NUTRIENT COMPOSITION AND YIELD OF TOMATO UNDER FOLIAR APPLICATIONS OF HERBAGREEN AND SIDALCO LIQUID FERTILIZER

BY

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AUGUST, 2015

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KUMASI, GHANA

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

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A Thesis submitted to the Department Of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, in partial fulfillment of the requirements for the degree of

MASTER OF PHI LOSOPHY

IN

SOIL SCIENCE

BY

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(BSc Agriculture)

AUGUST, 2015

DECLARATION

I hereby declare that except references to other people's publications which have been duly cited, this research presented as a thesis for the award of the degree of Master of Philosophy in Soil Science, is the result of my own effort and it has neither in part nor in whole been submitted elsewhere for the award of a degree.

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DEDICATION

This dissertation is dedicated to my mother, ISATOU MARKALO for her continuous support and dedication to my life and in loving memory of my late father, KEBBA CAMARA.

ACKNOWLEGEMENTS

My sincere gratitude goes to my supervisor, Dr. Vincent Logah for his immense and remarkable contributions towards the success of this research work. His guidance and constructive criticisms of the numerous drafts of this work has given me an indepth understanding of scientific research. Special thanks go to Dr. E. A. Osekre, my co-supervisor and Dr. Charles Kwoseh for their advisory roles and support during the study. I am grateful to Professors A. Addo and Felix Akorley for providing the Herbagreen.

Special thanks to Mr. Gabriel Willie Quansah, Mr. Anthony Abutiate, and all laboratory staff of Soil Research Institute for the technical support. My sincere appreciation goes to Mr. Samuel Acquah, Mr. George Nortey and the entire staff of Soil Lab, Department of Crop and Soil Sciences, KNUST, and also all workers of the Plantation Crops Section of the Faculty of Agriculture. I also owe a great deal of appreciation to the entire Gambian WAAPP sponsored students in KNUST for their support and encouragement in one way or the other during the two year period.

I would like to express my sincere appreciation to the West African Agricultural Productivity Program (WAAPP), for funding this work through the National Agricultural Research Institute (NARI), Gambia. I sincerely thank the current and previous managements of NARI for creating an enabling environment for capacity building. I render appreciations and profound gesture in loving memories of late Dr. Musa Bojang and Dr. Babou Ousman Jobe, former Director General, NARI.

I notably thank the entire members of the Camara Kunda family, both home and abroad for their continuous moral support and prayers. I also owe special thanks to my wife, Mrs. Fatoumatta Camara Yarbo whose encouragement and unflinching support

have bought me this far. I pray that God the Almighty Allah grant each and every one their heart desires.

ABSTRACT

A field experiment was conducted at the Plantation Crops Section of the Faculty of Agriculture, KNUST, Kumasi to determine the comparative effects of Herbagreen and

Sidalco liquid fertilizer on nutrient composition of tomato prior to fruiting. The study also consisted of evaluation of pest and disease incidence and severity under the foliar applications Herbagreen and Sidalco liquid fertilizer in 2014 Major and Minor seasons. The two-season field experiment was laid out in a split-plot arranged in a randomized complete block design with three replications. The main plot factor consisted of two tomato varieties viz Petomech and Roma Savannah. The sub-plot factor comprised application of Herbagreen (HG) solution at 0.1 % concentration and Sidalco liquid fertilizer (NPK 10-10-10) at 9 ml/15 *l* of water at a weekly interval for four weeks. The application commenced three weeks after transplanting (WAT). A check (NPK 15-15-15 fertilizer + urea) and a control (no application) were also included as part of the treatments. Prior to fruiting, leaf samples were taken from five randomly selected plants in each plot for laboratory analysis of nutrient composition. Soil samples were also taken from each plot for routine soil nutrient analyses at the end of the experiment. Field and laboratory count of insects were done on aerial parts of five randomly selected plants in the middle rows of each plot. Disease incidence and severity were recorded on five randomly selected plants from the middle rows of each plot from 4 to 8 WAT. Foliar applications of Herbagreen and Sidalco liquid fertilizer significantly ($P < 0.05$) affected N compositions of tomato in the minor season with the former producing the highest value of 3.91 %. Sidalco liquid fertilizer significantly ($P < 0.05$) produced the highest K content in tomato in the major season whilst Herbagreen produced the highest values in the minor season. Varieties x fertilizer effect on Mg composition of tomato were significant ($P < 0.05$) only in the minor season. In both seasons of cropping, the fertilizer treatments significantly ($P < 0.05$) affected microbial biomass N. Foliar application of Herbagreen and Sidalco liquid fertilizer significantly ($P <$

0.05) reduced the densities of *Bemisia tabaci* (Gennadius) in both seasons of study. In the minor season, Herbagreen significantly ($P < 0.05$) reduced both incidence and severity of late blight. Herbagreen and the check equally produced higher number of fruits (6.2) per plant over Sidalco liquid fertilizer and the control in the major season. Herbagreen and Sidalco liquid fertilizer significantly ($P < 0.05$) increased fruit yield over the control but only in the major season. The results of the study showed that Herbagreen and Sidalco liquid fertilizer had similar effects on the agronomic characteristics of tomato. However, Herbagreen treated plants produced fruit yield comparable to conventional NPK and Sidalco liquid fertilizer with lower diseases incidence and severity as well as lower insect pest numbers, making it an option worth considering for tomato production in Ghana. It will be essential to investigate the synergistic effect of combined applications of conventional soil NPK and foliar fertilizers for effective crop nutrient management.

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CHAPTER ONE

1.0 INTRODUCTION

Many farmers in Ghana and other developing countries of late rely heavily on agrochemicals in their pursuit to produce food crops and vegetables, especially during the dry season (Amoah *et al.,* 2005). The farmers are increasingly relying on inorganic agriculture mainly because the soils are poor, and indigenous crop varieties have almost been replaced by improved high yielding varieties which are heavy nutrient miners (Laary, 2012). According to the author, these crops are also quite susceptible to many insect species, which may not only feed but also reproduce on them.

The application of the agrochemicals have had some undesirable impacts such as loss or depletion of topsoil, a drop in the population of microorganisms and change in soil acidity (Laary, 2012). The excessive use of such chemicals has resulted in pest resistance, resulting in the development of even stronger chemicals (Denholm and Williamson 2002; Kara and Sabir 2010). Consequently, the environment is damaged by toxic materials, chemical leaching into rivers and water reservoirs (Kara and Sabir, 2010).

The methods of nutrient application play an important role in nutrient supply to plants since the efficacy of fertilizers applied to soil is low due to various losses and fixations (Chaurasia *et al.*, 2005). Dewdar and Rady (2013) stated that soil application of macronutrients is very expensive and the availability of macronutrients are affected by several environmental factors such as leaching, microbial immobilization, denitrification and volatilization. In contrast, foliar feeding techniques as a particular way to supply nutrients minimize these factors and results in a rapid absorption (Jamal *et al.,* 2006; Dewdar and Rady, 2013).

Application of N, P and K in different ratios through foliar sprays is a modern method of fertilization in vegetable crops (Chaurasia *et al.*, 2005). Foliar feeding is more effective and less costly in most cases (Jamal *et al.*, 2006; Dewdar and Rady 2013). Foliar-applied nutrients have the benefit of being 4 to 30 times more efficient and pose no risk of groundwater contamination (Dixon 2003). Fageria *et al.* (2009) reported that crops respond to soil applied fertilizers in 5 to 6 days as compared to 3 to 4 days with foliar application.

Several authors have reported on soil fertility management practices and their effects on insect pests and diseases. Cultural practices formed one of the accepted and well conceived approaches in reducing the pest incidence in many crops (Karnataka 2011). Magdoff and Van (2000) indicated that farming practices that cause nutrition imbalances can lower pest resistance.

According to Sarwar (2011), the use of fertilizer within plant protection system can prove a key factor for pest management strategy. The author noted that better plant growth and yield depend on balanced fertilization, which in turn may have an indirect effect on pests and diseases. On the other hand, Yeboah *et al.* (2003) reported that proper and appropriate plant nutrients do not only increase fruit yield in tomato, but also prevent diseases and pests from affecting the plant. Therefore understanding the relationship between plant nutrition management and pests and diseases of crops is a basis for setting up a high yield production system (Sarwar,
2011).

Herbagreen is a beneficial foliar fertilizer for vigorous and healthy developments in both vegetative and generative respect to resist pests and diseases (Kara and Sabir, 2010). It is composed of carbonate calcium, silica, magnesium oxide, and certain trace elements such as iron, manganese and selenium. It is made up of 100 % natural

minerals that increases yield (30 to 60 %), reduces pests attack, fungal and bacterial diseases of plant and enhances soil fertility status (Herbagreen, 2010). Studies in Turkey by Kara and Sabir (2010) on the effects of Herbagreen application on grapevine rootstocks during nursery propagation indicated that application had obvious impact on the vegetative development of the grapevine by promoting shoot elongation, leaf enlargement, thickening, and final take of the plants.

The use of Herbagreen in crop production is an emerging technology. There is limited data on its impact on plant nutrition and soil fertility status (with regard to nutrient mining with time), incidence of insect pests and diseases of plants especially in tropical climate and the implication for crop yield, hence the need for this study.

The study was based on the hypothesis that foliar application of Herbagreen will increase nutrient composition of tomato and reduce depletion of soil nutrients by crop uptake, reduce pests and disease incidence and increase crop yield.

The specific objectives were to:

i. determine the effects of Herbagreen and Sidalco liquid fertilizer on N, P, K, Ca and Mg composition of tomato prior to fruiting.
ii. evaluate soil fertility status under the application of Herbagreen and establish the implication for potential nutrient mining or otherwise in the short term.
iii. determine the impact of Herbagreen on insect pests and disease incidence and severity in tomato and.
iv. evaluate tomato yield under the foliar applications of Herbagreen and Sidalco liquid fertilizer in the Semi-deciduous Forest Zone of Ghana.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Foliar fertilizers

Foliar fertilization is an agricultural practice that has been studied for more than 40 years (Eichert *et al.,* 1999). This notwithstanding, soil application is the most common method of supplying essential nutrients to plants. However, higher plants can also absorb mineral nutrients when applied as foliar sprays in appropriate concentrations (Fageria *et al.*, 2009). This fertilization mode has been recommended in integrated plant production system because it is environmentally friendly and provides the

possibility of achieving high productivity and good quality yields (Wo´jcik, 2004). Also, interest in foliar sprays increased because of the development of high concentration soluble fertilizers and the increasing use of machinery for spraying and overhead irrigation (Fageria *et al.,* 2009).

Foliar fertilizer is applied under conditions of decreased nutrient availability in soil, dry top soil and decreased root activity during reproductive stage (Marschner, 1995). Foliar feeding with mineral nutrients has also been widely used as a means to correct nutritional disorders in plants and is frequently used in agricultural practice to supplement soil-derived nutrients (Wo´jcik, 2004). The use of foliar-applied fertilizers alone, or in conjunction with soil-applied nutrients, is actively debated by producers and promoted by suppliers (Landgren *et al.,* 2013). Few studies have been conducted to determine whether foliar-applied nutrients are beneficial, either applied alone or as a supplement to soil-applied products (Fageria *et al.,* 2009). Jin *et al.* (2008) suggested that a foliar spray could be used effectively to overcome the problem of micronutrient deficiency in subsoil. In some instances, plants that seem to benefit from foliar uptake are actually benefitting from nutrient spray that reaches the soil and is taken up by roots (Wallay and Boyhan, 2014).

Application of micronutrients by foliar spray is more successful and effective because of the small amounts required, whereas soil application is effective for both macro and micronutrients (Fageria *et al.,* 2009). Most macronutrients are also immobile, for example, Ca and Mg are not easily translocated to leaves within the plant (Foth and Ellis, 1996). Similarly, most micronutrients, for example, Fe and Mn, are readily fixed in soils having an alkaline pH. Plant roots are unable to absorb these nutrients adequately from dry topsoil (Foth and Ellis, 1996). Therefore, foliar application of these nutrients is more efficient and uniform compared to soil application.

Foliar nutrient application can be essentially critical for plants at early growth stage and during reproductive stage (Chaurasia *et al.,* 2005). This is because at these stages of plant growth, the root systems are either not fully established or reduced in their efficiency of nutrient uptake (Alexander, 1986). Gholami *et al.* (2011) stated that root nitrogen (N) absorption reduces intensively in wheat upon shifts from vegetative to reproductive growth. At this stage and during the course of ripening, roots may either senesce or function less effectively. Several other authors have indicated a significant relationship between the plant development stage and ability of leaves to absorb mineral nutrients. According to Alexander (1986), foliar sprays of a given nutrient are most successful when applied at plant reproductive stage, when high amount of the nutrient is required. For example, Shaygany *et al.* (2012) evaluated the response of rice to foliar application of macro- and micronutrients under saline conditions. The results of their study indicated that rice responded favourably and exhibited improved tolerance to salinity hazards by decreasing the N/S ratio. The authors concluded that foliar applications of balanced amounts of fertilizers at the seedling stage, tillering and at panicle initiation and differentiation helped in enhancing yield and yield components of rice.

Researchers have discovered many agents that promote plant growth and/or restrict the attack of pest and diseases (Kara and Sabir 2010). There are new technologies emerging that allow farmers to increase yield and reduce chemical usage whilst lowering costs. Many of these products are environmentally safe and contain different bio-control agents (Herbagreen protocol, 2010). Kara and Sabir (2010) indicated that plant growth stimulating products such as Herbagreen are beneficial substances for vigorous and healthy developments in both vegetative and generative respect to resist pests and diseases.

2.1.1 Herbagreen foliar fertilizer

Herbagreen foliar fertilizer (100% natural product) is made of natural calcite originating from a mine in Austria (Dumancic, 2010). It is made up of calcium carbonate, silica, magnesium and certain trace elements (Table 2.1). The calcite rock is pulverized to a size of a molecule or a group of molecules and in that way the powder is obtained whose particles is charged with active energy (Dumancic, 2010). Herbagreen provides the optimal amount of carbon dioxide (CO_2) to the plant to actively increase, accelerate and significantly contribute to the harmonization and extensiveness of the process of photosynthesis (Dumancic, 2010; Akin, 2011). Carbon in the form of CO_2 is the most essential nutrient. All other nutrients or fertilizers are secondary and of no use unless CO_2 is plant available in sufficient quantity (Dumancic, 2010). According to the author, a typical biomass is composite of 95 % of CO_2 taken up by leaves from the atmosphere and only 5 % of the elements taken up from the soil.

Other components of Herbagreen involve primarily calcium oxide, which helps and intensifies primary and secondary metabolic processes, and all other physiological processes in the plant (Velkov and Petkova, 2014). Anonymous (2010) reported that Herbagreen supplies the plant with optimal amounts of calcium, silicon as well as partly with important micro-elements. These give the plant strength, the resistibility to adverse biotic and abiotic stresses particularly resistance to the incidence of diseases and pests. Herbagreen enhances enzyme activity and increases the plant's immune system, improves plant health and productivity (Akin, 2011).

Table 2.1 Main components of Herbagreen

Main components warranted	Percentage (%)
Calcium oxide ($CaCO_3$)	35.9
Silicon oxide (SiO_2)	11.3

Iron oxide (Fe_2O_3)	2.5
Aluminium oxide ($Al_2O_{3)}$	4.2
Magnesium oxide (MgO)	1.9
Potassium oxide (K_2O)	0.5
Titanium oxide	0.5
Phosphorus (P_2O_5)	0.02

Source: Kara and Sabir (2010)

Herbagreen significantly increases the yield of vegetable cultures, particularly, cucumbers. This increase varies from culture to culture, but on average ranges between 10 and 40% (Dumancic, 2010). Herbagreen increased yield, weight, berry red and blue color intensity values of grape (Akin, 2011). Dumancic (2010) reported that in Russia, tomato plants that were not treated with Herbagreen were exposed to diseases that commonly occur on tomato culture. Yellow leaves and various other damage to the fruit, stalk, or leaf can often be seen on untreated plants. Dumancic (2010) showed that plants which are properly and regularly treated with Herbagreen tolerate prolonged dry periods more easily. According to the author, similar observations were made in all arid climates, particularly in Libya.

Research results from Turkey by Kara and Sabir (2010) on the effects of Herbagreen application on grapevine rootstocks during nursery propagation indicated that foliar application had obvious impact on the vegetative development of the plant by promoting its shoot elongation, leaf enlargement, thickening, and final take. Other reports have been made on the effects of Herbagreen on the growth and yield of several crops such as rice, oil palm, cassava, banana and rubber in different parts of Europe and Asia. However, the use of Herbagreen in vegetable cultivation is yet to receive the needed research attention especially in Sub-Saharan Africa.

2.1.2 Sidalco liquid fertilizers

Sidalco liquid fertilizers contain nitrogen, potassium and phosphorous. They come in three different compositions namely N: P: K: 10:10:10, N: P: K: 20:2:4 and N: P: K: 6:0:20 (Afrifa *et al.,* 2006). Sidalco nitrogen-based liquid fertilizers are Sidalco balanced NPK10:10:10 (used to help replenish the soil), Sidalco nitrogen-rich NPK 20:2:4 (which helps with the healthy growth of the crop) and Sidalco potassium-rich NPK 6:0:20 (which helps increase yield, fruit formation and flavour) (Afrifa *et al.*, 2006; Lamptey, 2012).

In Ghana, Sidalco fertilizer works extremely well with cocoa due to the important contribution of cocoa to the country's economy. Sidalco fertilizer was also successful with non-traditional crops such as tomatoes, pawpaw, cotton and cashew (Lamptey, 2012).

Plants can only take up nutrients once they are dissolved in water. Sidalco 10:10:0+TE (trace elements) is already soluble, resulting in a very rapid response and uptake. The micro nutrients in Sidalco 10:10:0+TE are chelated by EDTA and thus, remain available to the plant (Lamptey, 2012).

Numerous applications may be needed to supply a meaningful amount of NPK through the leaves without burning them (Afrifa *et al.*, 2006). Sidalco 10:10:0+TE is formulated from fertilizer nutrients that are safe to the crop. The application rate depends on the age and type of crop plant. For vegetables, 10 ml of Sidalco liquid NPK 10:10:10 per 15 L of water is applied 3 times in a season repeated every 7-10 days interval (Lamptey, 2012).

2.2. Effect of foliar fertilization on crop nutrition and yield

The beneficial effects of foliar fertilizer applications for yield increase and improvement of crop quality were reported in many vegetable species such as cabbage, onion, cucumber, and squash (Charbaji *et al.,* 2008). For example, Chaurasia *et al.* (2005) reported maximum plant height, number of branches, fruit length, fruit diameter and number of fruits in the treatments with foliar sprays of water soluble formulation of NPK 19:09:19 on tomato grown under field conditions. Similarly, Ibrahiml *et al.* (2014) reported that increasing foliar application of salicylic acid rates resulted in significant increase in plant height, number of grain/spike, straw and grain yields of wheat. In his study, Amjad *et al.* (2014) showed that foliar spray of micronutrients significantly affected the quality of peach fruit. Leach and Hameleers (2001) reported a significant increase in starch content and cob index of maize but observed no effect on dry matter production following foliar applications of P and Zn.

Weinbaum (1988) indicated that crop responses to foliar application of nutrients may be inconsistent and nutrient specific. According to Amiri *et al.* (2008), these responses are strongly dependent on the demand of a crop at a given phenological state. Han *et al.* (1989) reported that up to 80 % of foliar N can be absorbed by the leaves. However, Ford (1968) showed that foliar N would increase leaf N concentration by less than 50%. Bhuyan *et al.* (2012) investigated the influence of foliar application of nitrogen fertilizer on growth and yield of transplanted rice and efficiency of rice-fallow-rice cropping system under raised bed cultivation method. Their results showed that foliar spray increased grain yield of transplanted rice up to 9.33 %.

Foliar fertilizers are fast acting because they are absorbed right at the site they are applied **(**Jiskani, 2008). For example, Donelon (2005) reported that up to 80 % of foliar-added phosphorus is directly absorbed by plants. Saleem *et al.* (2013) reported

an increased concentration and uptake of nitrogen in rice grain by foliar application of urea as compared to soil application. The authors concluded that the difference was due to efficient mobilization of nitrogen to grain after foliar fertilization. Yildirim *et al.* (2005) determined the effect of foliar urea applications on quality, growth, mineral content concentrations of broccoli cultivars. Their results indicated that soil nitrogen fertilization and foliar urea applications increased the content of almost all nutrients in both leaves and heads of both broccoli. Pandel *et al.* (2014) reported higher K and S concentrations in leaves of soybean treated with foliar and soil applied K.

In Maryland, Curley (1994) observed that foliar sprays of $MgSO_4$ and borax applied at critical intervals during the growth and fruiting of cantaloupes and tomatoes increased the percent soluble solids, and yield. Similarly, foliar spray of Fe-EDDHA was effective in increasing iron content of tomatoes fruit (Curley, 1994). Roosta and Hamidpour (2013) investigated the effects of foliar applications of some micro- and macro-nutrients on mineral nutrient content of tomato leaves and fruits in an aquaponic compared to hydroponic system. The results indicated that foliar application of potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) increased their corresponding concentrations in the leaves of aquaponic-treated plants.

However, in their study, Landgren *et al.* (2013) evaluated soil and foliar fertilization of Abies nordmanniana under pot and field conditions and found that soil-applied fertilizers were effective in increasing foliar N compared to untreated and foliar applications. The results of their study also indicated that foliar-applied products did not improve foliar N compared to untreated trees.

2.3 Comparative effects of foliar and soil fertilization on crop performance

Nutrients are only effective as long as they are supplying a nutritional need, but neither soil-applied nor foliar-applied nutrients are panaceas (Wallay and Boyhan, 2014). The use of foliar nutrient sprays in agriculture is increasingly widespread, because they are potentially more environmentally-friendly and target-oriented as compared to soil treatments (Fernández and Eichert, 2012). According to Kaur *et al*. (2010), N applied in four splits (foliar spray) increased N recovery under all dates of sowing over the treatment in which N was soil applied in two or three splits in wheat. Similarly, Ram *et al.* (2012) reported that foliar spray of 0.50 % and 0.41 % Ca $(NO_3)_2$ on rice increased the uptake of N, with the later producing higher N uptake than the former. The difference was attributed to the significant role of Ca in more rational utilization of soil N and active assimilation of NO_3^--N in roots and leaves.

Afrifa *et al.* (2006) reported that foliar fertilizer is adopted for efficient utilization of micronutrients by avoiding the interferences of some soil physico-chemical properties that may create "artificial" shortage in the soil. Fallahi *et al*. (2002) reported that a considerable amount of total N was lost through leaching of soil applied N, compared with foliar N applications. Similarly, Ozbahce and Zengin (2011) indicated that foliar spray of micronutrients is more effective to control deficiencies than soil application especially under certain environmental conditions such as saline and high pH soil.

The majority of researches on foliar fertilization were centered around plant nutrition, nutrient composition and yield or comparison of soil and foliar applied nutrients on quality, yield and yield components of crop plants. There is limited literature on the effect of foliar fertilization on soil fertility. However, the crucial question is whether or not foliar fertilization alone actually increases soil fertility or enhances yield and

quality (Fageria *et al.*, 2009). Zhen *et al*. (2014) stated that foliar application alone will not sustain long-term nutrient supply. Amiri *et al.* (2008) suggested that combinations of soil and foliar N applications might achieve optimum N use in crop production. Selvi and Rani (2000) treated okra plants with NPK alone, NPK+ micronutrients soil application of $FeSO_4$ and $ZnSO_4$, foliar spray of $FeSO_4$ and $ZnSO_4$, foliar + soil application of micronutrient and observed the highest yield from combinations of NPK+ micronutrients and foliar treatment of micronutrients; whereas, the lowest yield was recorded from the single NPK
treatment.

Most researchers suggest that foliar fertilizer should be used to supplement a soil applied fertilizer. For example, Lester *et al.* (2006) indicated foliar applications complement soil treatments and alternatively supply nutrients to plants in situations such as at peak nutrient demand periods or in conditions of low soil nutrient availability. However, Scott (2014) reported that increased efficiency of foliar fertilizer may reduce the need for soil-applied fertilizer and reduce leaching and runoff of nutrients thereby mitigating the impact on the environment of fertilizer salts. However, Bhuyan *et al.* (2012) reported that foliar fertilization may not totally replace soil-applied fertilizer but it does increase the uptake and hence the efficiency of the nutrients applied to the soil.

Kuepper (2003) indicated that foliar fertilization can be from 8 to 20 times as efficient as ground application in terms of nutrient absorption. Foliar application can also reduce the lag time between application and uptake by the plant (Ahmad and Jabeen, 2005). Afza *et al.* (1987) determined the effects of the amount, time and method of fertilizer N application on the efficiency of N uptake, N fixation and yield of soybean. The results of the study showed that foliar fertilizer N, applied during the pod-filling

stage were absorbed by plants with high efficiency, compared to an appreciably lower utilization efficiency for soil applied N. Barel and Black (1979) reported that 66 % of foliar applied P to youngest leaves of corn in a pot culture was absorbed within 10 days and 87 % P absorbed was translocated within that time. Similarly, Mosali *et al.* (1987) evaluated the effect of foliar application of phosphorus on winter wheat grain yield, phosphorus uptake and use efficiency. Results from the study suggested that low rates of foliar applied P might correct midseason P deficiency in winter wheat, and that might result in higher P use efficiencies when compared to soil applications.

Foliar fertilizers are not directly applied to the soil but rather on the plants. Tukey *et al.* (1961) reported that foliar-applied compound penetration would occur via the cuticle through cuticular cracks and imperfections, through stomata, leaf hairs and other specialized epidermal cells. Drops, run-off or drips of the chemical to the soil are also utilized by the plant through the roots (Afrifa *et al.*, 2006). Eichert *et al.* (1999) reported that nutrient uptake from the soil is only through plant root but foliar applied nutrients are taken up both via the leaf stomata and through hydrophilic pores within the leaf cuticle.

However, Karhadkar and Kannan (1984) reported that the effectiveness of foliar fertilization is limited by a number of factors, including nutrient-specific element type and degree of mineral uptake, or inability to supply the required amounts. Also, application of concentrations that are too high may unequivocally lead to leaf damage, a common risk associated with foliar sprays (Fernández and Eichert, 2012). Afrifa *et al.* (2006) indicated that the time of application during the day is before sunset, 2 h at least before rainfall; windy days and late application should be avoided.

2.4 Effect of soil fertility on insect pests and plant disease management

Soil fertility management practices can be used in the management of insect pests and plant diseases (Wepuhkhulu *et al.,* 2011). Environmental factors such as increased use of fertilizers and pesticides, the appearance of new virulent phytopathogenic races, and cultural practices such as irrigation and other environmental stresses, can modify disease resistance reactions (Reuven and Reuveni, 1998). Miguel and Nicholls (2003) reported that cultural methods such as crop fertilization can affect susceptibility of plants to insect pests by altering plant tissue nutrient levels. McMahon (2012) reported that soil function, plant nutritional status and cultural management practices have a strong influence on the incidence and severity of many diseases of tropical perennials. Similarly, Desaeger *et al.*

(2004) indicated that some diseases of tropical perennial species are often linked to deficient nutrient status caused by low soil fertility or poor plant nutrition and disease severity.

2.4.1 Impact of soil pH and organic matter on insect pest and plant diseases

Miguel and Nicholls (2003) reported that the ability of a crop plant to resist or tolerate insect pests and diseases is tied to optimal physical, chemical and mainly biological properties of soils. According to Leifert *et al.* (2007), soil properties affect the occurrence and severity of soil-borne diseases and diseases on foliar parts of the plant. Cowan (2007) reported that soil pH affect both soil nutrient availability, applied fertilizer and organic amendments and some key biological functions in the soil matrix. The author indicated that healthy plants and plants grown at suitable pH have less stress with better nutrient uptake and reduced diseases.

There is no general rule for using fertilizer to avoid plant diseases, but the best practice is to assure enough supply of the nutrients and maintain appropriate soil pH for the plant growth (Henn, 2004). However, Jones *et al.* (1989) reported that increase pH in

limed soils favours the growth of bacteria, actinomycetes, which include species that are antagonistic to fungal pathogens.

Organic matter plays several important roles in both the improvement of soil physical properties and biological functions. Healthy soils high in organic matter and with a biologically diverse food web support plant health and nutrition better than soils low in organic matter and soil microbial diversity (Zehnder, 2011). The author reported that healthy soils also contain many natural enemies of insect pests, including insect predators, pathogenic fungi, and insect-parasitic nematodes. Altieri and Nicolls (2003) stated that a shift from organic soil management to chemical fertilizers has increased the potential of certain insects and diseases to cause economic losses. For example, Chaul and Heong (2005) reported that manure and organic fertilizers are more effective than chemical fertilizer to induce rice plant growth and tolerance to insect pests and diseases. Similarly, Noble and Coventry (2005) indicated that application of composts to soils have a suppressive effect on soil-borne diseases such as damping off, root rots and wilts, both in controlled glasshouse experiments and in the field. The authors observed that the most minimally decomposed organic materials suppress root rots caused by pathogenic species of Pythium and Phytophthora.

2.4.2 Impact of soil N and general soil fertility status on insect pests

There are anecdotal observations that a “healthy” soil makes for “healthy” plants capable of repelling (or at least tolerating) feeding by insects (Mittenthal and Cullen 2011). Most pest management methods used by farmers can be considered soil fertility management strategies and vice versa (Miguel and Nicholls 2003). Both organic and conventional producers have proposed managing pests through the addition of livestock manure, green manures, compost, mineral fertilizers, and a host of other measures (Mittenthal and Cullen 2011). Soil fertility practices can impact the

physiological susceptibility of crop plants to insect pests by either affecting the resistance of individual plant to attack or by altering plant acceptability to certain herbivores (Miguel and Nicholls 2003). Meyer (2000) reported that soil nutrient availability do not only affects the amount of damage that plants receive from herbivores but also the ability of plants to recover from herbivores attack.

Because plants provide nutrients to herbivorous insects, an increase in the nutrient content of the plant is likely to increase its acceptability to pest populations (Helda *et al.* 2001). Farming practices such as excessive use of inorganic fertilizers, can cause nutrient imbalances (Miguel and Nicholls 2003) and farming practices that cause nutrition imbalances can lower pest resistance (Magdoff and Van 2000).

Soil fertility management and prevention of insect pest problems does not suggest a clear course of action in most cropping systems (Mittenthal and Cullen, 2011). Some evidence supports the observation that effective fertility management diminishes insect pest populations (Phelan *et al.,* 1995), other reports suggest that fertilization does not always diminish pest populations but even increase them (Letourneau *et al.,* 1996). For example, Baez *et al.* (2011) reported an increase in the number of thrips and their rate of reproduction in plots with N application above recommended rates, due to an increased level of aromatic amino acids in over-
fertilized plants that attract western flower thrips.

Total N has been considered critical for both plants and their insect pests. It is among the nutritional factors that influence the level of arthropod damage in crops (Mattson, 1980). According to Perrenoud (1990), nitrogen generally increases crop susceptibility to pests and diseases. For example, Baah (2013) evaluated the impact of different levels of Sidalco (NPK) liquid fertilizer on the population dynamics and within plant

distribution of Aphids and Thrips in eggplant and found that plots with the highest doses of N recorded the highest number of *Aphid gossypii* and *Thrip palmi*. Kuepper (2003) reported that the presence of excessive soluble nitrogen in soils increases the nitrate and water content of plant cells. This is especially attractive to aphids, which thrive on plant sap. Nitrogen fertilization increases tissue quality for many insect species and support larger insect population sizes by increasing plant tissue nitrogen, soluble nitrogen, and amino acid concentrations (Nordin *et al.,* 1998).

One specific fertility management approach that has been advocated to help plants repel or tolerate feeding by insects is the "basic cation saturation ratio" (BCSR) concept, sometimes referred to as the "soil balance" approach (Mittenthal and Cullen, 2011). The use of BCSR concept proposes that chemical, physical, and biological soil conditions are optimal for plant growth when the negatively charged exchange sites on soil clay and humus are filled with particular proportions of the cations Ca, Mg, and K (Exner, 2007).

Bear *et al*. (1951) proposed the proportions to be 65 % Ca, 10 % Mg, and 5 % K, filling the remaining exchange sites. Later, Graham (1959) and Albrecht (1975), gave ranges from 65 to 85 % Ca, 6 to 20 % Mg, and 2 to 5 % K. Calcium ions are usually added to soils with Ca saturation levels lower than these target to displace
Mg and K ions by fertilizing with either limestone or gypsum. According to Mittenthal and Cullen. (2011), calcium oxalate is a mineral that most vascular plants accumulate in crystalline form in their tissue, this helping plants defend themselves against predators. The authors suggest that possible increases in calcium oxalate concentration as a result of BCSR fertility management could provide a mechanism to explain insect pest effects observed in fields.

2.5 Effects of foliar fertilization on plant pests and diseases

It is believed that foliar fertilization causes the plant to suppress pests and diseases, increases the availability of nutrients and other biological activity (Kuepper, 2003). Wallay and Boyhan (2014) also reported that foliar nutrients are often expected to cure a variety of plant problems, many of which may be unrelated to nutrition. These include reducing stress-induced blossom drop, aiding in healing frost damaged plants, increasing plant resistance to various stresses and pests. For instance, Reuven and Reuveni (1998) reported that foliar application of phosphates and potassium salts can induce systemic protection against foliar pathogens in various crops such as cucumber, maize, rose, grapevine, apple, mango and nectarine. Wicks *et al.* (1991) reported that foliar application of phosphate after infection of plant, reduced the incidence of downy mildew disease and sporulation of *Plusmopam viticolua*.

In the same way, Kettlewell *et al.* (1992) indicated that foliar applications of potassium chloride reduced rust and powdery mildew diseases in barley. Foliar application of silicon as potassium silicate has also been shown to reduce the number of powdery mildew colonies on cucurbit species and grape leaves (Bowen *et al.*, 1992). Kuepper (2003) reported that foliar fertilization causes the plant to pump more sugars and other exudates from its roots into the rhizosphere.

Reduction in the expenses of crop production, conservation of beneficial biological enemies of pests, preservation of environmental quality and slowing the rate of development of pesticide-resistant strains represent the immediate beneficial impact of the use of 'foliar-fertilizer' therapy in the future (Reuven and Reuveni, 1998).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The study was conducted at the experimental fields of the Plantation Section Crops of the Faculty of Agriculture, KNUST. The study area lies between latitude 06^0 41 "N and longitude 01^0 33 "W in the semi-deciduous forest zone of Ghana with an annual rainfall of 1336 mm (Ghana Metro Agency, 2014). The maximum and minimum temperature is 30°C and 21.7 °C, respectively and the average humidity is 75%. The soil was a sandy loam (Asuansi series) classified by Adu (1992) as orthiFerric Arisol according to FAO (1988).

3.2 Sources of experimental materials

Seeds of tomato cultivars 'Petomech' and Roma Savanna, NPK (15-15-15), urea and Sidalco liquid fertilizer (NPK 10-10-10) were purchased from a local agrochemical shop in Kumasi. Herbagreen a natural product made in Thailand and yet to receive the needed research attention in Africa.

3.3 Experimental design

The two-season field experiment was laid out in a split-plot arranged in a randomized complete block design (RCBD) with three replications. The main plot factors consisted of two tomato varieties whilst the subplot factor comprised application of Herbagreen, Sidalco liquid fertilizer (NPK 10-10-10), solid granular NPK (15-15-15) + urea and a control (no application).

3.4 Nursery and transplanting

The seeds of the two tomato varieties were each planted separately on nursery beds of dimension $4m^2$. Prior to sowing in the nursery, seeds were dressed with Seed rex for

protection against soil-borne fungal diseases. Three-week old seedlings were transplanted onto experimental plots (measuring 3 m x4 m) at a spacing of 60 cm x 40 cm. All appropriate cultural practices including pricking out, weeding, watering and staking were timely performed.

3.5 Foliar and NPK fertilizer applications

Four applications of the manufacturer's recommended rate of Herbagreen (HG) solution at 0.1% (i.e. 0.3125 kg HG in 312.5 L of water per/ha) was applied in the form of light fog under and on the leaves at three weeks after transplanting (WAT) and repeated at weekly interval to the respective treatment plots. Sidalco liquid fertilizer was also applied according to manufacturer's recommendation of 9 ml/15L knapsack at weekly interval for four weeks starting from three WAT. A check (NPK 15-15-15 + urea) was applied at the rate of 50:30:30 kg/ha. The first dose of 30:30:30 kg/ha NPK 15:15:15 was applied three WAT, followed by a top dressing of 20 kg/ha urea at flowering stage. The control plots received no soil or foliar applications.

3.5.1 Preparation and application of Herbagreen

Herbagreen is in powder form and easily soluble when mixed well with water. The solution was applied on a leafy biomass of a plant by spraying with a knapsack. Herbagreen powder (15 g) was diluted in a smaller amount of water to make sure that the powder dissolves as evenly as possible. The mixture was then poured into the 15 *l* knapsack and filled to the mark, ensuring the required solution concentration of 0.1 % (i.e. 0.3125 kg in 312.5 *l* per/ha, or 1 kg HG in 1,000 *l* per 32,000 m^2). Four sprayings were carried out at weekly intervals in late evenings with good weather, without any wind, heat or rain.

3.6 Soil sampling / initial characterization

Prior to planting and fertilizer applications, composite soil samples were taken at random from each block at a depth of 0-20 cm for initial characterization. Part of the fresh samples were used for analysis of microbial biomass C, N, P, and NO_3^--N and NH_4^+-N. The remaining samples were air-dried and passed through a 2 mm sieve for analysis of routine soil nutrients.

At the end of each season (prior to harvesting), composite soil samples were taken from each plot. Part of the fresh samples were used for analysis of microbial biomass C, N, P, NO_3^- -N and NH_4^+ -N. The remaining samples were air-dried and passed through a 2 mm sieve for routine soil nutrient analyses (but only at the end of the season)**.**

3.7 Laboratory/ Analytical Methods

Soil total nitrogen, ammonium and nitrate, microbial C, N, P and plant total nitrogen were analysed in the Laboratory of the Soil Research Institute, Kwadaso, Kumasi. All routine soil and plant parameters with exception of total N and P were analyzed in the Soil Science Laboratory of Department of Crop and Soil Sciences, Faculty of Agriculture, KNUST.

3.7.1 Nitrate -nitrogen (NO_3^- -N)

The nitrate in the soil sample was determined with 0.5 M K_2SO_4 extracting solution. Ten grammes of fresh soil was weighed into a shaking bottle and 30 ml of 0.5 M K_2SO_4 added and shaken for 30 minutes. The mixture was filtered through Whatman No. 42 filter paper and the clear solution used to determine nitrate by the colorimetric method. A 2 ml aliquot of the extract was pipetted into a test tube and 1 ml salicylic acid solution added. This was prepared by dissolving 5 g salicylic acid in 95 ml

concentrated H_2SO_4. The solution was allowed to stand for 30 minutes and a 10 ml of 4.0 M sodium hydroxide solution added and mixed well. After full colour development, the absorbance of the yellow colour was read at a wavelength of 410 nm on a spectronic 21 D spectrophotometer. A standard series of 0, 2, 4, 6 and 8 mg/l NO_3^--N was prepared in 50 ml volumetric flasks from a 50 mg/*l* NO_3^--N stock solution. The absorbances of the standards were read on the spectrophotometer. A standard curve was obtained by plotting a graph of absorbance against standard concentrations. The concentrations of solution for the sample and blank were determined from the curve. The blank value was then subtracted from the sample value to give a corrected concentration value.

Calculation:

$$N(mg/kg) = \frac{C \times V}{W}$$

where:

C = corrected concentration (mg/l)

V= extract volume (ml)

W = weight of sample (g)

3.7.2 Ammonium - nitrogen (NH_4^+-N)

The determination of NH_4^+-N was carried with the same extract as NO_3^--N above. A 2 ml aliquot of the extract was pipetted into a test tube to which two different reagents (RI and RII) were added. RI was prepared by mixing three separately prepared solutions namely: 4 % EDTA (5 ml), 0.05 g/ml sodium nitroprussite (100 ml) and 1.12 g/ml sodium salicylate (50 ml). RII was prepared by dissolving 0.2 g of sodium dichlorocyanate in 10 ml of distilled water and transferred to a 200 ml flask.

The volume was made up to the mark with a buffer solution of 0.0746 *M* $Na_2HPO_4.12H_2O$ (adjusted to pH 12.3). The resulting solution was allowed to stand for 2 hours after the addition of 3 ml and 5 ml of RI and RII, respectively. Working standards of 0, 5, 10, 15 and 20 mg/*l* were prepared from 1000 mg/*l* NH_4+ -N stock solution. The absorbance of the sample, blank and working standards were read on the spectrophotometer at a wavelength of 660 nm. A graph of absorbance against standard concentrations was plotted. Solution concentrations for the sample and blank were then determined. The blank value was subtracted from the sample value to give a value for corrected concentration, C.

3.7.3 Microbial Biomass

3.7.3.1 Microbial Biomass C and N

Soil microbial biomass C and N were estimated in the fresh soils using a chloroform fumigation-extraction (CFE) procedure (Vance *et al.*, 1987). Stones, roots and other recognizable plant parts contained in the samples were removed and the soil was homogenized through a 2 mm sieve. Ten grammes field - moist soil samples were put in a crucible and placed in a desiccator and a shallow dish containing 30 ml of alcohol -free chloroform placed by it. Another crucible containing the control sample (10 g) was placed in a separate desiccator without chloroform and the desiccators were covered and kept at room temperature for 5 days (Anderson and Ingram, 1998). Unfumigated control soils were extracted immediately with 50 ml of 0.5 *M* K_2SO_4 solution and filtered through a Whatman No. 42 filter paper. After fumigation, 50 ml of 0.5 *M* K_2SO_4 solution was added to the soil samples to extract microbial carbon and nitrogen from the lysed microorganisms. The extract was then used to determine total nitrogen by the Kjeldahl method. Microbial carbon in the extract was determined using the colorimetric method. An aliquot (5 ml) of the extract was pipetted into 250 ml Erlenmeyer flask and 5 ml of 1.0 *N* (0.1667 *M*) potassium dichromate and 10 ml

concentrated sulphuric acid were added. The solution was allowed to cool for 30 minutes after which 10 ml of distilled water was added.

A standard series was developed concurrently with carbon concentrations ranging from 0, 2.5, 5.0, 7.5, 10.0 mg/ml C. A standard curve was obtained by plotting absorbance values of the standard solutions against their corresponding concentrations. Biomass C and N were estimated using extractability k -factors of 0.35 (Sparling *et al.,* 1998) and 0.45 respectively (Jenkinson and Ladd, 1981).

Microbial C (mg) = Ec/k

Microbial N (mg) = EN/k where:

EN = the extracted nitrogen produced following fumigation

Ec = the extracted carbon produced following fumigation

k = the fraction of the killed biomass extracted as carbon or nitrogen under standardized conditions

3.7.3.2 Soil microbial phosphorus

Microbial biomass P was determined using a 5 g field-moist soil which was weighed into a crucible and fumigated in a dessicator with 30 ml of alcohol-free chloroform for 5 days. After the five days of incubation, both fumigated and unfumigated soil samples were shaken with 35 ml Bray's No.1 extracting solution (0.03 *M* NH_4F + 0.025 *M* HCl) for 10 minutes and filtered through a Whatman No. 42 filter paper. Correction for adsorption of P during fumigation was made by simultaneously equilibrating unfumigated soil with a series of P containing standard solutions. The amount of chloroform released P was determined according to the relationship between P added (from standard solutions or microbial lysis) and P extracted by the Bray-1 solution (Oberson *et al.,* 1997). Phosphorus adsoerption during equilibrium is described by the

following equation according to Barrow and Shaw (1975) and adapted by Morel *et al*. (1997):

$$Ext_p = Ext_0 + b_1 Pad^{b2}$$

where:

Ext_p = Pi concentration (mg/l) extracted after equilibration with different amounts of P added

Ext_0 = Pi concentration extracted without P addition

b_1, b_2 = coefficients estimated by non- linear regression of mean values of Ext_p against Pad

Pad = amount of P added (0 - 20 mg/kg)

Chloroform released P corresponds to a P addition and is calculated from the equation:

$$P_{chl.} = (Ex_{chl} - Ext_0)/b_1 \times 1/b_2$$

where

P_{chl} = chloroform released P (mg/kg)

Ex_{chl} = Pi concentration in extracts of fumigated samples.

The amount of microbial P was estimated by assuming a kp factor of 0.4 (Brookes *et al.*, 1982).

3.7.4 Soil pH

Soil pH in water (1:2.5 soil: water ratio) was determined using the pH meter. A 20 g soil sample was weighed into 100 ml polythene bottles to which 50 ml water was added. The suspension was frequently stirred for 30 minutes. After calibrating the pH

meter with buffer solutions of pH 4.0 and 7.0, the pH was read by immersing the glass electrode into the upper part of the suspension.

3.7.5 Organic carbon

Soil organic carbon was determined using the modified Walkley and Black's Wet oxidation method as outlined by Nelson and Sommers (1982). Two grammes of soil was weighed into 500 ml conical flask. One reference sample and a blank were included. Ten millitres of 1.0 N (0.1667 M) potassium dichromate and 20 ml of concentrated H_2SO_4 were added to the sample and the blank flasks. The flasks were swirled and allowed to stand for 30 minutes on a fume cupboard. After 30 minutes 200 ml of distilled water and 10 ml concentrated orthophosphoric acid (H_3PO_4) were added and allowed to cool. Diphenylamine indicator (1 ml) was then added and titrated with 1.0 M ferrous sulphate solution.

Calculation:

$$\%C = \frac{N(V_{bl} - V_s) \times 0.003 \times 1.33 \times 100}{w}$$

where:

N =Normality of $FeSO_4$ solution

V_{bl} = ml of $FeSO_4$ used for blank titration

V_s = ml of $FeSO_4$ used for sample titration

g = mass of soil taken in gramme

0.003= milli-equivalent weight of C in grammes (12/4000).

1.33 = correction factor used to convert the Wet combustion C value to the true C value since the Wet combustion method is about 75 % efficient in estimating C value (i.e. 100/75 = 1.33).

3.7.6 Soil total nitrogen

Soil total N was determined using the Kjeldahl digestion method. A 0.5 g soil sample was weighed into a Kjeldahl digestion flask. To this 5 ml distilled water was added. After 30 minutes, concentrated sulphuric acid (5 ml) and selenium mixture were added and mixed carefully. The sample was then digested for 3 hours until a clear digest was obtained. The digest was diluted with 50 ml distilled water and mixed well and allowed to cool. The volume of the solution was made to 100 ml with distilled water and mixed well. The mixture was heated strongly to digest the soil to a permanent clear green colour. A 25 ml aliquot of the solution was transferred to a Tecator distillation flask and 20 ml of 40 % NaOH solution was added followed by distillation. The distillate was collected in 2.0 % boric acid and was titrated with 0.02 *N* HCl using bromocresol green as indicator. A blank distillation and titration was also carried out to take care of the traces of nitrogen in the reagents as well as the water used.

Calculation:

The % N in the sample was expressed as:

$$\%N = \frac{N \times (a - b) \times 1.4 \times mcf}{w}$$

where:

N = concentration of HCl used in titration a = ml HCl used in sample titration b = ml HCl used in blank titration w = weight of air-dry soil sample mcf = moisture correcting factor (100 % + % moisture) /100)

1.4 = 14 × 0.001 × 100 % (14 = atomic weight of N)

3.7.7 Available phosphorus

The available phosphorus was extracted with Bray's No.1 extracting solution (0.03 *M* NH4F and 0.025 M HCl) as described by Bray and Kurtz (1945). A 5 g soil sample was weighed into a shaking bottle (50 ml) and 35 ml of extracting solution of Bray's No.1 added. The mixture was shaken for 10 minutes and filtered through a Whatman No. 42 filter paper. An aliquot of 5 ml of the extract was pipetted into a test tube and 10 ml of the colouring reagent (ammonium molybdate and tartarate solution) added and uniformly mixed. A blank was included and treated the same way as the sample. The solution was allowed to stand undisturbed for 10 minutes for development of the blue colouration. The absorbance values were recorded at 660 nm wavelength on a spectrophotometer.

A standard series of 0, 1, 2, 3, 4 and 5 mgP / *l* was prepared from 20 mg/L phosphorus stock solution.

Calculation:

$$P(mg/kg\ soil) = \frac{(a-b) \times 35 \times 15 \times mcf}{w}$$

where:

a = mg/*l* P in sample extract

b = mg/*l* P in blank

mcf = moisture correcting factor

35 = ml extracting solution

15 = ml final sample solution

w = sample weight in grammes

3.7.8 Exchangeable cations

Exchangeable bases (calcium, magnesium, potassium and sodium) in the soil were extracted with 1.0 *M* ammonium acetate extract (Black, 1986) and the exchangeable acidity (hydrogen and aluminium) was determined in 1.0 *M* KCl extract (Page *et al.,* 1982).

Ten grammes of soil was weighed into a 150 ml extraction bottle and 100 ml of 1.0 *N* NH_4AOc solution at pH 7 added. The mixture was shaken for 1 hour on a mechanical reciprocating shaker and the solution was filtered using leaching tube. Potassium content was read on Jenway PFP 7 flame photometer after calibration with prepared potassium and sodium standards series. Potassium and sodium standards were prepared by diluting both 1000 mg/l K and Na solutions to 100 mg/l.

In doing this, 25 ml portion of each solution was taken into 250 ml volumetric flask and made up to the volume with distilled water.

3.7.9 Determination of calcium and magnesium

Calcium plus magnesium determination was carried out by measuring 10 ml of the aliquot into a 250 ml conical flask, followed by additions of 5 ml of ammonium chloride – ammonium fZhenride buffer solution, 1.0 ml of 30 % triethanolamine, 3 drops of 2 % KCN (potassium cyanide) and one drop of 0.2 % of EBT (Eriochrome Black T) indicator solution. The mixture was shaken vigorously and then titrated with 0.02 *N* EDTA (ethylene diamine tetraacetic acid) to a pure turquoise blue endpoint colour.

Calculation:

$$0.02 \square (Va \square Vb) \square 1000$$

$$\text{Mg (or Ca) (cmol}_{(+)}\text{ / kg soil)} = \frac{}{\text{w}}$$

where:

g = mass (g) of air dry soil used in the extraction

Va = ml of 0.02 *N* EDTA solution used in the sample titration

Vb = ml of 0.02 *N* EDTA solution used in the blank titration

0.02 = concentration of EDTA

1000 = conversion factor from g to $cmol_{(+)}$ / kg

3.7.10 Determination of calcium only

Calcium titration was done by measuring 10 ml of the filtrate into a 250 mL conical flask followed by additions of 10 ml of 10 % KOH solution, 1.0 ml of 30 % triethanolamine, 3 drops of 2 % KCN solution and two drops of 0.4 % calcon-red indicator in 99 % alcohol. The mixture was vigorously shaken and then titrated with

0.02 N EDTA solution to a pure blue endpoint colour.

3.7.11 Particle size analysis

Soil texture with was determined by the hydrometer method. A 51 g of air-dried soil was weighed into a measuring cylinder and 50 ml of calgon (sodium hexamethaphosphate) added. The suspension was shaken and allowed to stand.

Corrected hydrometer readings at 40 seconds and 5 hours were taken.

Calculation:

% sand = 100 – [(A / W) × 100]

% clay = 100 × (B/ W)

$$\% \text{ silt} = 100 - (\% \text{ sand} + \% \text{ clay})$$

where:

A= corrected hydrometer reading at 40 seconds

B = corrected hydrometer reading at 5 hours

W = weight of dry soil

The textural class was then determined from the textural triangle.

3.8 Plant sample analysis for nutrient composition

Prior to fruiting, 25-30 young leaves were collected from five randomly selected plants (from the middle rows) in each plots for laboratory analysis of nutrient content. Leaf samples were oven dried at 70 ^{0}C for 48 h and ground. The following nutrients were determined using standard laboratory protocols: total C, N, P, K, Ca and Mg. Dry ash digestion procedure was used for the analyses. One gram of plant sample was weighed into a clean ceramic crucible. An empty crucible was included for a blank in each batch of 24 samples. The samples were arranged in a cool muffle furnace and temperature ramped to 500 ^{o}C over a period of 2 hours. This temperature was allowed to remain for an additional 2 hours. The samples were allowed to cool down in the oven. Samples were then removed from the oven ensuring that the environment is free from breeze. Ashed samples were transferred first into already numbered 50 ml centrifuge tubes. Crucibles were rinsed with 10 ml of distilled water into the centrifuge tubes. More rinsing of the crucible with 10 ml of aqua regia was done. The samples were shaken for five minutes for proper mixing on a mechanical reciprocating shaker. Samples were centrifuged for 10 minutes at 3000 rpm and then transferred into 100 ml volumetric flask and the volume made up to the 100 ml mark. The clear supernatant digest were decanted into clean reagent bottles for macro-nutrients determination.

3.8.1 Total nitrogen

Total N was determined using the Kjeldahl digestion method. Two grammes of plant material was weighed into a 500 ml Kjeldahl digestion flask and one spatula of catalyst (copper sulphate + sodium sulphate + selenium powder mixture) followed by 20 ml of concentrated H_2SO_4 added. The mixture was heated strongly to digest the plant material to a permanent clear green colour. The digest was cooled and transferred to a 100 ml volumetric flask and made up to the mark with distilled water. A 10 ml aliquot of the digest was transferred into a Tecator distillation flask and 20 ml of 40 % NaOH solution added. Steam from the Foss Tecator apparatus was allowed to flow into the flask. The ammonium distilled was collected into a 250 ml flask containing 15 ml of 4 % boric acid with mixed indicator of bromocresol green and methyl red. The distillate was titrated with 0.1 *N* HCl solution. A blank digestion, distillation and titration were carried out as a check against traces of nitrogen in the reagents and water used.

Calculation:

The total N in the sample was expressed as:

$$\%N = \frac{N(a-b)1.4NV}{st}$$

where:

a = ml HCl used for sample titration

b = ml HCl used for blank titration

1.4 = 14 x 10^{-3} x 100 % (14 = atomic weight of N)

N= normality of HCl.

V = total volume of digest

S = mass of oven dry plant sample taken for digestion in grammes (2.0 g)

t = volume of aliquot taken for distillation (10.0 ml)

3.8.2 Total phosphorus determination

A 5 ml aliquot of the supernatant digest was pipetted into a 50 ml volumetric flask. Five millilitres of ammonium molybdate – ammonium vanadate solution was added. The volume of the mixture was made up with distilled water to the 50 ml mark and allowed to stand undisturbed for 30 minutes for colour development. A standard curve was developed concurrently with P concentrations ranging from 0.0, 5.0, 10.0, 15.0, 20.0 mg P / kg. The absorbance of blank, control and the samples were read on the spectrophotometer at a wavelength of 410 nm.

A graph of absorbance versus concentration P ppm was plotted. The blank and unknown standards were read and the P ppm was obtained by interpolation on the graph plotted from which P concentrations were determined.

Calculation:

P content (µg) in 1.0 g of plant sample = C x df

P content (g) in 100 g plant sample (%P) C df 1000 100 C 1000 100 C
1000000 1000000 10

where:

C = concentration of P (µg / ml) as read from the standard curve

df = dilution factor, which is 100 x10 = 1000, calculated as :

1.0 g of sample made up to 100 ml (100 times) 5.0 ml

of sample solution made up to 50 ml (10 times)

1000 000 = factor for converting µg to g.

3.8.3 Plant potassium and sodium determination

The potassium in the supernatant digest was determined using Jenway PFP 7 Flame photometer. Standard solutions of KH_2PO_4 with concentrations of 0, 200, 400, 600, 800 and 1000 mg/l were prepared and emissions read from the photometer. The K emissions of the plant samples were also read from the photometer. A graph of emissions versus concentrations of the standards was plotted from which the K concentrations of the plant samples were calculated.

Calculation:

K, Na content (µg) in 1.0 g of plant sample = C x df

K, NA content (g) in 100 g plant sample (% K) $\frac{C \times df \times 1000 \times 100}{1000000}$ $\frac{C \times 1000 \times 100}{1000000}$ $\frac{C}{10}$

where:

C = concentration of K, Na (µg / ml) as read from the standard curve

df = dilution factor, which is 100 x1 = 100, calculated as :

1.0 g of sample made up to 100 ml (100 times)

1000 000 = factor for converting µg to g.

3.8.4 Determination of total calcium

A 5.0 ml of sample solution was transferred into a 100 ml Erlenmeyer flask. Ten ml of 10 % KOH solution was added followed by 1 ml of 30 % TEA (Triethanolamine). Three drops of 10 % KCN and few drops of EBT indicator solution were then added. The mixture was shaken to ensure homogeneity and the mixture was titrated with 0.02 *N* EDTA solution from a red to blue end point.

Calculation:

Calcium in mg = Titre value of EDTA x 0.40

$$\% \text{ Calcium} = \frac{\text{mg Calcium} \times 100}{\text{mg of sample}}$$

where:

0.40 = Volume of EDTA

3.8.5 Determination of magnesium

Sample solution of 5.0 ml was emptied into a 100 ml Erlenmeyer flask. A 5 ml of ammonium chloride – ammonium hydroxide buffer solution was added followed by 1 addition of ml 30 % TEA. Three drops of 10 % KCN and a few drops of EBT indicator solution were added. The mixture was shaken to ensure homogeneity and was titrated with 0.02 *N* EDTA solution from a red to blue end point.

Calculation:

Magnesium in mg = Titre value of EDTA x 0.24

$$\% \text{ Mg} = \frac{\text{mg magnesium}}{\text{mg sample}} \times 100$$

were: 0.24 = Volume of EDTA

3.9 Determination of insect population

Field and laboratory count of insects were done one week after the first application of treatments (4 WAT) and was continued every week prior to the successive biweekly application of treatments. Insect counts were done on aerial parts of five randomly selected plants in the middle rows of each plot. One lower and upper leaves from each of the plants were collected and immediately placed in a 100% liquid soap solution. The solution containing the leaves were brought to the lab, allowed to settle down for a day, observed under the microscope and the number of insets recorded. The

observations continued until one week after the last application of treatment (8 WAT) and the data were tabulated to determine insect population dynamics.

3.9.1 Determination of disease incidence and severity

Disease incidence and severity were recorded on five randomly selected plants from the middle rows of each plot from 4 to 8 WAT. Disease incidence, defined as the extent of infection in the field was calculated according to Allen *et al*. (1983) formula as:

$$\text{Disease incdence}(\%) = \frac{\text{Numberof disease plant}}{\text{Totalnumberplantsample}} \times 100$$

Incidence was recorded and estimated as percentage infection (Nono-womdim and Atibalentja 1993).

where:

1-20 % = low,
21-40 % = moderate,
50-100 % = high incidence

Disease symptom severity was scored on a scale of 1-5, based on extent of leaf damage and percentage number of leaves showing symptoms, whereby 1=1-20 % (very mild); 2=21-40 % (mild); 3=41-60 % (severe); 4=61-80 % (very severe); and 5=81-100 % (almost dead) (Ssekyewa, 2006).

3.9.2 Determination of fruit yield

At maturity, fruits were harvested by hand from each plot at the pink stage every other day in the mornings and immediately placed under shade to maintain fruits temperature. Fruits were transported to the laboratory and sorted out to eliminate bruised, punctured and damaged or diseased ones. The good fruits were counted and

weighed. The total fruit yield over the period was obtained by adding up fruit yields at individual harvest.

3.9.3 Data analysis

Data was subjected to ANOVA (analysis of variance) using the Genstat statistical package (Discovery edition 3 2012). Means separation were undertaken using the least significant difference (LSD) at $P < 0.05$.

CHAPTER FOUR

4.0 RESULTS

4.1. Initial soil properties

The results of the initial soil analysis before imposition of treatments are presented in Table 4.1. The mean organic carbon and total soil N content were 1.48 % and 0.11 % respectively.

Soil properties	Mean Value	SD
Microbial biomass (mg / kg)		
Carbon	11.3	(0.1)
Nitrogen	2.4	(0)
Phosphors	2.0	(0.2)
NO_3^--N (mg / kg) NH_4^+-N	17.7	(0.3)
(mg / kg)	5.2	(0.2)
pH OC	6.02 1.48	(0.02)
(%)		(0.07)
Total N (%)	0.11	(0.02)
Available P (mg / kg)	10.5	(0.1)
Exchangeable cations (cmol $_{(+)}$ / kg)		
K^+	0.2	(0.02)
Ca^{2+}	4.8	(0.1)
Mg^{2+}	0.2	(0.02)
Na^+	1.5	(0.05)

Particle size distribution		**Table 4.1: Summary of initial soil**
Silt (%)	82.4	
Silt (%)	7.5	
Clay (%)	11.1	
physical and chemical characteristic of the study site		
Soil Texture	**Sandy Loam**	

Values are means of duplicate samples, SD: Standard deviation

Available P content was slightly > 10 mg/kg soil while exchangeable K was < 0.3 cmol $_{(+)}$ / kg soil. Microbial biomass C, N and P values were generally low. NitrateN value was higher than that of ammonium-N. The soil texture was sandy loam with a mean pH of 6.02.

4.2 Plant nutrient composition

Results for nutrient composition of tomato as affected by Herbagreen and Sidalco liquid fertilizers in the major and minor seasons are presented in Tables 4.5a and b. Foliar application of Herbagreen and Sidalco liquid fertilizer significantly ($P < 0.05$) affected N composition of tomato in the minor season but not in the major season. Similarly, varieties and fertilizer treatments interacted significantly ($P < 0.05$) to affect total N composition of tomato (Table 4.2 a). The control and check (NPK 1515-15 fertilizer) produced similar effects ($P > 0.05$) on total organic C N and P contents of the plant as the foliar treatments in the major season.

Table 4.2 a: Mean effects of Herbagreen and Sidalco liquid fertilizer on nutrient composition of tomato at 5 WAT in 2014 major and minor seasons

Treatments	**Total nutrients (%)**					
	Major season			**Minor season**		
Variety	**O/C**	**N**	**P**	**O/C**	**N**	**P**
Petomech	56.6	4.06	0.11	35.2	3.44	0.30
Roma savanna	56.6	3.87	0.12	33.5	3.80	0.33

Lsd (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	1.2	5.1	24.4	3.3	7.6	22.8
Fertilizer Treatments						
CTRL	56.1	3.84	0.11	33.7	3.38	0.23
NPK	57.7	4.07	0.12	34.7	3.52	0.27
Sidalco	56.1	4.01	0.11	34.3	3.91	0.38
Herbagreen	56.5	3.93	0.11	34.7	3.67	0.41
Lsd (0.05)	NS	NS	NS	NS	0.36	NS
CV (%)	1.1	1.6	14.2	2.6	1.0	12.9
Interactions						
P x CTRL	55.9	3.91	0.10	35.2	3.77	0.26
P x NPK	59.2	4.19	0.12	36.6	3.82	0.28
P x Sidalco	53.7	4.14	0.11	34.1	3.80	0.26
P x Herbagreen	57.7	4.00	0.10	34.9	3.80	0.43
R x CTRL	56.4	3.77	0.11	30.9	2.98	0.26
R x NPK	56.3	3.96	0.14	34.1	3.23	0.49
R x Sidalco	58.5	3.88	0.11	34.5	4.02	0.20
R x Herbagreen	55.3	3.86	0.12	34.5	3.54	0.38
Lsd (0.05)	NS	NS	NS	NS	0.74	NS
CV (%)	4.9	12.6	14.9	9.3	7.9	54.7

P= Petomech, R= Roma savanna, CTRL= Control, WAT= weeks after transplanting

Generally, higher values of total organic C and total N recorded were higher in the major season than in the minor season (Table 4.2 a). Conversely, P concentrations in the plants in the minor season were higher than that of the major season. Herbagreen produced significantly ($P < 0.05$) higher K content of tomato in the minor season whilst Sidalco produced the highest value in the major season (Table 4.2 b). Varieties and fertilizers treatments interacted significantly ($P < 0.05$) to affect K content of tomato in the major season (Table 4.2 b).

Table 4.2 b: Effects of foliar and soil nutrient applications on nutrient composition of tomato leaf

Treatments	**Total nutrients (%)**					
	Major season			**Minor season**		
Variety	**K**	**Ca**	**Mg**	**K**	**Ca**	**Mg**
Petomech	1.49	4.65	3.87	1.82	0.91	0.74
Roma savanna	1.69	5.49	4.08	2.02	0.80	0.87
Lsd (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	14.4	12.3	22.5	25.1	20.2	15.3
Fertilizer Treatments						

Control	1.05	4.54	3.71	1.15	0.65	0.62
NPK	1.69	5.13	3.68	1.60	0.85	0.77
Sidalco	1.97	4.92	4.15	1.60	0.85	0.83
Herbagreen	1.64	5.69	4.36	3.32	1.07	1.0
Lsd (0.05)	0.38	NS	NS	1.71	NS	NS
CV (%)	3.9	18.2	5.1	9.5	11.3	13.9
Interactions						
P x Control	1.73	3.91	4.11	1.52	0.62	0.76
P x NPK	1.20	5.03	3.44	1.34	1.19	0.83
P x Sidalco	1.43	4.51	3.94	1.40	0.88	0.87
P x Herbagreen	1.59	5.14	3.99	3.00	0.94	1.02
R x Control	0.90	5.16	4.61	0.78	0.67	0.47
R x NPK	2.21	4.71	3.93	1.85	0.76	0.71
R x Sidalco	1.96	5.75	4.36	1.80	0.95	0.78
R x Herbagreen	1.68	6.36	3.43	3.64	0.83	0.97
Lsd (0.05)	0.65	NS	NS	NS	NS	0.44
CV (%)	19.1	22.1	22.2	50.9	47.0	30.5

P= Petomech, R= Roma savanna, CTRL= Control, WAT= weeks after transplanting

No significant differences ($P > 0.05$) were observed between Herbagreen and Sidalco treatments on the foliar composition of Ca and Mg. Petomech and Roma savanna had similar K, Ca and Mg contents in both seasons of study. In the minor season, varieties x fertilizer treatments interaction effect on Mg composition of tomato were significant (Table 4.2 b). Though generally not significant, Ca and Mg contents of tomato were relatively higher in Herbagreen treated plants in both seasons of cropping.

4.3 Mineral N ($NO3^-$-N and NH_4^+-N) and Microbial biomass

Table 4.3 shows soil nitrate-N and ammonium-N values recorded under fertilizer treatments and varieties in both seasons of the study. Relatively, the results of both seasons showed a substantial increase in soil nitrate-nitrogen and ammoniumnitrogen level over the initial values (Table 4.3).

Table 4.3: Soil ammonium-N and nitrate-N composition under soil and foliar nutrient applications at harvest in both major and minor seasons

Treatments	Major season	Minor season

Variety	NO_3^--N (mg N/kg)	NH_4^+-N	NO_3^--N (mg N/kg)	NH_4^+-N
Petomech	21.1	48.0	22.9	35.6
Roma savanna	22.0	56.1	16.06	37.2
Lsd (0.05)	NS	NS	NS	NS
CV (%)	8.7	30.6	10.7	8.3
Fertilizer Treatments				
CTRL	18.1	46.1	14.43	36.1
NPK	24.1	52.0	17.59	35.4
Sidalco	20.7	51.6	18.51	33.1
Herbagreen	23.4	58.5	16.49	41.0
Lsd (0.05)	NS	NS	NS	NS
CV (%)	5.8	17.8	0.8	5.4
Interactions				
P x CTRL	16.6	45.6	12.91	29.9
P x NPK	30.1	43.0	21.16	39.5
P x Sidalco	19.9	38.2	19.40	31.7
P x Herbagreen	17.7	58.8	16.32	41.4
R x Control	19.6	45.6	15.94	31.3
R x NPK	18.0	49.2	14.03	34.5
R x Sidalco	21.5	65.0	16.66	40.6
R x Herbagreen	29.1	58.2	16.66	56.4
Lsd (0.05)	NS	NS	NS	NS
CV (%)	31.9	30.7	10.7	29.6

P= Petomech, R= Roma savanna, CTRL= Control,

In both seasons, varieties and fertilizer treatments had no significant impact ($P < 0.05$) on the nitrate-N and ammonium-N levels in the soil, though the check was expected to differ significantly from Sidalco and Herbagreen plots.

Similarly, there were no significant varieties x fertilizer interactions on both parameters. Generally nitrate-N and ammonium-N values under all treatments declined in the major season over values recorded in the minor season.

Table 4.4: Effects of foliar and soil nutrient application on microbial biomass C, N, P in the major and minor seasons

Treatments	Major season			Minor season	
	MBC	MBN	MBP	MBN	MBP
Varieties	(mg / kg soil)			(mg / kg soil)	
Petomech	34.2	31.9	24	3.06	2.80
Roma savanna	41.0	32.2	1.58	2.85	2.98

Lsd (0.05)	NS	NS	NS	NS	NS
CV (%)	16.4	4.1	6.8	38.6	25.1
Fertilizer Treatments					
CTRL	39.0	31.5	1.52	1.93	2.72
NPK	33.2	23.7	2.02	4.17	3.23
Sidalco	39.7	36.7	1.86	3.10	2.85
Herbagreen	38.1	36.2	1.84	2.64	2.76
Lsd (0.05)	NS	9.93	NS	1.54	NS
CV (%)	13.5	11.8	33.9	14.4	6.6
Interactions					
P x CTRL	32.6	31.5	2.03	1.93	2.93
P x NPK	31.3	25.1	2.85	5.06	3.61
P x Sidalco	40.1	40.8	1.37	3.55	2.71
P x Herbagreen	31.9	30.1	1.92	1.71	1.95
R x CTRL	44.3	31.5	1.01	1.00	2.84
R x NPK	35.1	22.4	1.19	3.28	2.84
R x Sidalco	37.7	32.6	2.35	2.64	2.99
R x Herbagreen	46.9	42.4	1.76	3.56	2.50
Lsd (0.05)	NS	NS	1.71	1.92	NS
CV (%)	33.5	24.6	41.6	41.4	48.7

P= Petomech, R= Roma savanna, CTRL= Control, MBC= microbial biomass C, MBN= microbial biomass nitrogen, MBP= microbial biomass P

Ammonium-N in both seasons was predominantly higher than nitrate-N contrary to what was observed initially (Table 4.1). The effects of foliar and soil nutrient application on microbial biomass C, N, P in the major and minor season are shown in Table 4.3.As expected, soil microbial biomass N was generally higher during the major season than in the minor season. Soil and foliar nutrient applications significantly ($P < 0.05$) affected MBN with Sidalco liquid fertilizer producing the highest values in the major season (Table 4.4).

Similarly, variety and fertilizer treatments interacted significantly to influence MBP and MBN in the major and minor season respectively. Biomass P showed the highest variability (CV > 30 %) in the major season but the least (CV > 10 %) in the minor season (Table 4.4).

4.4 Routine soil properties

Though significant differences in SOC were not observed among treatments, values recorded at the end of the season were generally lower than those initially observed at the beginning of the study (Table 4.5). For instance, SOC decreased by 5.4 % at the end of the season on NPK treated plots over initially value. However, there was only 0.7 % decrease in Herbagreen treated plots at the end of the season compared to the initial soil value. No significant differences (P> 0.05) were observed between treatments at the end of the season with respect to total N but the parameter increased marginally in all treatments expect the control. The total N increases compared to the initial value were 18 % for the check (NPK 15-15-15 fertilizer) and 9.1 % for Sidalco and Herbagreen plots. Like total N, available P at the end of the season showed increases over values recorded at beginning of the study. The interaction effect of variety and fertilizer treatments on organic C, total N and available P were not significant (P < 0.05) at the end of the study

Fertilizer treatment and varieties as well as their interactions generally did not significantly affect exchangeable K composition of the soil at the end of the study. Exchangeable Mg content however, differed significantly between the fertilizer treatments. The highest values were observed in Herbagreen plots (Table 4.5). Similarly, fertilizer treatment as well as variety x fertilizer significantly (P < 0.05) influenced exchangeable Na at the end of the study.

Table 4.5: Soil nutrient composition under soil and foliar application at the end of the study Treatments OC N P K Ca Mg Na

Varieties	(%)		(mg/kg)		(cmol (+) / kg)		
Petomech	1.36	0.12	13.4	0.10	3.58	1.51	1.51
Roma savanna	1.46	0.12	12.4	0.10	4.34	1.34	1.34

Lsd (0.05)	NS	NS	NS	NS	NS	NS	NS
CV (%)	13.0	5.1	3.8	10.7	6.5	6.5	6.5
Fertilizer Treatments							
CTRL	1.39	0.11	12.1	0.09	3.95	1.41	1.41
NPK	1.40	0.13	12.4	0.10	3.82	1.21	1.21
Sidalco	1.36	0.12	13.3	0.11	3.94	1.31	1.31
Herbagreen	1.47	0.12	13.6	0.10	4.13	1.73	1.73
Lsd (0.05)	NS	NS	NS	NS	NS	0.24	0.24
CV (%)	9.4	2.2	3.0	12.2	12.2	6.8	6.8
Interactions							
P x CTRL	1.50	0.11	11.9	0.08	3.77	1.61	1.61
P x NPK	1.35	0.13	13.6	0.11	3.59	1.97	1.97
P x Sidalco	1.24	0.12	15.0	0.12	3.06	1.34	1.34
P x Herbagreen	1.34	0.13	12.4	0.10	3.91	1.11	1.11
R x CTRL	1.29	0.11	12.1	0.10	3.99	1.11	1.11
R x NPK	1.46	0.13	11.3	0.09	4.05	1.31	1.31
R x Sidalco	1.48	0.12	14.2	0.11	4.50	1.28	1.28
R x Herbagreen	1.60	0.12	12.4	0.11	4.81	1.50	1.50
Lsd (0.05)	NS	NS	NS	NS	NS	0.34	0.34
CV (%)	15.8	7.7	20.4	14.7	18.2	13.5	13.5

P= Petomech, R= Roma savanna, CTRL= Control,

4.5 Insect population as affected by foliar applications of Herbagreen and Sidalco liquid fertilizer

Table 4.6 shows insect pests aggregations on tomato as affected by Herbagreen and Sidalco liquid fertilizers in the two seasons.

In both seasons, foliar application of Herbagreen and Sidalco significantly ($P < 0.05$) reduced the aggregations of *Bemisia tabaci* (Gennadius). No differences ($P > 0.05$) were observed in the aggregations of *Thrips tabaci* (Lindeman) and *Aphis gossypii* (Glover) under the fertilizer treatments.

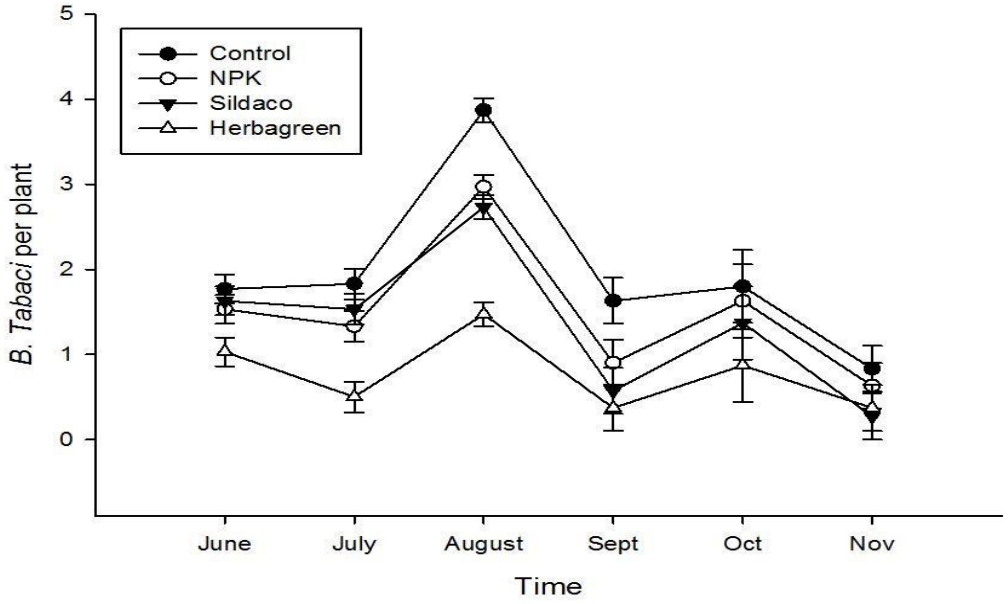
Table 4.6: Mean number of insect pests collected on tomato treated with Herbagreen and Sidalco in the major and minor cropping season in Kumasi, Ghana

Treatments	Major season			Minor season		
Varieties	*B. tabaci*	*T. tabaci*	*A. gossypii*	*B. tabaci*	*T. tabaci*	*A.gossypii*
Petomech	4.6	0.1	0.3	2.2	0.2	0.1
Roma savanna	6.5	0.2	0.3	2.7	0.2	0.3
Lsd (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	27.8	25.2	29.6	22.1	21.0	24.5
Fertilizer Treatments						
Control	7.5	0.2	0.5	3.6	02	0.2
NPK	5.8	0.2	0.3	2.7	03	0.1
Sidalco	5.9	0.1	0.2	2.0	01	0.3
Herbagreen	3.0	0.1	0.1	1.4	0.0	0.03
Lsd (0.05)	1.2	NS	NS	0.67	NS	NS
CV (%)	10.1	25.2	12.9	16.0	20.8	9.3
Interactions						
P x Control	5.4	0.2	0.5	2.9	0.2	0.1
P x NPK	5.4	0.1	0.5	2.6	0.3	0.0
P x Sidalco	5.7	0.1	0.1	2.6	0.1	0.2
P x Herbagreen	2.0	0.1	0.2	0.9	0.0	0.1
R x Control	9.5	0.2	0.5	4.3	0.2	0.4
R x NPK	6.3	0.3	0.1	2.9	0.2	0.1
R x Sidalco	6.1	0.3	0.3	1.8	0.3	0.1
Rx Herbagreen	4.0	0.1	0.1	1.8	0.0	0.0
Lsd (0.05)	4.3	NS	NS	1.45	NS	NS
CV (%)	17.5	37.3	37.6	22.0	37.2	42.8

P= Petomech, R= Roma savanna, CTRL= Control

4.5.1 Population dynamics of *B. tabaci and T. tabaci*

Foliar application of Herbagreen significantly produced the lowest densities of whiteflies (*B. tabaci*) in August. Similarly, significant differences ($P < 0.05$) were observed between treatments on the density of *B. tabaci* in June and July. Peak densities of *B. tabaci* were recorded in August with the control plots having 3.87 insects per plant. Population of *B. tabaci* was generally lower in July compared to June across treatments (Fig. 4.1).



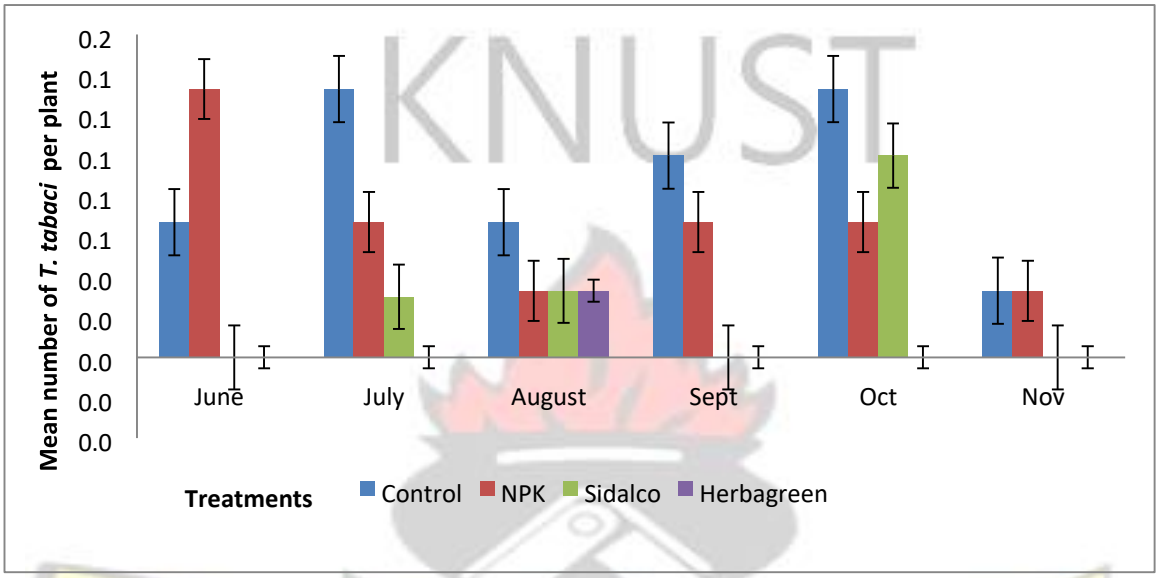
Bars represent standard errors of means at 5 %.

Figure 4.1. Population of *B. tabaci* as affected by foliar and soil application of nutrients in the 2014 major and minor seasons.

Herbagreen and Sidalco liquid fertilizer significantly ($P < 0.05$) influenced the aggregations of *B. tabaci* in September and October. Probably due to the low number of *B. tabaci* per plant recorded in November, no significant difference ($P > 0.05$) was observed in the aggregations of *B. tabaci*. In the minor cropping season, the aggregations of *B. tabaci* was relatively high during September and increased to the peak (1.8 per plant) in October in the control plots but then reduced substantially by 54% in November (Fig. 4.1).

Aggregations of thrips (*T. tabaci*) remained relatively low to have any significant ($P < 0.05$) influence on plant growth throughout the study period (Fig. 4.2). Peak density value of 0.13 *T. tabaci* per plant was recorded in the control plot during July and October. No *T. tabaci* was observed on Herbagreen treated plants throughout the study period except in August where the lowest number of 0.03 per plant was found. Similarly, zero *T. tabaci* per plant was observed for Sidalco treated plots in September

and also for control plots in November (Fig. 4.2). The population dynamics of *T. tabaci* varied across treatments in the decreasing order of CTRL > NPK >Sidalco > Herbagreen.



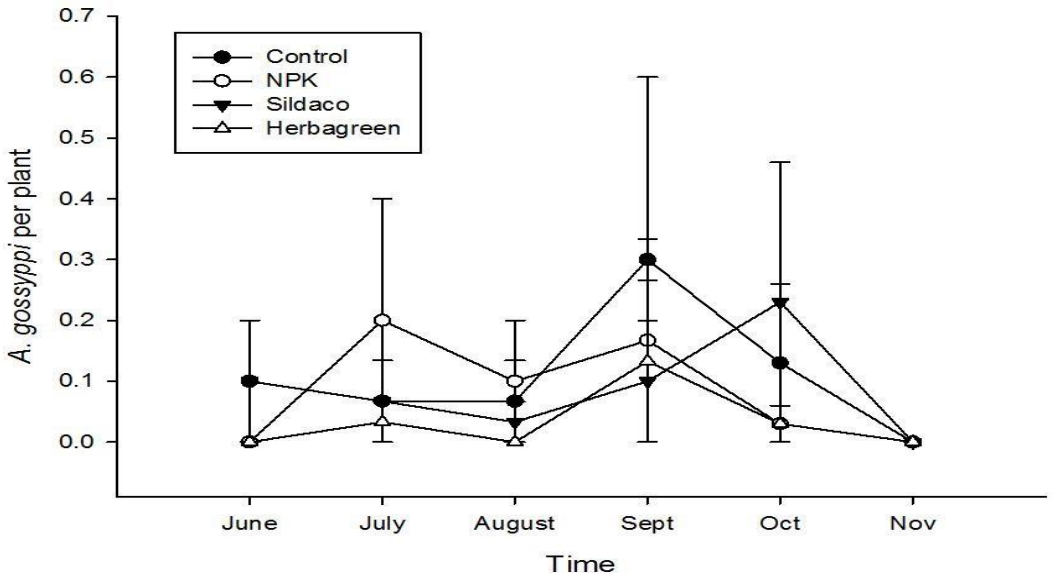
Bars represent standard errors of means at 5 %.

Figure 4.2: Mean effects of Herbagreen and Sidalco liquid fertilizer on the population dynamics of *T. tabaci* in the major and minor seasons of 2014.

4.5.2 Population dynamics of Aphids (*A. gossypii*)

Like *T. tabaci*, the aggregations of *A. gossypii* remained very low to have any significant ($P < 0.05$) effect on plant growth throughout the study period. The highest population of 0.3 per plant was recorded on control plots in September while no *A. gossypii* were found in all treatments in November (Fig. 4.3).

Number of A. *gossypii* was low in Herbagreen treatment in June and August. From July to September, the number of A. *gossypii* was relatively higher in the check. Sidalco treatment produced higher number ($P < 0.05$) of A. *gossypii* than the control in October.



Bars represent standard errors of means at 5 %.

Figure 4.3: Mean effects of foliar and soil nutrient application on the population dynamics of *A. gossypii* in 2014 major and minor season.

4.6 Disease incidence and severity

Table 4.7 shows the percentage incidence of diseases of tomato under foliar applications of Herbagreen and Sidalco liquid fertilizer. Major diseases symptoms observed in the field were early blight, late blight and tomato yellow leaf curl virus (TYLCV). In the major season, foliar application of Herbagreen at all levels (variety, fertilizer treatments and interactions) significantly ($P < 0.05$) reduced incidence of early blight. In both seasons, foliar application of Herbagreen significantly ($P < 0.05$) reduced incidence of late blight. Herbagreen and Sidalco liquid fertilizers recorded low (1-20 %) incidence of late blight in the major season. In the minor season, foliar application of Herbagreen reduced incidence of late blight compared to Sidalco liquid fertilizer and the check. In both seasons, incidence of TYLCV was generally low (21-40 %) with no significant difference ($P > 0.05$) between treatments.

Table 4.7: Percentage disease incidence on tomato treated with Herbagreen and Sidalco in 2014 major and minor season Treatments Major season Minor season

Varieties	Early blight	Late blight	TYLC	Early blight	Late blight	TYLCV
Petomech	23	16	6	9	7	5
Roma savanna	30	17	5	9	8	5
Lsd (0.05)	6.0	NS	NS	NS	NS	NS
CV (%)	25	8	15	25	18	25
Fertilizer						
Control	29	20	7	13	12	6
NPK	30	19	6	9	8	6
Sidalco	27	13	5	8	8	4
Herbagreen	19	14	4	7	4	4
Lsd (0.05)	8	4	NS	NS	4	NS
CV (%)	7	8	7	10	16	9
Interactions						
P x Control	24	21	8	14	13	5
P x NPK	28	18	7	10	8	5
P x Sidalco	24	12	5	5	6	5
P x Herbagreen	17	12	5	6	3	5
R x Control	35	19	5	11	11	7
R x NPK	32	20	5	8	7	7
R x Sidalco	31	14	5	10	10	3
R x Herbagreen	22	15	3	8	6	3
Lsd (0.05)	4	NS	NS	NS	NS	NS
CV (%)	26	17	41	49	42	43

P= Petomech, R= Roma savanna, CTRL= Control, TYLCV= Tomato yellow leaf curl virus, 1-20 % = low, 21-40 % = moderate, 50-100 % = high incidence.

However, Herbagreen treated plants showed the lowest incidence but comparable to Sidalco in the minor season. Unlike incidence, disease severity remained relatively similar for early and late blight in both seasons. Disease severity ranged from severe (41-60 %) to very severe (61-80 %) in all treatments for early and late blight, respectively. In the minor season, severity of early and late blight was significantly ($P < 0.05$) lower in both foliar treatments compared to the control and the check.

Table 4.8 Disease severity on tomato as affected by foliar application of Herbagreen and Sidalco liquid fertilizers in 2014 major and minor seasons Treatments

	Major season			Minor season		
Varieties	Early blight	Late blight	TYLCV	Early blight	Late blight	TYLCV

Petomech	3	3	2	3	3	3
Roma savanna	3	3	3	3	3	3
Lsd (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	14	6	8	5	4	6
Fertilizer Treatments						
Control	3	4	3	4	4	3
NPK	4	3	3	4	4	3
Sidalco	3	3	3	3	3	2
Herbagreen	3	3	2	3	3	2
Lsd (0.05)	NS	NS	NS	0.6	0.4	NS
CV (%)	4	5	8	4	4	3
Interactions						
P x Control	3	4	3	4	4	3
P x NPK	4	4	2	3	3	3
P x Sidalco	3	3	2	3	3	3
P x Herbagreen	3	3	2	3	3	2
R x Control	4	3	3	4	3	3
R x NPK	4	3	3	3	3	3
R x Sidalco	3	3	3	3	3	2
R x Herbagreen	3	3	2	3	3	2
Lsd (0.05)	NS	NS	NS	1.45	0.5	NS
CV (%)	14	18	14	14	10	10

P= Petomech, R= Roma savanna, CTRL= Control, 1=1-20 % (very mild); 2= 21-40 % (mild); 3= 41-60 % (severe); 4= 61-80 % (very severe); 5=81-100 % (almost death)

Similarly, variety x fertilizer significantly ($P < 0.05$) influenced severity of early and late blight. TYLCV was the least severe disease showing mild (21-40 %) to severe (41-60 %) symptom in both seasons. Although, no significant ($P > 0.05$) differences in severity of TYLCV was observed among treatments, Herbagreen and Sidalco liquid fertilizer generally showed only mild symptoms in the major and minor seasons (Table 4.8).

4.7 Yield of tomato

Yield response of tomato to foliar in treatments 2014 major and minor seasons are presented in Table 4.9. Application of Herbagreen and Sidalco liquid fertilizer significantly increased grain yield over the control in the major season.

Table 4.9.Effects of soil and foliar applications on number of fruits and yield of

tomato

Treatments / Varieties	Major season		Minor season	
	Number of fruits per plant	Total fruit yield (kg.ha^{-1})	Number of fruits per plant	Total fruit yield (kg.ha^{-1})
Petomech	6.3	7223	4.4	6346
Lsd (0.05)	NS	NS	NS	NS
CV (%)	33.5	41.9	17.0	26.1
Fertilizer Treatments				
Control	3.9	4238	3.5	4286
NPK	6.2	6601	4.7	5950
Sidalco	4.5	5294	4.2	5781
Herbagreen	6.2	6560	4.5	5241
Lsd (0.05)	1.28	1509.3	0.72	NS
CV (%)	11.6	12.1	3.9	10.1
Interactions				
P x CTRL	4.1	4825	3.8	5311
P x NPK	7.7	8099	4.9	6439
P x Sidalco	5.5	7199	4.2	7189
P x Herbagreen	8.0	8771	4.9	6446
R x Control	3.8	3652	3.3	3260
R x NPK	4.7	5103	4.5	5461
R x Sidalco	3.6	3389	4.2	4036
R x Herbagreen	4.4	4349	4.2	3027
Lsd (0.05)	4.98	NS	NS	NS
CV (%)	19.6	21.1	13.4	23.7
R savanna	4.1	4123	4.0	4282

P= Petomech, R= Roma savanna, CTRL= Control,

However, the two foliar applications produced similar yield ($P > 0.05$). Though the check produced the highest yield, it was comparable to that of Herbagreen and Sidalco. Fertilizer x variety significantly ($P < 0.05$) influenced the number of fruits per plant.

The check and Herbagreen treatments equally produced higher number of fruits (6.2) per plant over Sidalco and the control in the major season. In the minor season, no significant ($P < 0.05$) differences were observed between fertilizer treatments, varieties and their interactions with respect to fruit yield. The check produced the

highest number of fruits per plant ($P < 0.05$) and subsequently highest fruit yield over all treatment although not significant (Table 4.9). In both seasons, no significant differences ($P < 0.05$) were observed between varieties in terms of number of fruits and fruit yield kg / ha^{-1}. However, Petomech produced higher number of fruits per plant and subsequently a higher fruit yield compared to Roma savanna in both cropping seasons.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Initial soil characteristics

Results of the initial soil analysis showed that most of the nutrient elements were present in amounts close to the critical level. The soil organic carbon content was low. According to Metson (1961), a productive soil should have organic carbon content of

2.3 %. Exchangeable K, Mg and Ca contents were also low (CSIR, 2011). However, total N and available P contents were moderate (CSIR, 2011).

The pH of 6.02 recorded was considered suitable for tomato production as it can enhance nutrient availability (Olaniyi and Ajibola 2008). Generally, the soil at the study site was low in plant nutrient suggesting inputs of fertilizer elements to sustain crop growth.

5.2 Plant nutrient composition

Comparatively, foliar nutrients content of tomato were higher in the major season than in the minor season under both foliar and soil nutrients applications (Table 4.2 a and 4.2 b). Foliar application of fertilizer seemed more effective in increasing nutrient content of plants in the major season compared to the minor season. This was due to the relatively higher rainfall amount in the major season (Appendix 1) leading possibly to higher soil moisture content than in the minor season. Foliar application, like soil application is also less effective when soil moisture is limited (Fageria *et al.*, 2009).

Unlike Sidalco, Herbagreen does not contain nitrogen and therefore the former was expected to increase the N composition of treated plants. However, results showed similarity ($P > 0.05$) in N content of plants treated with both products and even the check and or the control in the major season. This was possibly due to the moderate N content of the soil (0.11) which was more utilized by the plants than the foliar or soil applied nutrients. On the other hand, though Herbagreen contained high concentration of Ca (35.9 %) (Table 4.5) and was expected to increase the concentration of the nutrient in the treated plants, results were not significantly different from that of Sidalco liquid fertilizer treated plants and the check.

The total P content of plants treated with Herbagreen and Sidalco liquid fertilizer was similar to that of the check. Results of the study therefore does not support the obvious assertion that nutrient applied to the leaf are more likely to enter the leaf in large quantity than the same nutrients applied to the soil (Scott, 2014).

5.3 Mineral N (NO_3^--N and NH_4^+-N) and Microbial biomass

Though soil mineral nitrogen composition was not affected by foliar and soil nutrient application treatments, results of the study showed a substantial increase in levels at the end of the study over the initial values. This was probably due to higher mineralization rate over time. Ammonium-N was predominantly higher than nitrateN levels in both seasons. This was due to higher ammonification rates and mineralization of organic N pool in the wet season than in the dry season. This is in line with the observations of Singhl *et al.* (2009**)** who reported higher levels of NH_4^+-N in croplands soils due to higher percentage of net ammonification rates and its accumulation in the top horizon of the soil. Sabina and Islam (2012) suggested that mineralization of organic N pool increases NH_4^+ content of soil during the growing season. Nitrate is the principal form of nitrogen used by plant. It leaches since it is a negatively charged ion and is not attracted to soil clay. Ammonium-N is less subjected to leaching or denitrification losses, so N maintained as NH_4^+ in the soil should be available for late season uptake (Tsai *et al.,* 1992).

Soil microbial biomass acts as a sizable reservoir for plant nutrients in the soil. Crop productivity depends on the amount of available plant nutrients which reflects the soil fertility and are mostly derived from the soil microbial biomass (Jamil *et al.*, 1990). Microbial biomass-N (MB-N) contributes to the primary N source of potentially mineralizable N in soil (Bonde *et al.* 1988; Singhl *et al.,* 2009).

As expected, microbial biomass was generally higher during the major season than in the minor season (Table 4.4). This might be due to variations in soil moisture and temperature which favoured the growth and activities of microbes and fungi (Acea and Carballas, 1990) during the major season. Haripal and Sahoo (2014) also reported that seasonal variation of soil microbial biomass C, N and P were significantly higher during the rainy season and lower in the dry season. The authors attributed the differences to variation in soil moisture and temperature.

Generally, fertilizer treatments substantially increased microbial biomass N in both seasons over the control. Microbial biomass is sensitive to factors that can influence its size and structure and this include microclimate and fertilizer amendment practices (Moore *et al.*, 2000).

5.4 Routine soil properties under foliar and soil nutrients application

Soil nutrient status under the two foliar fertilizers and the check were similar at the end of the study (Table 4.5). However, SOC values recorded at the end of the study were lower than that initially observed at the beginning of the season (Table 4.1). This is attributed to increased decomposition of organic matter due to adequate soil moisture, high temperatures and aeration favouring microbial activities during the study period.

Nitrogen and phosphorus are the nutrients most limiting the production of vegetable crops, though other nutrients such as K are required (Olaniyi and Ajibola 2008). From a quantitative point of view, nitrogen is the most important nutrient in crop production in comparison with phosphorus and potassium (Olaniyi and Ajibola 2008). Unlike organic C, there were marginal increases in total N at the end of the season compared to initial values (Table 4.5). This was due to increased Nmineralization during the

study period. Manguiat *et al.* (1996) reported that mineralization of soil organic N is a key process for the supply of N and availability for plant growth.

Like total N, available P at the end of the study showed increase over the initial level. Changes in available P were generally high in all the treatments when compared with the initial value. There was a substantial increase from an initial P value of 10.5 mg / kg to a range of 12.1-13.6 mg / kg at the end of the two cropping seasons indicating a buildup of soil P with time (Table 4.5). This increase in P content could be due to mineralization of organic matter. Olaniyi and Ajibola (2008) reported that under tropical conditions, rapid mineralization of organic matter can liberate sufficient P for plant growth. The P range recorded at the end of the study could be rated as medium (Page *et al.,* 1982). Though Ca and Mg content of the soil were initally low, values recorded at the end of the study were moderate. Landon (1996) rated Ca > 5 cmol $_{(+)}$ /kg soil and Mg > 5 cmol $_{(+)}$ /kg soil as moderate. The higher Ca and Mg values recorded compared to the initial values could be due to the release of Ca from Mg containing minerals in the soil during the cropping season.

Final soil nutrient status under applications of Herbagreen and Sidalco liquid fertilizers did not generally decline with respect to the initial values suggesting no nutrient mining in the short term. Sole foliar applications may however, be expected to cause nutrient mining in the long term if not supplemented with the application of

soil nutrients.

5.5. Insect population dynamics as affected by foliar and soil application of nutrients

Generally, higher number of insects was observed per plants in control plots during the major season (August) than in the minor season (October) probably due to seasonal

climatic variations and crop stage growth. Horowitz and Gerling (1992) reported that *B. tabaci* are mobile pests and are therefore subject to migration when the plant condition is no longer favourable (for example, leaf senescence).

The Figure 4.1 showing seasonal variation in the population dynamics of *B. tabaci* indicated a steady increase in their number from 1.77 in June to 3.87 per plant in August when a peak was attained. In September, the population was reduced to 1.63 per plant and then rose again in October to 1.80 before finally declining to 0.85 in November during the second cropping season. These seasonal variations may be due to environmental conditions wherein the raining season soil moisture and temperatures were most suitable and host plant quality and quantity were on the rise (Horowitz, 1986). As the dry season approaches, host plants quality decreases, less leaf area and insect populations decline (Byrne and Houck, 1990). Horowitz and Gerling (1992) reported similar findings in their study of seasonal variation of sex ratio in *B. tabaci* on cotton in Israel. They reported few adults per plant in May-June, a build-up phase during July and early August, a high or peak population phase at the end of August and during early September; and a decline phase at the end of September and during early October.

Foliar application of Herbagreen and Sidalco liquid fertilizer significantly reduced the population of *B tabaci* compared to NPK and the control in both cropping seasons. Low numbers of 1.4-3.0 *B tabaci* per plant were recorded in Herbagreen treatments in the minor and major seasons. Herbagreen is composed of nutrient elements that are reported to influence insect pests. For example, Reuven and Reuveni (1998) indicated that foliar sprays of phosphate and potassium salts can induce systemic protection against pests. Although, not analyzed in this experiment, studies showed that high silicon content is linked to a higher pathogen resistance. For example, SANOVITA

(2001) reported that silicon increases the tolerance against a number of pathogens and the ability for resistance against infestation of insects. Similarly, Feng (2004) reported that silicon deposited on the tissue surface acts as a physical barrier and suppresses insect pests such as stem borer, brown plant hopper, rice green leafhopper and white backed plant hopper, and non insect pests such as leaf spider and mites (Savant *et al*., 1997). The silicon content of Herbagreen was 11.3 % (Table 4.1) which possibly accounted for lower number of insets in treated plants as observed in the study.

Generally, *T. tabaci* and *A. gossypii* populations remained too low (> 1 per plant) to adversely impact plant growth during the two cropping seasons. The low population recorded for both insect pests could be due to high rainfall amounts during the cropping seasons. The results are in line with that of Karnataka (2009) who reported on incidence of aphids and thrips on cotton throughout the year except July, August and September which received high rainfall. Similarly, Patel *et al.* (1997) reported that during high rainfall period, aphid population did not attain peak. Similar reports were made by Vennila *et al.* (2007) that scanty rainfall aggravated the severity of sucking pests. According to them, *T. tabaci* has population peaks during dry spell with high temperature and low humidity which are optimum for its population build up.

5.6. Disease incidence and severity under foliar nutrient application

Comparatively, disease incidence for early and late blight was higher in the major season than in the minor season, possibly due to high rainfall amount in the former (Appendix 1). Early and late blight spread under conditions of high moisture (rainfall) (Seaman *et al.,* 2003).

Foliar applications of Herbagreen and Sidalco liquid fertilizer substantially reduced the incidence of early blight in the major season and were also effective in reducing

late blight in both seasons. Similarly, in the minor season, foliar applications of Herbagreen and Sidalco reduced severity of early and late blight in treated plots compared to the check and control. Silicon contained in Herbagreen must be responsible for the reduced incidence and severity of disease in the crop. Schwarz and Weihrauch (2012) reported a synergistic effect in the combined use of copper preparations and Herbagreen in the control of downy mildew in hops.

Despite the relatively higher incidence of early and late blight in the major season than in the minor season, the expression of symptom severities was similar in both cropping seasons. This could be that the second season crops were infected during early vegetative growth when weather conditions were still favourable for dispersal of the pathogen but as the moisture levels reduced the diseases rather increased in severity than incidence. Seaman *et al.* (2003) reported that early and late blight can be most severe when plants are under drought stress caused by a lack of soil moisture or poor soil conditions.

5.7 Yield

Yield responses of tomato to foliar and soil application of nutrients appeared to be positive in the two cropping seasons. Herbagreen application produced number of fruits per plant and fruit yield (kg/ha^{-1}) comparable to the NPK 15-15-15 check (Table 4.7). Tracynski (2011) reported significantly increased yields in cabbage and tomato when Herbagreen was applied compared to N fertilized plots. Similar results were reported by Velkov and Petkova (2014) that Herbagreen increases the number of fruits per plant in cucumber, melon and zucchini. Herbagreen affects plants in different ways, by being directly involved in photosynthetic processes (Velkov and Petkova 2014). Carbon dioxide is included in the process of photosynthesis, this way CO_2 from Herbagreen is absorbed directly in leaves thus increasing photosynthesis (Dumancic, 2010). The relatively higher fruit weight and number of fruits per plant obtained in this study under Herbagreen application could be a result of increased photosynthesis. Additionally, observations in the field showed an improvement in vegetative growth and in the physiology of the leaves of Herbagreen plants especially during the minor season. Dumancic (2010) reported that the direct effect of Herbagreen is expressed in enhanced vegetative growth, increased yields and the tolerance of plants to biotic and abiotic stresses.

Comparatively, fruit yield obtained in the major season was considerably higher than that of the minor season. This was as result of the differences in rainfall distribution between the two seasons.

CHAPTER SIX

6.0 CONCLUSION AND RECOMENDATIONS

6.1 Conclusion

Nutrient composition of the tomato under foliar applications of Herbagreen and Sidalco liquid fertilizer was comparatively higher in the major season than in the minor season due to relatively higher rainfall in the former. Organic carbon, total N and P were similarly influenced by the application of Herbagreen and Sidalco. Foliar application of Herbagreen and Sidalco significantly increased total N composition of tomato over the control in the minor season. The results of the study contrast the assertion that nutrient applied directly to the leaf will more likely enter the leaf in large quantity than the same nutrient applied to the soil. Though Herbagreen contains high level of calcium (35.9 %), concentration of the nutrient in plants treated with the product was similar to that of the Sidalco liquid fertilizer.

Generally, soil fertility indices under the foliar applications of Herbagreen and Sidalco liquid fertilizer did not show decline over levels initially recorded. Since the foliar treatments were imposed solely without any other source of nutrients (directly applied to the soil), nutrient mining was expected. However, due to the short term nature of the study, this effect was not observed.

In both seasons of study, four times foliar application of 0.1% solution of Herbagreen effectively reduced the insect number per plant compared to NPK 15-1515 fertilizer, Sidalco liquid fertilizer and the control. Similarly, Herbagreen was effective in the reduction of both incidence and severity of early and late blight in tomato. Although, not significant levels of TYLCV were lower in foliar treatment of Herbagreen.

Yield response of tomato to foliar applications of Herbagreen and Sidalco liquid fertilizers appeared positive in both cropping seasons. Although, higher number of fruits and fruit weight were obtained from the NPK 15-15-15 fertilizer plots, the yield was comparable to that of Herbagreen and Sidalco foliar fertilizers in both cropping seasons.

6.2 Recommendations

Since Herbagreen treated plants produced fruit yield comparable to conventional NPK and Sidalco liquid fertilizer but showed lower incidence and severity of diseases as well as lower insect pest numbers, it is thus a good option for tomato production in Ghana. Besides, it is a natural product and will not pose environmental threats as NPK and other synthetic fertilizers.

From the study it is clear that sole foliar applications of Herbagreen and Sidalco liquid fertilizer did not produce any significant changes in soil chemical properties in terms of nutrient mining or otherwise. There is therefore the need to conduct longterm research in multi-locations to determine the sole effects of foliar application of Herbagreen to establish its sustainability in crop production as claimed by the manufacturers.

Furthermore, it will be essential to investigate the synergistic effect of combined applications of conventional soil NPK and foliar fertilizers for effective crop nutrient management. Sine Herbagreen is known to work well on other crop types e.g. cereals, tree crops; it is recommended that the product is tested on such crops as well.

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APPENDIX

Appendix 1. Climatic data of the experimental site

Month	Temperature (^{0}C)		Relative Humidity (%)	Total monthly rainfall (mm)
	Min	Max		
May	22.7	32.1	83	103
June	22.5	30.9	85	270
July	21.5	28.7	87	93.21
August	20.9	27.7	90	125.6
Sept	21.3	29.3	89	162.9
Oct	21.7	30.3	86	91.4
Nov	22.4	32.1	88	107.2

Source: Ghana Meteorological Agency

Appendix 2. Rating of soil chemical properties

Soil nutrient (mineral) content	Rating
Organic Matter (%)	
< 1.5	Low
1.6 – 3.0	Moderate
> 3.0	High
Nitrogen (%) <	
0.1	Low
0.1 – 0.2	Moderate
> 0.2	High
Phosphorus, P (mg kg^{-1}) – Bray's No.1	
<10	Low
10-20	Moderate
>20	High
Calcium, Ca (cmol $_{(+)}$ kg^{-1}) / Mg	
< 5	Low
5-10	Moderate
> 10	High
Exchangeable Potassium (cmol $_{(+)}$ kg^{-1})	
< 0.2	Low
0.2 – 0.4	Moderate
> 0.4	High

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