A graph of absorbance was plotted against standard concentration .The solution concentration for each unknown and the two blanks were determined by subtracting the mean blank value from the unknown to get the corrected concentration.

$$\text{P in sample (\%)} = \frac{c x v x f}{W} \quad \textbf{Equation 8}$$

where;

c = corrected concentration of P in the sample

v = volume of the digest

f = dilution factor

w = weight of the sample

$$\text{P in sample (\%)} = \frac{C \times 0.05 \text{ for a 5ml aliquot.}}{W}$$

3.4.8 Determination of Sodium, Potassium, Calcium and Magnesium in fruits, wastewater and biogas effluent.

Total nutrient cations contents of fruits, wastewater and biogas effluent after complete oxidation and digestion of the samples, analysis was done using flame photometer for Na and K and atomic absorption spectrophotometer for Ca and Mg determination .Standard solution containing known mixtures of both sodium and the nutrient cation were used because of the interference that may occur as a result of mutual excitation between elements. Using a micro pipette, 2ml of each of the digested sample were then pipetted into a 50 ml volumetric flask and diluted to the mark with distilled water and mixed well. The solutions starting with the standards, the samples and the blanks were sprayed into the flame of atomic absorption photometer (for Na and K analysis) at a wave length of 766.5 nm. The amount of potassium present in the solution was read off from the calibration curve prepared by plotting absorbance readings against Sodium and Potassium concentrations in the standard series and calculations of the potassium and sodium concentrations were done as follows for each sample.

$$K(\%) \text{ in the sample} = \frac{(a-b) \times v \times f \times 100}{1000 \times w \times 1000} \quad \text{..............} \textbf{Equation 9}$$

where;

a = concentration of Potassium in the digest

b = concentration of the blank digest

w = the weight of the sample

v = volume of the digest solution

f = dilution factor

$$Na(\%) \text{ in the sample} = \frac{(a-b) \times v \times f \times 100}{1000 \times w \times 1000} \quad \text{..........} \textbf{Equation 10}$$

Where;

a = Concentration Sodium in the digest

In summary

ppm K = C x 25

ppm Na = C x 25

Where C, is the corrected concentration after subtracting the blanks.

Then, 10 ml of the digested sample was then placed in 50 ml volumetric flask and 10 ml of 0.15% lanthanum chloride was added and topped to the mark with distilled water after thorough shaking of the contents. The standards, the blanks and the sample solutions were sprayed into the flame of the atomic absorption spectrophotometer at a wave length of 422.7 nm. A calibration curve of the standard series readings was constructed and the concentration of calcium and magnesium measurements in the samples and the blanks was read off from the curve .

The concentration of calcium and magnesium in the sample was calculated as;

$$Ca\ (\%) = \frac{(a-b) x v x f x 10}{1000 \times w \times 1000}$$ ……………………..**Equation 11**

Where;

a	=	concentration of calcium in the digest.
b	=	concentration of the blank digest
w	=	the weight of the sample
v	=	volume of the solution
f	=	dilution factor

3.4.9 Determination of manganese, copper, Zinc and iron in soils, wastewater and fruits.

To measure these micronutrients in fruits, soil and wastewater, the digested samples were then aspirated into the flame of an air-acetylene mixture and analyzed using atomic absorption spectrophotometer. For manganese standards 0, 2.0, 4.0, 8.0, 12.0, 16.0 and 20.0 ml of the working solution 50 ppm manganese were pipette into a clean set of 100 ml volumetric flasks with 0.8 M sulphuric acid. The diluted samples ,blank digests and the standard series were then aspirated into the atomic absorption spectrophotometer calibrated for manganese measurement at 279.5 mm and their absorbencies measured .A calibration curve was plotted from the absorbance of the standard series was plotted and used to determine the concentrations of the samples.

The concentration of the manganese in the samples expressed in mg Mn/kg was calculated as follows.

$$Mn\ (mg/kg) = \frac{(a-b) \times v \times f \times 100}{1000 \times w} \quad \text{....Equation 12}$$

a = concentration of Mn in the solution

b = concentration of Mn in the mean values of the blanks

v = volume of the digests

w = weight of the samples taken

f = the dilution factor

To prepare copper standards 0, 2.0, 4.0, 8.0, 12.0, 16.0 and 20.0 ml of the standard working solution of 50 ppm Copper was pippeted into a set of 100 ml volumetric flasks and made to the mark with 0.8 M of sulphuric acid. The standard series, the digest samples and blank samples were aspirated into atomic absorption spectrophotometer calibrated for copper measurement at wavelength of 324.7 mm and their absorbance was measured. A calibration curve was plotted from the absorbance readings of the standard concentration series against the digested samples. The concentration of copper in Cu mg/kg was calculated as follows;

$$Cu\ (mg/kg) = \frac{(a-b) \times v \times f \times 1000}{1000 \times w} \quad \text{................}\textbf{Equation 13}$$

where;

a = concentration of Cu in the solution

b = concentration of Cu in the mean values of the blanks

v = final volume of the digestion process

w = weight of the sample taken

f = the dilution factor.

Iron standards 0,2.0,4.0,8.0,12.0,16.0 and 20.0 ml of the standard solution 50 ppm of Iron was pippeted into a clean set of 100 ml volumetric flasks and made upto 100 ml mark with 0.8 M sulphuric acid to form standard series containing 0,1,2,4,6,8 and 10 mg Fe/litre. The standard series, diluted sample and blank digests were then aspirated into the flame of the atomic absorption spectrophotometer for iron measurements at a wavelength of 248.3 nm and their absorbance measured .A calibration curve was plotted against the concentration of the standard series and concentrations of the unknown samples was determined as follows.

$$Fe\ (mg/kg) = \frac{(a-b) \times v \times f \times 1000}{1000 \times w}$$ ……………………..…**Equation 14**

where;

a = concentration of Fe in the solution

b = Concentration of Fe in the mean values of the blanks

v = final volume of the digestion process.

w = weight of the sample

f = the dilution factor.

Using a Pipette 0, 10, 2.0, 4.0, 8.0 and 10.0 ml of the working solution 50 ppm of zinc was pippeted into a clean set of 100 ml volumetric flask. The standard series, the diluted sample and the blanks digests were then aspirated into the atomic absorption spectrophotometer at a wavelength 213.9 nm and their absorbance measured .A calibration curve of the absorbance readings of the standard series against the concentration was plotted and then used to determine the concentration of the unknown samples and calculated as follows;

$$\text{Zinc (mg/kg)} = \frac{(a-b) \times v \times f \times 100}{1000 \times w} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Equation 15}$$

Where;

a = concentrated of zinc in the solution

b = concentration of Zinc in the measurement values of the blanks

v = final volume of the digestion process

w = weight of the sample taken

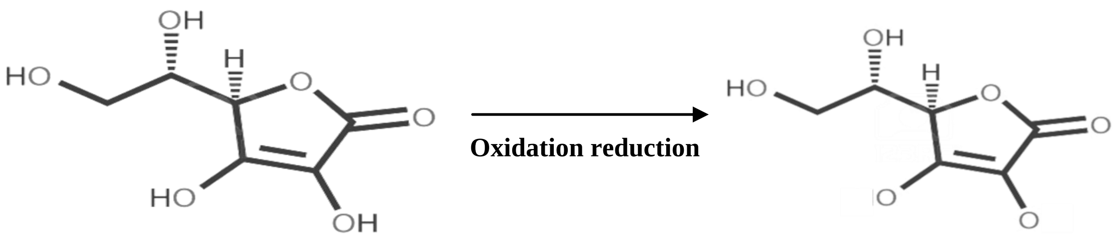
f = the dilution factor

3.5 Determination of vitamin C in the fruits (Redox titration)

100 g of fruit sample from each treatment were cut into pieces and was grounded in a mortar and a pestle 10 ml portion of distilled water was added as grinding continued with the samples. 1g of oxalic acid was added to the samples to prevent oxidation by atmospheric oxygen .The filtrate was obtained through decanting 20 ml aliquot of each sample was pipetted into a 250 ml conical flask and 150 ml of distilled water

was added .After 1ml of starch indicator addition, titration was done with 0.005 ml/l iodine solution to the end point which was identified by first permanent trace of blue-black colour. From the average volume of iodine solution used, the number of reacting moles of iodine was calculated .Using the equation of titration reaction, the number of moles of ascorbic acid reacting in mol/ 1 litre of ascorbic acid, calculation in mg/100 ml of ascorbic acid to each treatment sample was obtained.

Ascorbic Acid



3.6 Determination of Plant Attributes

3.6.1 Plant Survival, Height and Fruit Field analysis.

The plants that survived after one month from transplanting were counted and expressed as a percentage of all the transplants which were planted for each treatment. Ten random plants were selected and plant heights was measured and averaged to obtain average plant height for each treatment. During harvesting, mature fruits for each treatment were picked weighed and recorded. At the end of harvest time the total weights of fruits harvested was divided by the number of plants to obtain average plant yield for each treatment. Average plant yield for each treatment was then used to reflect average plant yield in tones per hectare.

3.6.2 Fruit Quality Attributes and Nutritional Content

Fruit sample from each treatment was obtained by cutting 100 g of selected fruits into pieces and crushed and then 10 ml of distilled water was added and sieved to obtain fruit aliquot used in analysis of vitamin C, percentage calcium, phosphorus and protein.

3.7 Yield comparison across season and location

Fertility of amended wastewater mixed with urea, lime and biogas effluent was investigated by evaluating the yields of California wonder. The yields measured included fruit size, fruit weight, fruit yield and plant yield. These yields were compared using factorial ANOVA with two categorical factors, Treatment and season or location. In the two-way ANOVA, the season and location each had two levels. Season had season I and II levels while location had field and green house. The basis of comparing yields across season and location is to cater for any variability that may arise due to the levels of those factors. Therefore the green house data for season I and II were compared to cater for variability arising due to season i.e. the period when the crop was grown. On the other hand season II data for the field and greenhouse were compared to cater for variability arising due to the location i.e. the physical conditions under which the crop is grown. The treatment factor had ten levels and in the green house experiment included the 3 pot experiment with the same treatment forming a block. The levels were NIL, DAP, WW, BE, WWL, WBE, LM, LWU, BLW and BLWU. The factors season and location together with treatment factor comprised the independent variables while the yield (fruit size, weight, fruit yield and plant yield) comprised the dependent variable.

3.8 Statistical data analysis

The ANOVA test was conducted by using statistical package STATISTICA Release 7. All analysis conducted at 95% confidence Interval (0.05 level of significance).
All data was analyzed statistically using SPSS software package statistical analysis consisted of analysis of variance (ANOVA) for mean separation and Pearson correlation coefficient.

CHAPTER FOUR

RESULTS.

This chapter presents the results and findings of the study of the green house and field experiments.

Table 4.1 Components of Biogas Effluent and Waste water

Property	Waste water	Biogas Effluent
P %	0.009	0.607
N %	0.077	1.750
OC %	2.783	35.920
K (ppm)	30.677	2.197
Pb (ppm)	0.017	-
Cd (ppm)	0.000	-
Cr (ppm)	0.000	-
Fe (ppm)	0.070	-
Zn (ppm)	0.134	-
Cu (ppm)	0.363	-
Na (ppm)	21.823	-
Ca (ppm)	0.480	-
Mg (ppm)	0.713	-

The waste water was found to contain 0.009% phosphorous, 0.077% nitrogen, 2.783 % organic carbon and 0.480 ppm Calcium while the biogas effluent was found to contain 0.607% Phosphorous, 0.1750% nitrogen and 35.920% organic Carbon among other essential elements as shown in table 4.1 above.

4.1 Soil chemicals analysis

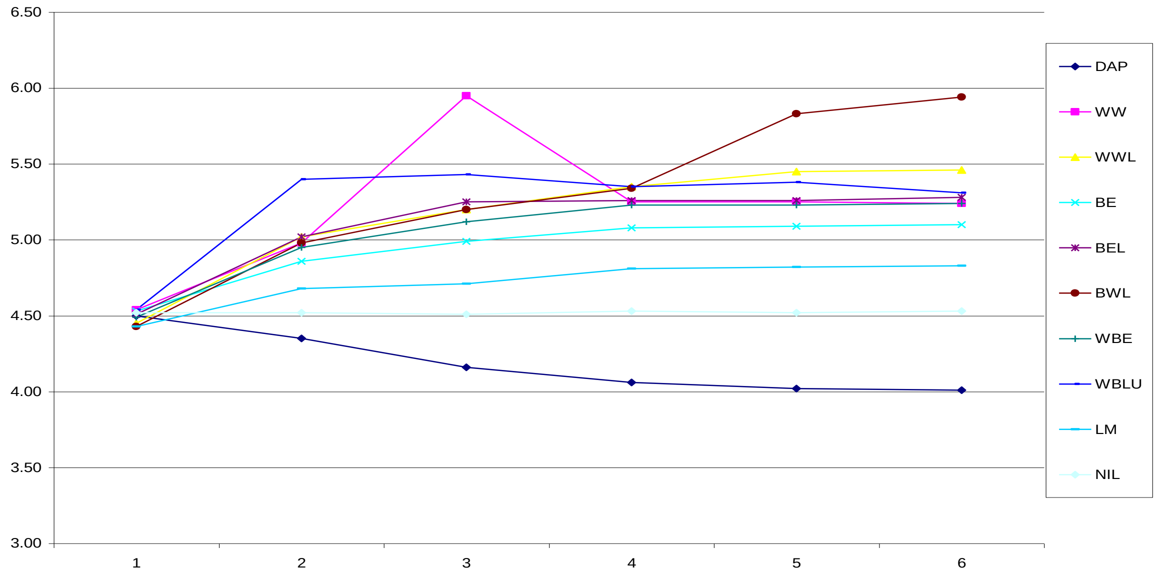


Figure 4.1Changes in soil pH relating to treatments over six sampling periods

4.1.1 pHChanges during the cropping season in Green house.

KEY: DAP – Diammonium phosphate;
WW – Waste Water
WWL – Waste water + Lime
BE – Biogas effluent
BEL – Biogas effluent + Lime
BWL – Biogas effluent + Waste water + Lime
WBE – Waste water + Biogas effluent
WBLU – Waste water + Biogas effluent + Lime + Urea
LM - Lime
NIL - Control

The sampling of soil was done before planting, two weeks after planting, the 6th, the 8th, the 10th week andafter harvesting.The pH of the control remained fairly constant. DAP treatment pH dropped during the cropping season with 0.49 units. The greenhouse BLW pH rise was1.51 units while BWLU showed a fair rise of 1.01 units. For WWL treatments the pH change was 0.98 units. Use of DAP over time leads to reduction of pH. It is acting as an acidifying agent to the soil. On the other hand, waste water and its modifiers reverse soil acidity. Figure 4.1 shows the trend and relationship of pH changes during the growing season for the greenhouse experiments.

4.1.2pHChanges during Cropping season of Field experiments

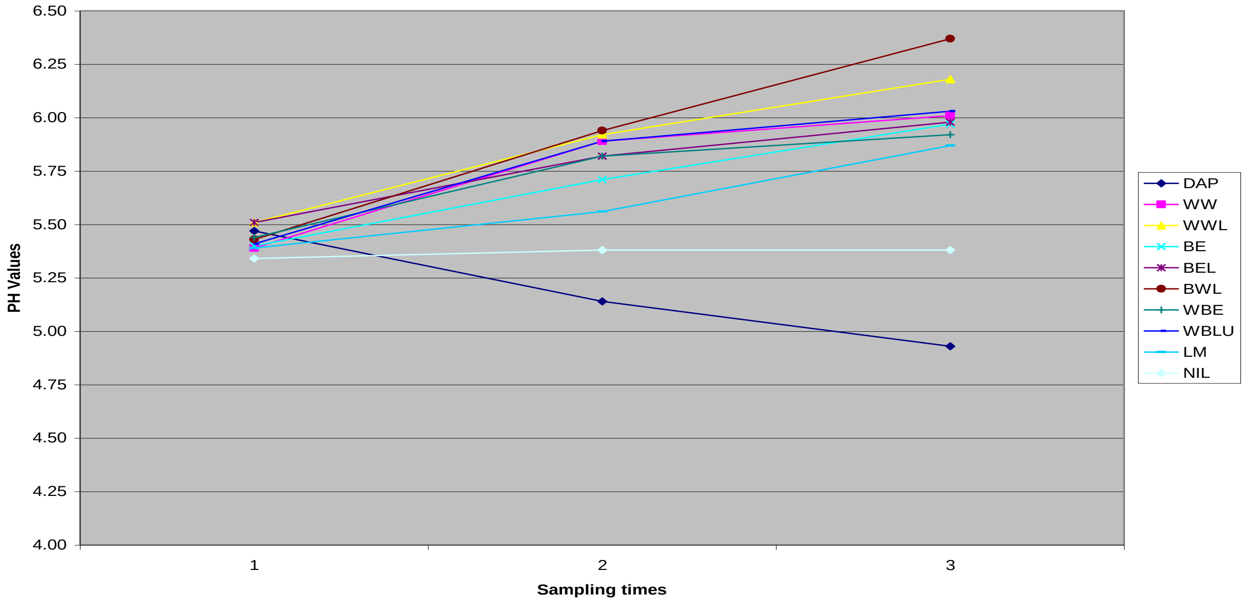


Figure 4.2Changes in soil pH related to treatments over the three sampling periods

KEY: DAP – Diammonium phosphate;
WW – Waste Water
WWL – Waste water + Lime
BE – Biogas effluent
BEL – Biogas effluent + Lime
BWL – Biogas effluent + Waste water + Lime
WBE – Waste water + Biogas effluent
WBLU – Waste water + Biogas effluent + Lime + Urea
LM - Lime
NIL - Control

The sampling was done three times before planting 4 weeks after planting and after harvest.

The pH range of field experiment was between 5.31 -5.51.The pH of DAP decreased during the cropping season with 0.46 units while that of the control remained fairly constant .For WWL treatment ,the change was 0.67 units and WBLU was 0.62 units .The BLW treatment gave the highest rise of pH of1.14 units just like the green house experiment. The other treatments had remarkable increase as figure 4.2 shows the trend of pH changes during the growing season

Comparison of trends in pH for Green house and field Experiment

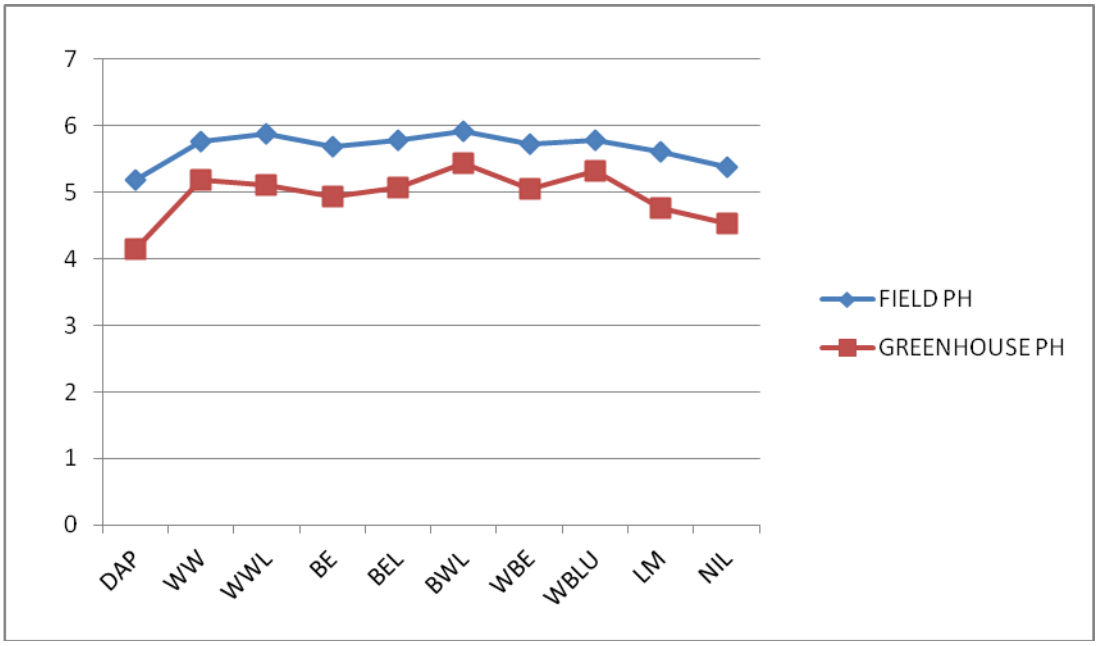


Figure 4.3: Field and green house pH changes in the treatments

The figure 4.3 shows that there was a similar trend in pH changes for specific treatments in both the greenhouse and field experiments.

4.2 Soil Chemical Properties in Green house

Table 4.2Soil chemical properties in the green house experiment

Treatment	ST	EX.Acidity Mol/kg	CaMol/kg	AlMol/kg	MgMol/kg	HMol/kg	KMol/kg	NaMol/kg	OCMol/kg	OlsenMol/kg	NMol/kg
NIL	1	0.783	2.105	0.137	1.130	0.687	0.812	2.320	1.897	6.407	0.180
	2	0.781	2.114	0.134	1.150	0.672	0.840	2.337	2.103	10.218	0.201
	3	0.782	2.132	0.135	1.165	0.670	0.843	2.301	2.205	9.106	0.198
DAP	1	0.742	2.018	0.180	1.242	0.632	0.769	2.259	1.905	5.859	0.154
	2	0.859	1.978	0.124	1.213	0.651	0.782	2.243	1.879	5.075	0.579
	3	0.890	1.951	0.103	1.203	0.673	0.759	2.292	1.897	4.674	0.489
WW	1	0.801	1.989	0.172	1.139	0.632	0.813	2.290	1.989	6.103	0.149
	2	0.869	2.301	0.148	1.509	0.719	0.830	2.430	2.143	9.872	0.208
	3	0.767	2.518	0.108	1.601	0.597	0.808	2.302	2.147	8.031	0.192
BE	1	0.853	2.080	0.209	1.129	0.667	0.798	2.285	2.051	6.070	0.160
	2	0.745	2.135	0.172	1.194	0.638	0.850	2.371	2.193	9.973	0.510
	3	0.740	2.104	0.151	1.245	0.613	0.820	2.103	2.224	8.192	0.381
BEL	1	0.813	1.993	0.217	1.184	0.650	0.801	2.282	1.942	6.270	0.158
	2	0.762	2.314	0.103	1.303	0.598	0.881	2.328	2.282	18.213	0.592
	3	0.709	2.403	0..83	1.285	0.612	0.819	2.301	2.223	13.632	0.273
WWL	1	0.842	2.103	0.161	1.183	0.642	0.788	2.280	1.873	6.001	0.163
	2	0.742	2.337	0.117	1.243	0.624	0.848	2.354	2.031	16.201	0.205
	3	0.661	2.340	0.079	1.146	0.589	0.816	2.312	2.055	14.010	0.174
WBE	1	0.874	2.023	0.189	2.023	0.660	0.834	1.280	1.976	6.023	0.173
	2	0.742	2.081	0.142	1.253	0.600	0.829	2.302	2.208	10.320	0.245
	3	0.736	2.203	0.131	1.197	0.612	0.787	2.283	2.186	9.301	0.189
LM	1	0.853	0.123	0.167	1.185	0.645	0.778	2.245	1.882	6.354	0.165
	2	0.689	2.265	0.114	1.242	0.623	0.849	2.389	1.892	9.815	0.212
	3	0.657	2.281	0.082	1.189	0.601	0.832	2.301	2.012	8.765	0.145
BLWU	1	0.871	2.025	0.169	1.188	0.680	0.774	2.283	1.876	6.215	0.165
	2	0.643	2.473	0.143	1.282	0.601	0.852	2.412	2.285	23.201	0.812
	3	0.609	2.538	0.072	1.261	0.526	0.814	2.418	2.263	17.989	0.615
BLW	1	0.855	2.013	0.184	1.185	0.684	0.766	2.283	1.899	6.793	0.153
	2	0.697	2.367	0.097	1.289	0.612	0.842	2.302	2.250	22.103	0.784
	3	0.621	2.502	0.078	1.259	0.586	0.809	2.401	2.245	17.870	0.589

From the table 4.2 soil chemical properties improved remarkably with the use of the amended organic fertilizer.

4.2.1The Soil Organic Carbon.

In greenhouse experiments, BLW range was (1.8999-2.245) mol/kg while BLWU range was (3.241-4.003) mol/kg. DAP range was (1.876-2.262) mol/kg.

4.2.2 The Olsen P of the soil

The results showed the range of BLW (6.793-22.103) mol/kg while BLWU range was (6.215-23.201) mol/kg. DAP range was (5.859-4.674) mol/kg.

4.2.3 The Soil Extractable Calcium

In the greenhouse experiments.BWLmol/kg treatment range was (0.153-2.502) while BLWU range was (2.025-2.538) mol/kg. DAP range was (2.018-1.951) mol/kg.

4.2.4 The soil available nitrogen

The greenhouse trials BWL range was (0.153- 0.589) mol/kg posted a range of (0.393-0573) mol/kg. DAP range was (0.154-0.489) mol/kg. Olsen p, OC and nitrogen showed the highest increase in the second .and remarkable decrease after harvesting in WWL, BEL, BLWU and BLW treatment while DAP showed persistent drop in Olsen P and notable increase in available N. Olsen P and Calcium concentration increased in all treatments with lime generally . But all the elements showed a drop in the third sampling testing possibly due to fruiting of the plants.

4.2.5 Hydrogen aluminum and exchange able acidity of the soil

For DAP, exchangeable acidity range was (0.742- 0.890) mol/kg, aluminium concentration range was (0.180-0.103) mol/kg and hydrogen concentration was (0.632-0.673) mol/kg. For BLW treatment, exchangeable acidity range was (0.855-0.625) mol/kg, aluminium concentration range was (0.766-0.809) mol/kg. For BLWU treatment, exchangeable acidity range was (0.871-0.609) mol/kg, aluminium concentration range was (0.169-0.072) mol/kg and hydrogen ion concentration was (0.680-0.526) mol/kg. Hydrogen, aluminium and exchangeable acidity showed a notable decrease in all treatments except DAP treatment which showed an increase in the soil acidity during the cropping season.

4.3 Soil chemical properties of the fields experiments

The soil pH increased in all treatment containing lime while DAP treatment showed remarkable decrease during the cropping season. This resulted in increase of extractable cations, P and mineralizable N. After harvesting, significant drop in P and N was noted with DAP, BLWU and BLW posting the highest residual concentration of the same. The Mg and K saturation are high while OC is high ranging from (3.2-4.3) %. Available P is in low range < 5.5 ppm which is below the required supply capacity of the soil. Also, Zn, Mn and Cu showed low concentration while Fe range was high between (5.5 -11.5 ppm).Exchangeable Al and bases was moderately high. Extractable soil P mineralizable N, Ca, Mg and K increased in all treatments with lime Olsen P and % N decreased after harvesting .Hydrogen , aluminum and exchangeable acidity showed notable decrease in all the other treatments except DAP and the control .Remarkable % N was noted in the second sampling. Organic carbon increased in treatments with organic manure. The concentration of the ions was higher than in the greenhouse experiments except calcium which showed slightly low concentration compared to the other cations.The K saturation of the soil was high during the first sampling and percentage organic carbon while available P was low. Treatments with BE increased N% P, Mg, Ca, K and micro-nutrients such as Cu, Zn and Mn.

Table 4.3 Soil Chemical properties of the field experiments

Trtment	ST	Ex Acidity mol/kg	Ca mo/kg	Al mol/kg	Mg mol/kg	H mol/kg	K mol/kg	Na mol/kg	OC mol/kg	Olsen P mol /kg	N mol/kg
NIL	1	0.856	2.008	0.186	2.1	0.404	0.581	1.894	3.545	5.315	0.364
	2	0.852	4.709	0.176	2.11	0.532	0.602	2.041	3.456	4.708	0.358
	3	0.958	2.703	0.164	3.07	0.438	0.681	2.113	3.683	4.547	0.297
DAP	1	0.863	1.813	0.176	2.204	0.513	0.734	2.214	3.487	5.402	0.353
	2	0.991	2.404	0.178	2.345	0.677	0.814	2.145	3.493	5.089	0.893
	3	1.203	3.004	0.184	2.673	0.692	0.742	2.312	3.481	4.731	0.572
WW	1	0.808	2.613	0.197	2.308	0.509	0.834	2.102	3.503	5.534	0.403
	2	0.842	2.904	0.184	2.573	0.573	0.794	2.151	3.632	6.345	0.537
	3	0.789	3.343	0.164	0.429	0.429	0.772	2.402	3.93	4.983	0.301
BE	1	0.932	2.534	0.182	2.363	0.487	0.821	2.301	3.495	5.284	0.411
	2	0.841	3.035	0.178	2.663	0.621	0.803	2.298	3.423	7.475	0.797
	3	0.824	2.909	0.134	2.241	0.549	0.793	2.291	3.673	4.378	0.395
BEL	1	0.997	2.503	0.209	2.195	0.534	0.834	2.189	3.673	5.348	0.378
	2	0.891	3.454	0.187	2.934	0.521	0.889	2.201	3.864	12.734	0.899
	3	0.864	4.241	0.112	2.254	0.434	0.801	2.221	3.998	10.374	0.475
WWL	1	0.874	2.564	0.184	2.243	0.519	0.912	2.433	3.734	5.475	0.501
	2	0.852	3.324	0.142	2.643	0.473	0.942	2.483	3.984	4.875	0.693
	3	0.767	4.634	0.093	2.535	0.409	0.891	2.401	4.114	10.002	0.473
WBE	1	0.889	2.478	0.214	2.314	0.522	1.124	2.181	2.875	5.574	0.387
	2	0.721	2.503	0.201	2.575	0.518	0.973	2.219	3.745	9.875	0.637
	3	0.725	2.734	0.172	2.321	0.578	0.985	2.228	4.287	7.347	0.435
LM	1	0.879	2.602	0.209	2.289	0.535	0.997	2.321	2.987	5.772	0.378
	2	0.857	2.682	0.173	2.475	0.531	0.113	2.331	2.991	8.973	0.402
	3	0.803	2.697	0.129	2.21	0.498	0.871	2.187	3.029	7.183	0.289
BLWU	1	0.908	2.918	0.234	2.273	0.589	1.218	2.113	3.241	5.678	0.393
	2	0.812	2.993	0.209	2.587	0.512	1.278	2.152	3.897	18.783	1.834
	3	0.786	3.214	0.151	2.374	0.409	0.978	2.089	4.003	12.374	0.573
BLW	1	0.912	2.534	0.228	2.174	0.581	1.113	2.327	3.234	5.428	0.389
	2	0.734	2.983	0.201	2.321	0.504	1.345	2.387	4.324	16.897	1.687
	3	0.683	3.097	0.157	2.079	0.374	0.874	2.219	3.875	10.324	0.873

4.3.1 The Soil Organic Carbon

In the field experiments, BLW range was (3.234-4.324) mol/kg, BLWU range was (3.241-4.003) mol/kg while DAP range was (3.487-3.493) mo/kg.

4.3.2 The Olsen Phosphorus of the Soil

The results posted the following ranges; BLW was (5.428-16.897) mol/kg, BLWU was (5.678-18.783) mol/kg while DAP posted (4.731-5.402) mol/kg.

4.3.3 The Soil Extractable Calcium

The field experiments posted the following results; BLW range was (2.534-3.097) mol/kg, BLWU range was (2.918-3.097) mol/kg, while DAP range was (1.813-3.004) mol/kg.

4.3.4 The Soil Available Nitrogen

The results were as follows; BLW range was (0.389-1.687)mol/kg BLWU range was (0.393-1.834) mol/kg while DAP range was (0.353-0.893) mol/kg.The plant essential element olsen P, organic carbon and available Nitrogen showed the highest increase in the second sampling and remarkable decrease after harvesting. For DAP there was persistent drop in olsen phosphorus and increase in available nitrogen. After harvesting, significant drop in P was noted in DAP treatment (4.73mol/kg), BLWU (12.374 mol/kg) and BLW (10.324 mol/kg) posted the highest residual concentration. Remarkable available nitrogen was noted in the second sampling and decreased after harvesting. Organic carbon increased in treatments with organic manure. The concentration of the ions was higher than in green house experiments except calcium which showed slightly low concentration compared to the other cations. The K saturation of the soil was high during the first sampling.

4.3.5 Hydrogen, Aluminium and exchangeable acidity of the soil

For DAP, exchangeable acidity increase was from (0.863-1.203) mol/kg, Aluminium concentration was (0.176-0.184)mol/kg and Hydrogen concentration (0.513-0.692) mol/kg.

For BLW, exchangeable acidity decrease was from (0.912-0.683) mol/kg, Aluminium concentration was (0.228-0.157) mol/kg and Hydrogen concentration was (0.581-0.374) mol/kg. For BLWU, exchangeable acidity decrease was from (0.908-0.786) mol/kg, Aluminium concentration decreased from (0.234-0.151)mol/kg while Hydrogen concentration decreased from (0.589-0.409) mol/kg. Hydrogen, aluminium and exchangeable acidity decreased in all the other treatments except DAP which showed a remarkable decrease in pH.

4.4 The effects of treatment on seedling survival plant height, fruit size and weight and yields

SEASON 1

Table 4.4Survival, height, fruit size and yields for Green house Experiments

Treatment	**Survival %**	**Av. plant height (cm)**	**Av. fresh fruit size (cm)**	**Av. fresh fruit weight (g/pot)**	**Av. yield/ plant (kg/pot)**	**Av. No of plants /ha**	**Av. cost of production/ha**	**Fruit yield in tonnes/ha**	**Profit In Kshs/**
DAP	77.778	32.345	6.394	1.317	0.83	35555.660	98,000.00	6.672	235600
WW	87.681	24.024	5.042	1.453	0.741	40082.745	94,200.00	4.874	149500
WWL	83.333	42.784	6.849	1.879	0.847	68095.089	134,200.00	6.787	205150
BEL	94.444	46.592	6.874	2.154	0.948	43174.404	122,400.00	7.043	229750
BWL	99.987	48.354	8.453	2.895	1.497	45708.347	186,200.00	9.125	270150
WBE	83.333	45.734	6.782	2.451	0.835	38,.95.090	107,000.00	6.982	242100
WBLU	72.322	52.628	8.041	3.104	1.292	33061.489	186,700.00	8.796	253100
LM	88.887	31.674	5.897	1.475	0.586	40634.061	119,200.00	4.784	120000
NIL	55.556	25.124	4.294	1.128	0.438	25397.031	70,200.00	2.243	41950

SEASON 2

Table 4.5Survival, height, fruit size and yields

Treatment Treatment	Survival %	Av. plant height (cm)	Av. fresh fruit size (cm)	Av. fresh fruit weight (g/pot)	Av. yield/ plant (kg/ pot)	Av. No of plants Per hectere	Av. cost of production/ha	Fruit yield in tonnes/ha	Gross Profit InKshs/ha
DAP	77.778	35.234	6.538	1.375	0.814	35560.660	97400	6.681	236650
WW	87.681	24.345	5.845	1.935	0.859	40086.404	96200	5.626	185300
WWL	83.333	46.874	7.3168	2.130	0.901	38095.090	132500	7.504	242700
BEL	94.444	50.418	7.623	2.865	1.179	43174.405	120800	9.440	351400
BWL	99.987	52.714	9.754	3.517	1.578	45708.347	187300	12.447	435050
WBE	83.333	48.895	7.152	2.625	0.898	38095.090	108000	7.483	266150
WBLU	72.322	57.628	8.789	3.234	1.434	35015.775	188500	10.537	329350
LM	8.887	39.456	6.525	1.785	0.658	40634.061	115300	5.347	151850
NIL	55.556	25.236	4.357	1.139	0.458	25397.031	70000	2.431	51550

The survival percentage of transplants treated with BWL was 100% followed by BEL, WW and LM. For BLWU treatment, survival percentage (72%) of the transplants was the least followed by DAP. The survived plants of DAP were healthy, branched plants of moderate height approximately 35cm with very dark leaves.

The DAP treatment had few flowers which matured to fruits giving average yield per plant of 0.814 kg while BLWU had more flowers which resulted in large and healthy fruits (average yield per plant 1.434 kg) . For BWL treatment, the plants were well established, well branched with many flowers maturing to healthy large and dark green fruits giving an average yield per plant of 3.517kg. Average fresh fruit size and weight with BLWU (8.789 cm and 3.234 kg/pot) and BLW (9.754 cm and 3.517g/pot) treatments were the highest giving 4-lobed fruits which were dark green, long and heavier. For WW, LM and the control, the fruits produced were 2-lobed or pointed and small in size, 5.845 cm and 1.935 g/pot, 6.525 cm and 1.785 g/pot and 4.357 cm and 1.139 g/pot. The average yields per hectare were less than the expected yields although season II were higher than season I.

Table 4.6Yield (tones/ha) in Season I and II

	Season I	Season II (tones/ha)
BWL treatment	9.125	12.447
BWLU treatment	8.796	10.537
DAP treatment	6.672	6.681
Control	2.243	2.431

According to Desai (2004), the expected yields are 25-40 tonnes/hectare. From the results, BLW showed an increase of 344% over the control while DAP showed an increase of 174% over the control. The average fresh fruit weight of BWL (3.517 g/pot) and BWLU (3.234 g/pot) were the highest among the treatments. In all treatments where N% increased, the number of fruits per plant increased DAP (0.814 g/plant) ,BWL (1.497 g/plant) BLWU ,(1.434 g/plant) and WWL (0.901 g/plant) compared to treatments without Nitrogen like the LM (0.658 g/plant) and the control (0.458 g/plant). Average fresh fruit weight was good for all treatments with lime.

4.7 Field Experiment

Table 4. 7 The effects of treatment on survival, height, size, weight and average fruit yields

Treatment	Survival %	Av. plant height (cm)	Av. fresh fruit size (cm)	Av. fresh fruit weight (g/pot)	Av. yield per plant (kg/pot)	Av. No of plants /ha	Av.cost of production /ha	Fruit yield in tones /ha	Gross Profit InKsh/ha
DAP	95.387	51.883	7.993	1.874	0.918	43605.486	86,000.00	9.511	422460
WW	99.082	51.034	7.925	2.341	0.698	45294.633	97,200.00	8.053	402650
WWL	98.872	52.352	8.214	2.451	0.895	45198.633	133,000.00	9.096	439760
BE	98.123	51.578	7.874	2.125	0.732	44906.976	83,340.00	9.005	366910
BEL	98.234	53.901	8.598	2.967	0.934	44907.186	121,300.00	11.501	453750
BWL	99.907	78.325	10.857	3.898	1.834	45671.776	186,350.00	18.998	763550
WBE	99.024	54.789	8.879	2.875	0.839	45268.119	108,480.00	9.416	362320
WBLU	97.34	65.572	10.087	3.801	1.452	44498.290	189,230.00	17,723	696920
LM	98.689	52.031	7.542	1.904	0.681	45114.976	121,540.00	8.006	278760
NIL	93.598	45.234	7.234	1.434	0.635	42787.661	71,450.00	4.431	150400

The seedlings showed a high survival in the field compared to the greenhouse experiments in all treatments with BLW (99.907%) posting the highest survival percentage and good plant height of 78.3 cm. For BLWU average height was 65.6 cm and average fresh fruit size was 10.087cm. Their fruits were dark green and 4-lobed with an average fresh fruit weight of 3.801 g/pot. For BLW the average fresh fruit size was 10.857 cm while the average fresh fruit weight was 3.898 g/pot. The seedlings showed a higher survival in the field compared to the green house experiments in all treatments. Plant heights and fruits of all the treatments were good. Plants were well established with strong branches, dark green leaves and good number of fruits. BWL and BWLU and BEL were leading in plant heights, fruit size and weight. Their fruits were dark green and 4-lobed with BWLU and BWL setting more fruits per plant. This may be explained by increased Nitrogen absorption in presence of soluble calcium in treatments implied more extractable calcium in the soil which were absorbed by the plants.

The yields were drastically higher than those of the green house experiments. This may be due to reduced plant density per unit area, better soil pH which implies more available N, P and K or high and direct light intensifies in the field. Increased Nitrogen in BWLU (Biogas effluent waste water + lime + urea) treatment showed more fruits per plant than even BWL whose fruits were big in size and heavier.

Yield

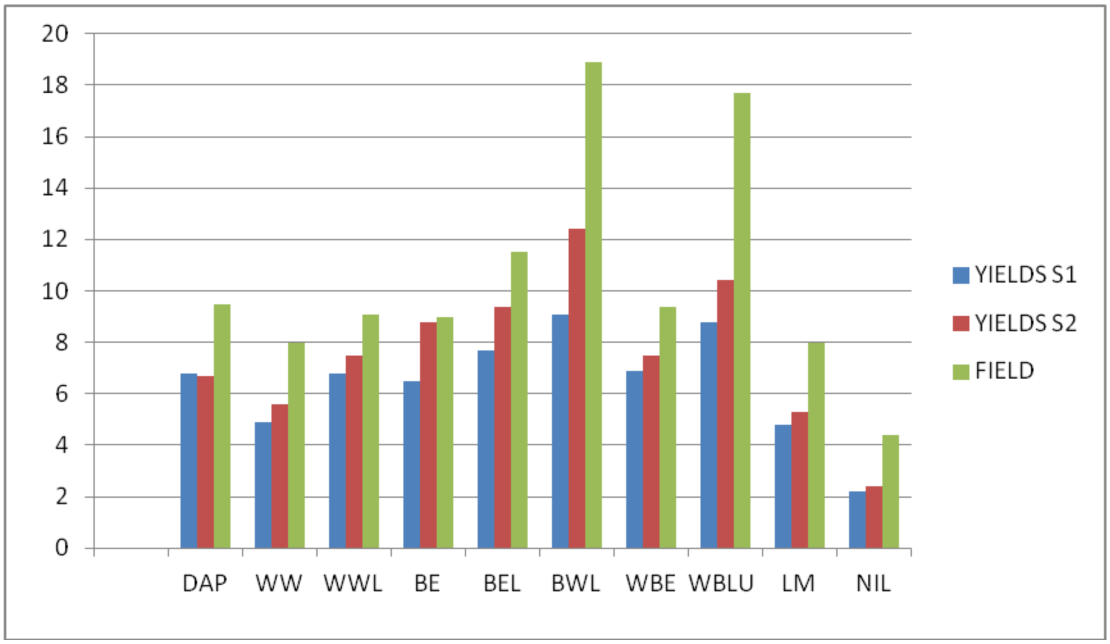
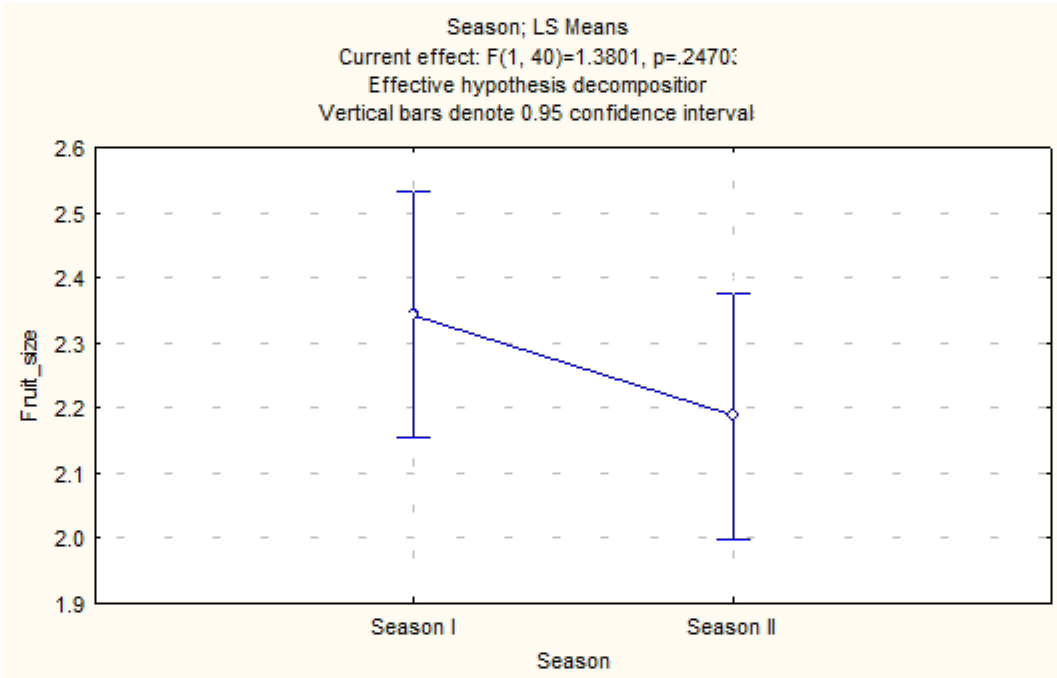


Figure 4. 4 Comparison of field and green house experiments of fruit yields per treatment

4.4.1 Fruit size

Figure 4. 5 All effects graph between season I and season II

(Source:Author 2011)



The results indicated that there was a general reduction in fruit size across seasons. The mean reduced from 2.36 cm in the first season to below 2.2 cm in the second season. The all effects graph below shows these results. The F-ration test obtained is 1.380. Clearly, this is not different from 1. This means that the population (fruit size data) for season I and II comes from the same population and it is one i.e. the period in which the California wonder was planted does not matter, i.e. the season effect is not significant, p = 0.247033. However, the effects of the treatments were significant, F-ratio was equal to 4.524.. The treatments were significantly different. The table below shows the ANOVA table for fruit size. Significance is highlighted in red font.

Table 4.8 ANOVA Results, Fruit Size

Effect	Univariate Tests of Significance for Fruit_size				
	SS	**Degr. of**	**MS**	**F**	**p**
Intercept	307.9626	1	307.9626	1166.736	0.000000
Season	0.3643	1	0.3643	1.380	0.247033
Treatment	10.7469	9	1.1941	4.524	0.000383
Season*Treatment	0.4026	9	0.0447	0.169	0.996111
Error	10.5581	40	0.2640		

The results further indicated that the interaction between season and treatment was not significant.

4.4.2 Fruit weight, Fruit yield and plant yield

Similarly, Analysis of variance was conducted for the dependent variables fruit weight, plant yield and fruit yield. The table overleaf gives the results of the ANOVA for the dependent variable. In the table fruit weight is not different across seasons but treatment is significant in the two seasons. The interaction between the season and treatment was not significant. However there was no significant difference in fruit yield and plant yield.

Table 4.9 Analysis of variance (ANOVA) for treatment and season by fruit weight, plant yield and fruit yield

Effect	Univariate Tests of Significance for Fruit_weight				
	SS	Degr. of	MS	F	p
Intercept	351.6795	1	351.6795	166.3986	0.000000
Season	1.4958	1	1.4958	0.7077	0.403539
Treatment	39.4174	9	4.3797	2.0723	0.046381
Season*Treatment	1.0441	9	0.1160	0.0549	0.999964
Error	126.8086	60	2.1135		
Effect	**Univariate Tests of Significance for Plant_yield**				
	SS	Degr. of	MS	F	p
Intercept	5568088	1	5568088	167.9151	0.000000
Season	21965	1	21965	0.6624	0.420535
Treatment	568812	9	63201	1.9059	0.079051
Season*Treatment	13262	9	1474	0.0444	0.999984
Error	1326405	40	33160		
Effect	**Univariate Tests of Significance for Fruit_yield**				
	SS	Degr. of	MS	F	p
Intercept	3668.351	1	3668.351	129.6957	0.000000
Season	41.514	1	41.514	1.4677	0.232811
Treatment	460.907	9	51.212	1.8106	0.096398
Season*Treatment	20.433	9	2.270	0.0803	0.999802
Error	1131.372	40	28.284		

4.5 Yield comparison by location and treatment

4.5.1 Yield Comparison

Table 4.10 Analysis of variance (ANOVA) for treatment and location by fruit size,fruit weight, plant yield and fruit yield

Effect	Univariate Tests of Significance for Fruit_size				
	SS	**Degr. of**	**MS**	**F**	**p**
Intercept	381.2140	1	381.2140	1211.488	0.000000
Location	6.6533	1	6.6533	21.144	0.000042
Treatment	8.6315	9	0.9591	3.048	0.007163
Location*Treatment	0.6316	9	0.0702	0.223	0.989321
Error	12.5866	40	0.3147		
Effect	**Univariate Tests of Significance for Fruit_weight**				
	SS	**Degr. of**	**MS**	**F**	**p**
Intercept	459.8885	1	459.8885	222.7743	0.000000
Location	2.1576	1	2.1576	1.0452	0.310730
Treatment	46.8498	9	5.2055	2.5216	0.016008
Location*Treatment	1.3879	9	0.1542	0.0747	0.999867
Error	123.8622	60	2.0644		
Effect	**Univariate Tests of Significance for Plant_yield**				
	SS	**Degr. of**	**MS**	**F**	**p**
Intercept	6272667	1	6272667	149.3994	0.000000
Location	11	1	11	0.0003	0.987012
Treatment	778135	9	86459	2.0592	0.057313
Location*Treatment	37891	9	4210	0.1003	0.999506
Error	1679436	40	41986		
Effects	**Univariate Tests of Significance for Fruit_yield**				
	SS	**Degr. of**	**MS**	**F**	**p**
Intercept	2.501104E+08	1	250110421	1.010750	0.320767
Location	2.479954E+08	1	247995400	1.002202	0.322796
Treatment	2.229540E+09	9	247726656	1.001116	0.455013
Location*Treatment	2.228108E+09	9	247567516	1.000473	0.455495
Error	9.898016E+09	40	247450406		

KEY: 0.05 Confidence

According to Desai (2004), the expected yields are 25-40 tonnes/hectare. From the results, BLW showed an increase of 344% over the control while DAP showed an increase of 174% over the control. The average fresh fruit weight of BWL (3.517 g/pot) and BWLU (3.234 g/pot) were the highest among the treatments. In all treatments where N% increased, the number of fruits per plant increased DAP (0.814 g/plant) BWL(1.497 g/plant) BLWU(1.434 g/plant) WWL (0.901g/plant) compared to treatments without Nitrogen like the LM(0.658 g/plant) and the control (0.458 g/plant). Average fresh fruit weight was good for all treatments with lime. In terms of fruit size, the ANOVA results indicated that where the crop was grown i.e. the location was significant. Treatment effect was also very significant. A treatment effect wasonly significant in terms of fruit weight. However, both location and treatment are insignificant in plant yield and fruit yield. Treatmenteffects were generally significant while location and season effects were not significant. Yields were higher for treatments of BLW and BLWU.

4.6 The effects of treatments on the Fruit quality attributes of CaliforniaWonder in Greenhouse Experiments

The properties of fruit under different treatments are presented in Table 4.8 while the correlation between these observations and soil conditions are summarized in the Appendix viii.

Table 4.11 The mean effects of treatments on fruit quality attributes and nutrient content of Bell per 100g edible portion of greenhouse experiments

Treatment	C%	P%	Ca%	Protein%	Ascorbic acid %
NIL	9.146	5.512	2.392	0.199	1.038
DAP	9.149	5.619	2.428	0.220	1.057
WW	9.189	5.519	2.421	0.208	1.048
BE	9.204	5.520	2.401	0.210	1.032
BEL	9.211	5.518	2.452	0.224	1.053
WWL	9.201	5.524	2.445	0.229	1.043
WBE	9.332	5.518	2.438	0.210	1.069
LM	9.158	5.515	2.408	0.201	1.041
WBLU	9.257	5.689	2.580	0.245	1.078
BWL	9.457	5.839	2.882	0.231	1.085

4.6.1 Fruit quality attributes and nutrient content

The treatment BWL, BWLU and WBE resulted in fruits with significant ascorbic acid which showed 27.64%, 25.588% and 14.6.7% increase over the control. This might have been contributed by well-established plants well branched plants resulting in healthy fruits. This implied the plants got most of the nutrients they required. Treatments containing lime such as BEL, BWLU, WWL and WBL showed an increase in the calcium in the fruits may be due to calcium in lime. Biogas effluent and wastewater increased solubility of lime resulting in more calcium absorbed by the plants. Lime (LM) alone showed insignificant calcium increase in the fruits because its solubility in water is very low and slow and takes a longer time for any meaningful cation exchange to take place. The content in the same treatments showed similar trend in both field and greenhouse experiments. Improved soil pH and solubility of lime might have contributed to absorption of soil Nitrogen by the plants. Phosphorus content was fairly constant in all other treatments except BWL, BWLU and DAP which showed some increase of 5.933%, 3.211% and 1.944% over the control respectively.For Carbon, BWL, BWLU and WBE showed 3.40%, 1.21% and 2.03 over the control. This was contributed by biogas effluent in the amendments which has a high OC% content.

4.6.2 Heavy metals in the fruits

The concentration of Pb in fruits of WW, BEL and WWL treatments were below 0.01 ppm which are above the WHO and FAO but below KEBS recommended concentration limits. The other heavy metals such as Cd, Cr, Fe, Zn and Cu were below the WHO, FAO and KEBS recommended concentration limits.

4.6.3 Fruit quality attributes and nutrient control

The content in the same treatments showed similar trend in both field and GH experiments and were better than those of the control according to results in fig. 4.8 and fig. 4.9.

Table 4.12 Comparison of fruit quality attributes in Field and Green house Experiments

		Field	Greenhouse Expts
DAP	Protein %	0.299	0.220
	Ascorbic acid %	1.127	1.057
BWL	Protein %	0.325	0.245
	Ascorbic acid %	1.183	1.078
BWLU	Protein %	0.343	0.231
	Ascorbic acid %	1.173	1.085
NIL	Protein %	0.265	0.199
	Ascorbic acid %	1.103	1.038

Treatments containing lime showed an increase in calcium content in the fruits.
BEL (2.392%), BWLU (2.580%), WWL (2.445%) and WBL (2.882%).

Table 4.3Comparison of Ca attributes in Field and Green house Experiments

	GH (Ca%)	Field (Ca%)
BEL	2.452	2.538
BLWU	2.580	2.669
BLW	2.882	2.589
WWL	2.445	2.530
NIL	2.392	2.489

4.7 The effects of treatments on fruit quality of California wonder in the field experiments

There properties of fruit under different treatments are represented in table 14 while the correlation between these observations and soil conditions are summarized in Appendix viii.

Table 4.14 The mean effect of treatments on fruit quality attributes and nutrient content of bell pepper 100g edible portion of the field experiments

Treatment	C%	P%	Ca%	Protein%	Ascorbic acid %
NIL	9.218	5.581	2.489	0.265	1.103
DAP	9.219	5.688	2.513	0.29	1.127
WW	9.283	5.59	2.518	0.298	1.12
BE	9.278	5.585	2.495	0.298	1.13
BEL	9.281	5.603	2.538	0.312	1.12
WWL	9.282	5.6	2.53	0.307	1.138
WBE	9.423	5.594	2.519	0.279	1.164
LM	9.23	5.613	2.48	0.268	1.119
WBLU	9.344	5.762	2.669	0.343	1.173
BWL	9.218	5.581	2.489	0.265	1.103

CHAPTER FIVE

DISCUSSION

ln the study, California Wonder (Capsicum annum) was used to evaluate the fertilizing value of the waste water. This pepper is of tropical origin which thrives well when the temperatures are warm and is highly susceptible to frost. They make handsome potted plants which produces, firm tasty peppers.

They produce a large number of fruits in a small space making them suitable for even small gardens .They have a unique taste and are rich in vitamin A and C .Though this pepper is prolific, trouble free and productive pepper ,it is affected by soil acidity ,water stress,pests and diseases and soil infertility. Pepper production is also affected by poor seed quality which later on give poor plant establishment of low yields,with fruits of low P,Ca,N and vitamin contents. The introduction of this amended fertilizer helps to solve partly the problem of decreasing pepper production and other garden plants through rectification of soil acidity, improved soil structure and reduced cost of production. The expected production is 37 tonnes /ha and yet in Kenya is about 2.5 tones/ha Waithaka, (1971)and Desai ,(2004) .Low extractable P, N soil acidity and Ca are major limiting factors of this crop and other crops in the vast stretch of land and deficient at pHvalues below 5.5

5.1 The effects of treatments on soil chemical properties.

5.1.1 Greenhouse experiments

The soil pH of Chepkoilel Campus, was (4.50 – 4.54) and Kaiboi (5.34-5.47) where the experiment were done. The soil pH indicates that the soil was acidic and therefore below the pH of(6.0 – 7.5) range required for productive cultivation of California Wonder. The pH of the control remained fairly constant throughout the cropping time of the two seasons. The treatments WW, WWL, BE and BEL showed a fair increase of pH(4.81 – 5.35) in the greenhouse experiments and pH range of (5.97-6.18) in the field .DAP showed a remarkable decrease in pH during the seasons and this was confirmed by Fenn et al., (1987) to be partly due to absorption of ammonium ions by plant roots releasing H^+ which contributed to the reduced pH. The decreasing pH leads to the release of the soluble Al^{3+} into the soil. The two processes increased overall exchangeable acidity. The WBLU treatment posted the highest pH in the first six weeks compared to the other treatments may be due to better solubility of lime in the treatment. But the pH dropped later with time to pH of 5.31. This is explained by Fenn et al (1986) as due to urea precipitations of absorbed and soluble Ca in the fertilizer band thus creating a low Ca and a high NH_4^+ environment.

$$2NH_4^+ \longrightarrow 2NH_3 + 2H^+$$

The dissociation of ammonium ions releases hydrogen ions which increase the acidity of the soils. The WBL showed the highest pH at the end of the cropping season. This is due to high solubility of lime in the treatment which resulted in increased exchangeable Ca in the soil which caused a decreasing Al level by forming insoluble Aluminium hydroxide as confirmed by the negative correlation between Al and H ions and extractable Ca which contributed to the decrease in soil pH as shown by Appendix (1V). OC increased in the soil receiving treatment in which waste water and biogas effluent was incorporated which was found to contain 2.78% and 36% of OC respectively. WBL and BLWU showed an increase of 21% OC over the control while BE treatment showed 18% OC and this led to improvement of soil physical properties such as moisture retention capacity, soil texture and structure at the end of cropping season. Improved pH lead to high rates of OC due to high decomposition of organic complexes and residues by microorganisms and subsequent mineralization of different organic complexes.The OC of DAP and the control remained fairly constant.

The amount of %N in the experimental soil before planting was between 0.1 -0.2 % which is considered to be moderate according to Tekalign et al, (1991). The soil receiving DAP and BLWU showed remarkable increase within eight weeks after planting due to readily available N in form of ammonium. Other treatments that showed increased N% include BE, BEL, WBE and BLW. This may have been due to increased microbial activity in the soil caused by high soil pH which increases breakdown of organic matter to release nitrogen. Soluble Ca may also be playing a role in stimulating absorption of nitrate and ammonium ions from the soil being monovalent ions and are found within the fertilizer band. Liming acid soil increases the number of microorganisms involved in N mineralization and particularly ammonium and nitrate oxidizers. This could also be as a result of N2-fixation due to increased pH in the soil receiving these treatments. This is because it has been established that the activity of Symbiotic Rhizobium bacteria is remarkably reduced at low pH. The %N showed a drop at the end of the cropping season. Concentration of Ca and Olsen P increased in the soil in which lime was incorporated to the treatment. This is partly due to low mobility of P in acidic soil leading to its accumulation near the surface. BEL, BWL and BWLU showed remarkable increase of both. Lime increases soil pH which induces an increase in P uptake and extractable Ca and Olsen P of the soil. The increased pH reduces concentration of Al in the soil by forming insoluble hydroxides. This leads to release of phosphates to the soil which had been absorbed by Al and Fe as explained Sanchez *et al*., (1997). The short time taken by these phosphates to be released in to the soil (8 weeks after planting) and for the pH to increase is a clear indication of high solubility of lime in the treatments. Other addition of P probably originated from the decay and release of organically bound P held by organic resources applied in combinations as described by Russel (1998). Significant drop of Olsen P in the soil during harvesting confirms the uptake of P by plants for flowering and fruiting. The control and soil receiving DAP had Olsen P and Ca concentration remaining constant and dropping during fruiting. This is linked to low pH in this treatment which leads to sorption of phosphates by Al and Fe ions in the soils Sanchez*et al.*,(1997) which are fairly soluble at pH below 5.0 and observed in the site where the experiment was carried out.

5.2 The effect of treatment on seedling survival and plant growth.

All the treatments where lime and wastewater were incorporated showed the highest survival percentage with BWL being the highest. Liming increases the soil pH and exchangeable Ca and Mg of the soil and stimulate uptake of other plants essential nutrients such as P and N. Also, increased solution Ca is thought to improve plant tolerance to unfavorable acidity, and high salinity at the root-soil interface at the subsoil where Al toxicity and soil acidity are serious causes of poor plant growth and development Sanchez *et al.*, (1997).

Al toxicity is considered as the most severe component of stress in acidic soil and has a major impact on growth and survival of legumes host plants as well as Rhizobia. Al affects plants by inhibiting cell division in the roots and this normally leads to shortening and thickening of roots. This could be due to the binding Al to DNA which might inhibit DNA replication Patra*et al*, (1988). Al binds the phosphate present on root surface possibly by forming a precipitate of aluminum phosphate, since distribution of aluminium phosphate precipitate on the cell wall is found to be closely similar to that of phosphates (Heynes*et al*., (1981). This explains the similarities between the symptoms of Al toxicity and those of P deficiency; this reason explains the observed low survival rates of the seedlings growing in the control.The positive effect of lime was also observed with increased plant heights, strong stem and branches and dark green leaves on the plants growing on the treatment with lime. Later in the season, many flowers matured to fruits. The rooting system of California wonder is extensive and not very deep therefore any P-N- absorption and use efficiency was high as Ca concentration increased which influenced plant growth. The Ca stimulation might also extend to other macro and micro plant nutrients whose integrated effects resulted in healthy growth of plants. The blossom end rot a disease caused by insufficient roots system in acid and calcium deficiency soil was not observed in plants treated with lime.

The BLWU treatment had about 72% survival of the seedlings.This may be due to ammonium toxicity which is deletrous young seedlings growing in acidic soils which have Ca deficiency Barlet*et al*., (1995).Though the plants which survived were the healthiest strong and productive plants in the experiment. This could be explained by N-use efficiency in the treatment. Urea is 46% N and is subject to N losses through ammonia volatilization, nitrification leaching and run-off. Increased Ca concentration stimulated ammonia absorption by the plants. Fenn*et al*., (1987) which improves N-efficiency by the plants.High survival percentage were observed in seedling growing in soil that received treatments in which waste water was incorporated compared to those growing in soil without. This is due to thrips, cutworms, aphids, snails and leaf hoppers damage on young pepper plants growing in soil without wastewater. This suggests the possibility of insecticidal effects in treatments in which waste water was incorporated. These pests affected only the greenhouse plants but not those in the field which received the ample distribution of rainfall throughout the growing seasons.

5.3 The effects of treatments on yield and yield components

All these showed increased average fresh fruit size and weight, average yield per plant and per hectare over the control. All the yield components were directly correlated with yields per hectare. Though all the yields were less than expected yields per hectare of 37 tonnes, Desai, (2004). In treatment where %N increased, the increase is due to increase in number of fruits per plant and not fruit sizes and weights. Treatments with lime showed both increase in number of fruits per plant and average weight per plant. Lime caused the increase of soil pH which accompanied increase of N ,P and S availability and decrease in toxic Al Fagaria *et al.,(*1991) Lime may have increased the exchangeable soil Ca, which is utilized both for plant growth and for protection of roots from deleterious effects of Al. Increase in Ca supply resulted in increased plant growth and fruit weight shows the importance of P in increasing fruits in plants (r=0.785).Olsen P per hectare showed positive correlation with all the fruit components. phosphorous is an important constituent of DNA and energy rich compound ATP, which is required for cell division and energy transfer during nodulationand nitrogen fixation process Sanchez*et al*.,(1997). P also promote development of meristematic tissue and efficient absorption and utilization of other plant nutrients .This may have increased vegetative growth in plants growing in BLWU and BWL treatments which produced high number of fruits per plant. This is because P may have helped translocation of N from vegetative parts to the fruits. California wonder showed high response in terms of vegetative growth probably because it's efficiency in translocation and utilization and this could have translated into improved performance with respect to yield components though season one yields were less than season two fresh fruit yields. But the field yields were generally higher than green house yields. This may have been contributed by several factors, such as enough space for extensive rooting system, a higher pH in the field than in the green house, more available nutrients and a high and a better rainfall distribution throughout the cropping season. This influence high survival percentage, nutrients uptake and minimal pest infestation on the plants. High light intensities might have also contributed to high yields.The green house control experiment fruits produced few and small fruits with no lobes with a light green colour while those of the field were two-lobed dark green and small in size.

5.4 The effects of treatments on fruit quality.

The treatments DAP, WBLU, WBL, BEL and WL showed high protein content in the fruit. This may be due to readily available N and DAP formulation which could have affected plant N- use efficiency. Ammonium is less mobile than NO_3 and generally remains near its original placement in the soil though some of it may be lost though NH_3 Volatilization,leaching and denitrification. This was confirmed by the positive correlation between N soil and fruit protein (r = 0.7474). The positive contribution of the other treatments may be due to presence of lime incorporated in the treatment. Lime increases the soil pH within the first months after application and also increases extractable Ca and P, Mg of the soil. Lime is known to increase seed N, P, Ca, Mg and S and seed protein concentration of cowpea .Direct correlation between Olsen P and fruit protein (r = 0.559) and ascorbic acid (r = 0.614) shows that P uptake by plants is also important in improving the quality of fruits. This was proved by low residual P after harvesting the fruits in all the treatments and a positive correlation between Olsen P and all the fruits quality parameters ensured. Soil Olsen P dropped drastically during fruiting of plant. Fruit P and ascorbic acid showed the strong correlation (r = 0.614). Average fresh fruit weight increased with liming in this treatment.

The heavy metals in the fruits were absent or within acceptable recommended concentration limits according to WHO, FAO and KEBS. This makes the fruits obtained from this treatments in which waste water were incorporated to be safe for human consumption.

5.5 Field Experiments

The field experiments were comparable with the green house experiments though the results were far much better in the field. BWL and BWLU gave the highest yields in both. Survival percentage was generally high in all the field experiments compared to green house experiments. This may be due to good rainfall during the growing season, less acidity and enough space for root expansion and elongation. Direct light intensities might have also contributed to the results. The ANOVA results showed that whether the plants were grown in the field or in the green houses is not significant but treatments played the key role in influencing the yields.

5.6 Solubility of lime

Solubility of lime was highest in solvent made by mixing waste water and biogas effluent among solvents used as treatments in the field. This could have been due to the fact that waste water contains components such as Gallic acid which could probably increase solubility of lime. Other possible reason for increased solubility is due to formation of complexion. Increased solubility of aluminium hydroxide due to formation of tetrahydroxyaluminumions Hicks, (1986) is possible explanation of increased solubility of lime in this solvent. This is further supported by the fact that when separate experiments was done in the laboratory, 15g of sodium nitrate in 100g of waste water was found to increases solubility of lime in the solution. Therefore it is highly suspected that presence of Na+ ions in both waste water and biogas effluent could have increased solubility of lime in this solvent. The solvent mixture which contained urea was expected to give the highest solubility of lime but it did not. This may be due to urea precipitating soluble Ca, thus creating a low Ca and a high NH_4 environment (Bartlett et al 1972). The solvent mixture of waste water biogas effluent and lime used gave the highest solubility of 3.07 g/dm^3.

5.7 Conclusion

The best way to dispose waste water from Muhoroni Agro-chemical and Food Company is through land treatment. When amended with lime, biogas effluent or any inorganic N formulation fertilizer, positive results are realized. The application of lime in solution reduces the time for possible cation exchange to take place and also makes application cheap and easy. This amended fertilizer has integrated nutrients which are released slowly for efficient plant uptake and helps to solve the problem of acidity apart from improving the soil physical properties and water retention capacity. The fertilizer is cost efficient and affordable to most small hold farmers who cannot afford in organic fertilizer. They offer a better option for good yields even in acidic soils where low soil pH and low available soil P, N and Ca are limiting factors for crop production.

The koru lime used is in - active lime which can be mixed directly with urea even in wet conditions because it does not promote NH^{+}_{4} volatilization. The soil pH influences the availability of nutrient to the plant such as phosphorous which is less available in low pH. When the pH is between 5.0 – 6.5 most of the nutrients are available for the plants uptake. It also influences the rate of multiplication and growth of micro-organisms in the soil. Low pH influences the outbreak of fungal diseases on the plants.

California Wonder is sensitive to acidic soil, low soil extractable N and Ca and other essential nutrients. Liming helps to solve this problem for better production by inducing Calcium supply increase, P retention and uptake, improving soil pH, increasing soil nitrogen availability and uptake and reduction in toxic Al. Liming favours accumulation of nutrients in the seeds, particularly Ca, P and N which contribute directly to increased fruits per plant. It increases fresh fruits weight and quality of the fruit produced. The amended fertilizer improves the organic carbon, percentage nitrogen, Olsen P and soil pH value of the depleting fertility and increasing acidity of UasinGishu and Nandi counties. The most viable way of disposing the polluting wastewater is though land treatment.

CHAPTER SIX

SIGNIFICANT OBSERVATION OF THE EXPERIMENT

i). Use of DAP over time increases soil acidity, which results in low productivity of crops.

ii). The amended fermented molasses waste water in presence of lime and biogas effluent not only reverses soil acidity but also improves soil structure and chemical properties.

iii). Treatments which contain the waste water was less affected by the insects and pests and showed high survival percentage.

iv). BWL treatment posted the highest yields in both green house and field experiments.

v). There was a similar trend for both the green house and field experiments in pH changes for respective treatments.

vi). Season and location of the experiment were not very significant in the growth and yields of California wonder but the treatment used.

6.1 RECOMMENDATION FOR FURTHER RESEARCH

1. The fertilizers from the waste water should be extended to other garden crops and large scale crops such as beans, maize, rice and wheat.
2. Machinery for applying the fertilizer in paste form to be developed
3. Farmers in Uasin Gishu and Nandi-North districts should be encouraged to adopt practices replenish soil organic matter, Nitrogen and phosphorous
4. BWL, BLWU and BEL which were the best treatments to be considered for further studies and refinement to make them better in both formulation and application.

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APPENDIX I: LAYOUT OF FIELD

DAP	DAP	DAP
WW	WW	WW
LM	LM	LM
BE	BE	BE
BEL	BEL	BEL
BLW	BLW	BLW
WBE	WBE	WBE
WWL	WWL	WWL
BLWU	BLWU	BLWU

APPENDIX II:LAYOUT OF GREEN HOUSE

DAP	DAP	DAP
WW	WW	WW
LM	LM	LM
BE	BE	BE
BEL	BEL	BEL
BLW	BLW	BLW
WBE	WBE	WBE
WWL	WWL	WWL
BLWU	BLWU	BLWU

KEY:

DAP Diammonium phosphate

WW Waste Water

LM Lime

BE Biogas Effluent

BEL Biogas Effluent and Lime

BLW Biogas Effluent and Waste Water

WBE Waste Water and Biogas Effluent

WWL Waste Water and Lime

BLWU Biogas Effluent Lime Waste Water and Urea

APPENDIX III: SOIL ANALYSIS DATASHEET GUIDELINE

MINERAL	**SUFFICIENCY**
Na (Me)	Minimum of 0.2 Me for brassicas
K(Me)	0.2 to 1
Ca(Me)	2 to 10
Mg(Me)	1 to 3
Mn(Me)	0.1 to 2
Fe	10 ppm
Cu	1 ppm
Zn	5 ppm
N%	0.2 % (44.8kg per hectare)
P(ppm)	Olsen 10 to 20
C%	2 to 4%

Adopted from Ministry of agriculture, EldoretMunicipality.

APPENDIX IV: CORRELATION BETWEEN SOIL CHEMICALPROPERTIES AND FRUIT ATTRIBUTES

	Ex. Acidity Cmol/kg	**Olsen P**	**N%**	**Al Cmol/kg**	**Ca Cmol/kg**	**H Cmol/kg**
Al Mol/kg	0.520	0.661*	0.650	1.000	0.239	0.271
Olsen P	0.732**	1.000	0.559	0.488	0.577*	0.661*
N%	0.249	0.599	1.000	0.090	0.488	0.090
CaCmol/kg	0.4.14	0.577*	0.488	0.239	1.000	0.136
Exchangeable acidity Cmol/kg	1.000	0.732**	0.249	0.520	0.414	0.687*
H Cmol/kg	0.687*	0.661*	0.379	0.271	0.136	1.000

	% C	**% P**	**% Ascorbic acid**	**% N. or Protein**	**Soil Ca**	**Fruit Ca**	**Soil OC**
% C	1.000	0.480	0.667*	0.620	0.139	0.758*	0.673*
% P	0.480	1.000	0.614	0.753	0.614	0.675	0.170
% Ascorbic acid	0.667*	0.614	1.000	0.632*	0.442	0.855**	0.115
% N. or Protein	0.636	0.821**	0.632*	1.000	0.467	0.867**	0.413
Soil Ca	0.139	0.614	0.442	0.461	1.000	0.394	0.309
Fruit Ca	0.758*	0.675	0.855**	0.867**	0.394	1.000	0.285
Soil OC	0.673*	0.170	0.115	0.418	0.309	0.285	1.000

KEY

Pearson correlation

Sig (2- tailed)

APPENDIX V: COMPONENTS OF BIOGAS EFFLUENT

Element	Mean	Std deviation
N	1.750	0.231
P	0.607	0.021
OC	35.920	0.226
K	2.197	0.161

APPENDIX VI: SOLUBILITY OF LIME

Element	**Mean**	**Std deviation**
WNa	3.31	11.89
WB	3.07	12.37
WW	0.00164	12.47
D	0.00195	12.03
B	0.0096	12.23
WU	0.00769	12.77