CSIR COLLEGE OF SCIENCE AND TECHNOLOGY

MINERAL NITROGEN AND SALICYLIC ACID RATES AND THEIR EFFECTS ON YIELD, QUALITY AND ALTERNARIA BLIGHT INCIDENCE IN CABBAGE

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BY

MILLICENT ALUAH ACKAH

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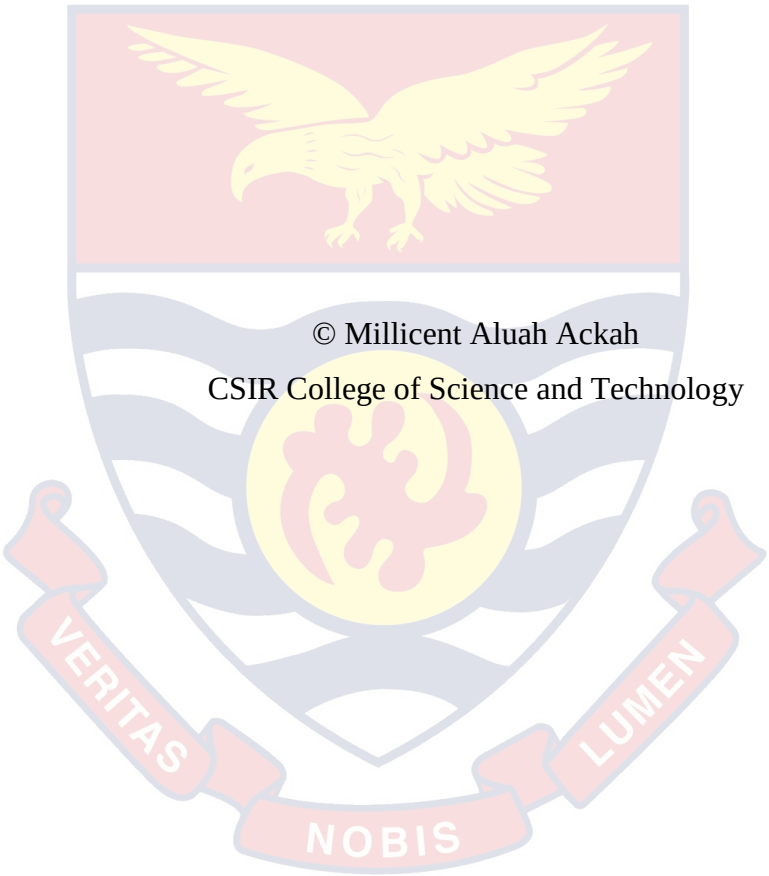

CSIR College of Science and Technology

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this College or elsewhere.

Candidate's Signature……..Date:……

Name: Millicent Aluah Ackah

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the CSIR College of Science and Technology.

Principal Supervisor's Signature……Date…….....

Name: Dr. Francis Marthy Tetteh

Co-Supervisor's Signature:……Date:……..

Name: Dr. Emmanuel Amoakwah

ABSTRACT

Cabbage is the main vegetable grown largely in Adarkabrunso/Adeito in the Bosome Freho District in the Ashanti region of Ghana. Lower yields and quality due to Alternaria blight and inappropriate use of fertilizers are setbacks in its production. A study was conducted to assess cabbage yield, quality and resistance to Alternaria blight under different rates of mineral nitrogen fertilizer and salicylic acid in 2019. Oxylus cabbage variety was planted in a randomized complete block design with six treatments: control (NPK (0-0-0) kg/ha), NPK (30-60-60) kg/ha, NPK (60-60-60) kg/ha, NPK (90-60-60) kg/ha, NPK (90-60-60) kg/ha+ 0.25 mM SA and NPK (90-60-60) kg/ha+ 0.5 mM SA which were replicated four times. Of the parameters studied, leaf area, leaf number and circumference of cabbage heads were significantly different whilst cabbage yield, Alternaria blight and pest resistance, number of folded and unfolded leaves were not significant at 5 % probability level. However, treatments (NPK (90-60-60) kg/ha and NPK (90-60-60) kg/ha + 0.5 mM SA gave an equal yield of (50.9 t ha^{-1}) and resisted the Alternaria blight most. NPK (60-60-60) kg/ha induced better leaf area (6.847 m^2) and number (19.875). Control plots (NPK (0-0-0) kg/ha) were more resistant to pests, treatments with salicylic acid (NPK (90-60-60) kg/ha + 0.5 mM SA and (NPK (90-60-60) kg/ha + 0.25 mM SA induced better leaf folding and circumferences (56.95 & 55.05 cm) respectively, Control (NPK (0-0-0) kg/ha) and (NPK (30-60-60) kg/ha) controlled unfolded leaves in cabbage. Meanwhile treatments with highest nitrogen rate NPK (90-60-60) kg/ha stood tall interms of yield, quality, cost and resistance to Alternaria blight in cabbage compare to NPK (90-60-60) kg/ha + 0.5 mM SA.

KEY WORDS

Alternaria Blight

Brassica Oleracea (Cabbage)

Cabbage Quality

Cabbage Yield

NPK

Salicylic Acid

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DEDICATION

To my sweet mum Madam Scholastica Efferh Ebba-Adwoa,

My family, Friends, Abled service and NABCO personnel

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
CSIR	Council for Scientific and Industrial Research
ECEC	Effective Cation Exchange Capacity
FAO	Food and Agricultural Organisation
ISR	Induce Systemic Resistance
RCBD	Randomized Complete Block Design
SA	Salicylic Acid
SAR	Systemic Acquired Resistance
SRI	Soil Research Institute
TEB	Total Exchangeable Base
TSP	Triple Super Phosphate

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CHAPTER ONE

INTRODUCTION

Background to the Study

Cabbage *(Brassica oleracea var. capitata) (L),* an exotic vegetable native to Europe and Asia and a descendant of the wild cabbage was identified as one of the top twenty vegetables and an important source of food globally, (Food and Agricultural Organisation [FAO], 1988). It is currently popular in Ghana. In 2004, it was reported by Timbilla and Nyarko to be produced all year-round especially in the Greater Accra, Ashanti, Central, Eastern, Brong Ahafo and Volta Regions. In Bosome Freho District in the Ashanti region of Ghana, cabbage is the most grown vegetable. About 20% population of farmers apart from cocoa, rice and the staple crops (plantain, maize, cassava and cocoyam) are into its cultivation. Adarkabrunso/Adeito stretch represents about 60 % of vegetable farmers in the District who are into its production and their livelihood depends solely on it (Department of Agriculture, 2018).

Cabbage has many uses. Its cultivation is however challenged by nutrients deficiencies, pests and diseases, marketing, poor storage, etc. which cause lower yield and quality affecting the farmer and the nation at large economically. These challenges especially lower yield, quality and diseases can be managed by altering the mineral elements specifically nitrogen and using salicylic acid. Though many research works have been done on cabbage, focused were on production, yield, factors affecting its growth and diseases. Very few studies have been done on the right rate of mineral fertilizer especially nitrogen and salicylic acid to be applied to improve yield, quality and to suppress Alternaria blight of cabbage.

Alternaria black spot, a fungi disease remains an increasing threat to *Brassicaceae* crops throughout the world (Meah, Hau, & Siddiqua, 2002) including Ghana. It is one of the major biotic problems that limits cabbage cultivation, quality and shelf life. Alternaria blight is a destructive disease on seed crop and older leaves are more susceptible. Potential yield loss is estimated at 100 % if the disease is left uncontrolled according to unpublished data by Puget Sound Seed Growers Association (2006). This study is thus aimed at the impact of mineral nitrogen and salicylic acid rates on yield parameters and quality of cabbage.

Statement of the Problem

Cabbage, though has many economic, nutritional and medicinal values but suffers from many important fungal and bacterial diseases which limits its production. Soil nutrients also stimulate these diseases thereby affecting yield and quality. Tiwari, Singh and Mal (2003) reported that yield and quality of cabbage were influenced by soil and nutrient status. Different soils and NPK rates are likely to influence growth and yield of different cabbage differently. It has also been found that a hectare of cabbage producing 70 tons consumes 370 kg of nitrogen from the soil.

Khan, Iqbal, Ahmad, Soomro and Chaudhary (2002) emphasized that though cabbage needs nitrogen in optimum amounts, excessive levels may cause loose head formation and internal decay. In some cases, if nitrogen is not adequate, it will not form heads. Cabbage demand for phosphorus also increases manifold during head formation stage while potassium deficiency can result in marginal necrosis and retardation of head quality but its excess

also causes the heads to open. Hossain, Haque, Abuyusuf, Riad and Iqbal Hussain (2011) reported that the response of cabbage is high to nitrogen and moderate to phosphorus application and thus the importance of N, P, K and S on the growth and yield of vegetable crops is well established. Brady, (1990) however stated that among the nutrients, nitrogen plays the most important role for vegetative growth of the crop thus its role in the yield and quality of cabbage needs to be investigated at varying rates to establish the best rate for yield and quality and also capable of suppressing Alternaria disease.

Alternaria blight (*Alternaria brassicae* or *Alternaria brassicicola*), is the most common disease and bigger challenge encountered in the production of cabbage at Adarkabrunso and Adeito stretch in the Bosome Freho District in the Ashanti Region of Ghana. The disease causes lower yield and also responsible for its poor quality and total economic loss. Seed crop and older leaves are more susceptible. Maude and Humpherson-Jones, (1980) found that 86 % of commercial brassica seeds produced in the UK between 1976 and 1978 were infected with *Alternaria brassicicola.* A questionnaire administered at Adarkabrunso and Adeito prior to this study also indicated that patches of fields are affected entirely when the disease sets in and so far, no recommended fungicides have been able to control the disease.

The fungi can spread via wind, splashing rain, contaminated soil or equipment, crop debris and residues of cruciferous plants including weed hosts or by surviving infected seed (du Toit et al., 2005). Symptoms of Alternaria on cabbage may first develop on young plants in seedbeds where leaf spots, stunting or damping off may take place. The initial symptoms are small dark yellow spots on the surface of leaf. The spots magnify later to

circular areas with concentric rings varying from pinpoint to 2-inches in diameter and possibly surrounded by yellow halos. In extreme instances, the entire plant defoliates and violets to tan spots develop on infected cabbage seed pods which intensify in wet atmospheric conditions.

Although Alternaria blight has been a challenge in the production of cabbage in the Bosome Freho District in the Ashanti Region of Ghana, it can be managed by mineral nutrition and the use of induced hormones such as salicylic acid. Mineral nutrition apart from influencing growth and yield, affect plant resistance or susceptibility to pathogens and pests. Though disease resistance is genetically controlled, it is considerably influenced by environmental factors (Spann & Schumann, 2013). In view of this, plants with an optimal nutritional status have the highest resistance or tolerance to pests and diseases. Susceptibility increases as nutrient concentrations deviate from this optimum. Mineral nitrogen has been reported by Huber and Thompson, (2007) as the most extensively mineral nutrient affecting plant diseases by making plants more susceptible to plant pathogens. Nitrogen is also the nutrient element applied in largest quantity and the most frequently deficient in cultivated soils (Datnoff, Elmer & Huber, 2007).

Salicylic acid (SA) has gained a particular attention in the field of disease control because its accumulation is essential for expression of multiple modes of plant disease resistance (Murphy, Holcombe, & Carr, 2000). Its exogenous application at nontoxic concentrations to susceptible plants can enhance resistance to pathogens. Until date, two types of induced resistance have been defined based on the nature of elicitors and the other based on the pathways involved (Van Loon, 2016). Plant Growth Promoting Bacteria can

induce systemic resistance that operates independent of SA (Walters, Walsh, Newton & Lyon, 2007) while the induction of SAR results from pathogen pre-treatments with SA or SA-like compounds.

Salicylic acid has a regulatory role in a range of physiological processes such as photosynthesis, transpiration, nutrient uptake, chlorophyll synthesis and plant development (Raskin, 1992). It was further recognized as an important signaling molecule that potentially influences plant tolerance to water stress because of its influence on the regulation of metabolic and physiological activities during the entire lifespan of the plant by affecting its growth parameters and bio-productivity (Popova, Pancheva & Uzunova, 1997).

Research Objectives

The main objective of the study was to improve cabbage yield, quality and suppress the occurrence of Alternaria blight through mineral nitrogen and salicylic acid applications. The specific objectives were to:

1. Study the effects of NPK mineral fertilizer and salicylic acid on the yield of cabbage.
2. Assess the yield and quality of cabbage under mineral nitrogen and salicylic acid applications.
3. Establish the impact of varying rates of salicylic acid and mineral nitrogen on the occurrence of Alternaria blight disease in cabbage.

Research Questions

1. What are the importance of NPK mineral fertilizer and salicylic acid on the production of cabbage?
2. Which rate of mineral nitrogen fertilizer would promote yield, ensure quality and suppress the incidence of Alternaria blight of cabbage?
3. What rate of salicylic acid will improve yield and quality of cabbage crop and stamp down the occurrence of Alternaria blight of cabbage?

Hypothesis

This study was conducted based on the following hypotheses:

1. Application of NPK mineral fertilizer and salicylic acid improved yield and quality of cabbage crop and suppress Alternaria blight of cabbage.
2. Rates of mineral nitrogen and salicylic acid application are key indicators on cabbage yield, quality and Alternaria blight occurrences.

Significance of the Study

Cabbage is a very nutritious and income generating crop. Using appropriate rates of mineral NPK, nitrogen and salicylic acid and sticking to the best practises will improve its yield, quality and suppress Alternaria which limits its production in Adarkabrunso. This will increase farmers' income and help the nation at large. The results of this study will provide adequate information on the best rate of mineral NPK and salicylic acid to apply to increase yield parameters (leaf area, leaf number, folded leaves, yield and

circumference of cabbage heads) and quality parameters (Alternaria blight, pests and unfolded leaves) in cabbage production. Cabbage farmers, MoFA staffs, Researchers, Agricultural Institutions and Colleges, Universities and other Stakeholders will be equipped with adequate knowledge on cabbage production and how to maximize yield, improve quality and prevent the occurrence of Alternaria blight on oxylus cabbage.

Delimitation

This study focused on the improvement of cabbage yield, quality and suppression of Alternaria blight through mineral nitrogen and salicylic acid applications. Despite the importance of mineral fertilizer and especially nitrogen in cabbage production, farmers at Adarkabrunso/Adeito do not apply the right rates. Some apply only nitrogen related fertilizer such as urea and ammonia which causes acidty to the soil. Also, NPK mineral fertilizer applied is not up to the required rate needed by cabbage crop and these practices trigger diseases especially Alternaria blight. This experiment was conducted at Adarkabrunso/Adeito located at the Western part of the Bosome Freho District to know the right rate of NPK fertilizer to apply in order to boost production, improve yield, quality and suppress Alternaria blight thus increasing farmers' income.

Limitations

This study was based on major constraints encountered in cabbage production especially incidence of Alternaria blight, lower yield and quality. Studies were on how to improve yield and quality and at the same time

suppressed alternaria by altering mineral nitrogen and using induced hormones (salicylic acid). These constraints were not fully achieved due to time and limited resources. Also, there was problem of drought and this made it not possible to weed during the drought period in order to conserve moisture.

Organisation of the Study

This study is presented in five chapters. Chapter One which is the Introduction elaborates the background of the study, problem statement and objectives, significance of the study etc. Chapter Two is a detailed review of literature on cabbage production, factors affecting its yield, quality and incidence of diseases like Alternaria blight (soil, nutrition and induced hormones, climatic) and how to control these factors. Chapter Three presents the methods, procedures, intruments and statistical tools used to collect and analyse data. Chapter Four brings out detailed results and discussions on the various parameters under study whilst Chapter Five spells out the conclusions, summary and recommendations.

CHAPTER TWO

LITERATURE REVIEW

Origin, Morphological and Nutritional Characteristics of Cabbage

Cabbage, *Brassica oleracea* is one of the most important cole vegetables grown nationwide from the mustard family *Brassicaceae*, formerly *Cruciferae* which includes broccoli, cauliflower, collards, kohrabi, brussel sprout and kale (Delahaut, 1997). *Brassica oleracea* var. *capitata*, tuba and sabauda are thought to be an early ancestor of the wild Brassica species.

Cabbages are sold by type, colour of head and shape rather than by individual variety. By type are savoy and Chinese cabbages. In colour, cabbage ranges from green, purple and red. The shape varies from rounded, soccer-ball size to cylinder-like and in maturity from early to late maturing. There is however, a wide range of varieties available and their suitability for a particular area can only be judged by growing them in the region (Murison, 2006). The green, round headed types are the most common. Cabbage releases a distinctive flavor and odour because of the present of a compound in the mustard oil it produces. Early season crops have small head of 1-2 pounds (2.205-4.410 kg) and takes 50-60 days to mature after transplanting. Full season, storage or processing cultivars require 130 or more days to mature and have a head weight of 10-12 pounds (22.05-26.46 kg) (Singh et al, 2006).

The consumption of cabbage has been on the increased. About 6.3 kg of Brassica vegetables are consumed per person annually (Jordbruksverket, 2003) either raw or processed in different ways, e.g., boiled or, fermented or, used in salads. Chemical components analysis has shown that the main constituents of cabbage are carbohydrates, comprising nearly 90 % of the dry

weight, where approximately 30 % is dietary fiber and 60 % are low-molecular-weight carbohydrates (LMWC). And like other cruciferous vegetables, cabbage contains specific sulphur compounds glucosinolates that increase its antioxidant activity (Wennberg, Ekvall, Olsson & Nyman, 2006).

Due to its antioxidant, anti-inflammatory and antibacterial properties, cabbage has widespread use in traditional medicine in the alleviation of symptoms associated with gastrointestinal disorders such as gastritis, peptic and duodenal ulcers and irritable bowel syndrome. Cabbage is also known in the treatment of minor cuts and wounds and mastitis. Šamec, Piljac-Žegarac, Bogović, Habjanič and Grúz (2011) stated that fresh cabbage juice when prepared separately or mixed with other vegetables such as carrot and celery is often included in many commercial weight-loss diets, diets that improve the bioavailable content of nonheme iron and as an alternative therapy for cancer patients (Maritess, Small & Waltz-Hill, 2005). Clinical research has shown positive effects of cabbage consumption in healing peptic ulcers and facilitating the reduction of serum LDL levels (Suido et al., 2002).

Cabbage Cultivation

In producing cabbage, several factors should be taken into account such as variety, soil and environmental conditions and cultural practices (FAO, 2000). Best temperature is 15.56-23.89 ^{0}C. Plant exposed to temperature of 10.00-12.78 ^{0}C for prolonged periods will produce premature seed stalk instead of heads (Khan, Iqbal, Ahmad, Soomro & Chaudhary, 2002). Soil and fertilizer management have been recorded under cultivated conditions to be the two main factors influencing cabbage growth and yield.

Well drained loamy soils with an effective rooting depth of approximately 600 mm are recommended. Cabbage seedlings are transplanted into the field when nursed seeds attain four to six weeks. At transplanting, an appropriate fertilizer starter solution should be applied. It is recommended that a plant spacing of 60 – 70 cm × 60 cm for the loose head market, 45 – 55 cm × 60 cm for the bagging and 25 cm × 25 cm for baby cabbage (Anonymous, 2014).

Cabbage production requires water management particularly in the dry season. Shortage of water leads to drought with obvious agricultural and societal impacts (Morrison, Baker, Mullineaux & Davies, 2007). Total water requirement is approximately 440 mm. In winter however, application of 10 to 15 mm per week for the first third to half of the growing season and about 25 mm per week thereafter is recommended. In summer, application of 20 to 25 mm per week for the first third to half of the growing season and 40 to 50 mm per week thereafter is essential (Anonymous, 2014)

Optimally, cabbage requires 60 – 85 kg N ha^{-1}, 68-80 kg P_2O_5 ha-1 and 30-90 kg K_2O ha-1 (Shika & Doug, 2001). Osei et al. (2013) however, established that recommendations based on soil tests resulted in the most effective lime and fertilizer management program to be possible. Delahaut, (1997) added that the best soil pH for cabbage production is 6.0-6.8 for mineral soil and 5.6 on muck or organic soil. Acidic soils influences club root disease and planting same site each year triggers the build up of soil pathogen. Lack of nitrogen or other nutrient stresses as well as competition from weeds, insects or diseases that slow vegetative growth can promote flowering. Harvesting of cabbage is done when heads are firm.

Overview of Cabbage Production

Cabbage is produced throughout Ghana but less in Upper East and Western regions. Its production was noted to be increasing particularly in the Greater Accra, Ashanti and Central Regions (Timbilla & Nyarko, 2004). Cabbage provides an excellent source of employment for both rural and urban dwellers as it is grown in many rural areas as well as in the outskirts of towns and cities. The cabbage industry has been found to have three distinct components namely, commercial or market gardening, medium scale production for contractors or middlemen and small-scale domestic or backyard gardening (Yeray Saavedra et al., 2014). Many constraints however, are encountered in cabbage production such as insect pests, diseases, land tenure system which is mostly rented or inherited, management practices, storage and marketing etc. Cabbage production is mostly done with irrigation and or with rainfall on relatively infertile soils under continuous cropping.

Ennin and Dapaah (2008) concluded that in Ghana, food production is characterized by no or very limited fertilizer application but not so with vegetable production. Most often, Ghana cabbage farmers only apply either NPK fertilizers or organic fertilizer in combination with NPK but rarely use organic fertilizer alone. Osei et al. (2013) further reported that about 96% of farmers in Ghana used fertilizer to boost cabbage production of which inorganic fertilizer comprises about 52% while a meagre of 7% used organic sources of fertilizer. They also stated that NPK was the most common inorganic fertilizer used amongst farmers (89%) whereas 2% use liquid fertilizer. The extent of fertilizer application was based on farmers' knowledge about the importance of the input to crop being grown and also on

the financial status. As such 53% of cabbage farmers apply fertilizer three times and 13% apply once before harvesting. The majority of farmers who apply fertilizer three times stand a better chance of increasing their production levels compared with those who apply fertilizer once.

In Bosome Freho district, Adarkabrunso/ Adeito and its environs, most cabbage producers do not follow proper fertilizer management practice. This is because there is no local scientifically based recommendation in place. Fertilizer application is estimated by farmers' experience, inputs available and financial status. Guess work approach to fertilizer application is unsuitable because it prevents cabbage crops from realizing their yield and quality potentials and makes them more susceptible to plant pathogens such as *Alternaria.* This is so since the right amount of fertilizer required to grow crop of desired yield, quality and boost their resistance cannot be ascertained correctly. And as stated by Ezzo, Glala and Singer (2008) that excessive application of NPK fertilizer may result in critically high nitrate concentration in leafy vegetables, most farmers in the area only apply nitrogen-based fertilizer of ammonia and urea with less of the compound fertilizer (NPK) which further causes soil acidity. Also, optimum potassium which should be between 100-200 mg/kg (100-200 ppm) and 26-50 mg/kg (26-50 ppm) for phosphorus (Delahaut, 1997) is not given to the plant to help improve their yield, quality and resistivity to plant diseases like Alternaria blight.

Plant yield, quality and disease resistance is a prerequisite for the successful utilization of crop species in modern agriculture. This is because major constraints facing modern agriculture is to achieve a satisfactory and environmentally friendly control method of plant diseases in order to increase

yield and quality. Using NPK mineral fertilizers and salicylic acid to boost cabbage crops yield and quality and their resistance to *Alternaria* is therefore a must.

Role of Nutrients on Yield and Quality of Cabbage

Plant nutrients supply is inevitable in the production of cabbage. To improve its production (yield and quality), some factors such as application of adequate fertilizers and disease control methods should be provided (Kumar and Rawat, 2002). Hossain, Haque, Abuyusuf, Riad and Iqbal Hussain, (2011) found that among the various factors involved, nutrient supply is an important input for realizing higher cabbage yield and its nutrient content**.** Apart from carbon (C), hydrogen (H), and oxygen (O) which plants take up through the fixation of carbon dioxide (CO_2) via photosynthesis and water (H_2O) uptake via roots, there are 13 mineral nutrients that are essential for normal plant growth and development. These nutrients play vital roles in plant biology (Dordas, 2008).

The requirement of these plant nutrients can be provided by either applying inorganic fertilizer or organic manure or both. However, excessive fertilizer application causes a higher production cost and worsens soil structure, causing physical, chemical and biological degradation (Li, Hu, Delgado, Zhang & Ouyang, 2007). As such, soils deficient in nutrients which are to be used for cabbage cultivation must be enriched with nitrogen, phosphorus, potassium, sulphur, and other micro nutrients through balanced use of fertilizer. Hossain, Haque, Abuyusuf, Riad and Iqbal Hussain (2011) stated that the response of cabbage is high to nitrogen and moderate to

phosphorus application thus the importance of nitrogen, phosphorus, potassium and sulphur on the growth and yield of vegetable crops is well established.

Effects of NPK Fertilizers on Cabbage Yield and Quality

The role of nitrogen cannot be overlooked in the establishment or cultivation of cabbage. Adequate nitrogen promotes vigorous vegetative growth and is also very vital in the formation of chlorophyll, being also a component of proteins. When nitrogen is not present or inadequate, plants become stunted in growth with pale leaves resulting in limited production (Hadfield, 1995).

Khare and Singh (2008) conducted a study to find out the effect of nitrogen on growth and yield of cabbage cv. Golden Acre. Twelve treatment combinations comprising four levels of nitrogen viz., 0%, 50%, 75% and 100% were laid out. Application of 75% nitrogen (135 kg/ha) significantly increased the growth parameters (number of unfolded leafs, leaf area and leaf area index), yield attributes (number of folded leafs, weight and diameter of head) and yield of cabbage, (341-366 q/ha). Singh, Rana and Rawat (2010) studied the effect of nitrogen and phosphorus fertilizers through drip irrigation on growth and yield of cabbage (CV Pusa Mukta). They reported that treatments with nitrogen level of 180 kg per hectare significantly performed better with regard to growth and yield parameters. Tanpure, Patil, Pingale, Gutal and Bote (2007) evaluated the effects of different levels of NPK on the yield of cabbage cv. Golden Acre. Treatments included 140, 120, 100, 80, and 60 % of the recommended rate of NPK (160:80:80) through drip irrigation. It

was observed that NPK applied at 140 and 120 % showed superiority over the other treatments in improving cabbage yield. Santosh, Soni and Jat (2012) studied the effect of different organic sources and fertilizers on the growth and yield of sprouting broccoli. It was found that growth and yield attributes were recorded under treatment combination of vermi-compost at 5.0 t ha^{-1} along with 125 % dose of fertilizers (NPK, 100, 80 and 60 kg/ha).

Studies conducted on the effect of organic manures and chemical fertilizers on growth and yield of cabbage showed that the inorganic fertilizer (160:80:80 N, P_2O_5 K_2O kg ha^{-1}) alone were effective enough to produce higher yield with better quality than the organic sources alone (FYM, vermicompost and poultry manure) (Jagtap, Kadam, Jagtap & Patil, 2009). Ouda and Mahadeen (2008) made a study to determine the effect of organic and inorganic fertilizers on the yield and quality of broccoli (*Brassica oleracea* var. *italica*). Three inorganic fertilizer doses (0, 30 and 60 kg/ha) were used. They indicated that the application of 60 kg inorganic fertilizers with 60 t ha^{-1} organic manure produced the greatest broccoli yield (40.05 t ha^{-1}).

Chatterjee (2010) experimented the influence of integrated use of inorganic fertilizers, organic manures, Azotobacter and Phosphate Solubilizing Bacteria (PSB) containing bio fertilizer on physiological attributes of cabbage. The results revealed that higher amount of organic manure and reduced levels of inorganic fertilizers not only influenced the physiological attributes significantly but also yield attributes and head yield of cabbage as compared to sole application of recommended inorganic fertilizers (150: 80: 75kg NPK/ ha). Meena, Ram and Singh (2011) conducted a study on

the growth and yield of cabbage and found that application of 180 kg N, 80 kg P_2O_5 and 40 kg K_2O/ha produced tallest plants, a greater number of open leaves, number of folded leaves, greater cross-sectional diameter, vertical length of head, and yield (129.66 q/ha). Neelam and Rajput, (2003) carried out a study on nutrient requirement of cabbage. They applied fertilizer at the rate of 40, 60, 80, or 100 % rates in the form of urea, diammonium phosphate and muriate of potash. Application of 100 % of the recommended fertilizer rates through fertigation resulted in overall yield increase of broccoli.

Role of Salicylic Acid on Yield and Quality of Cabbage

Agricultural production in the past was focused on maximizing the quantity of vegetables produced for commercial market (Pavla & Pokluda, 2008). In recent few decades, the organic management of crops has attained much popularity because consumers' awareness has been raised on the health challenges posed from food grown under conventional and intensive farming. Differences between organic and conventional farming systems especially in soil fertility management, diseases and pests control may affect the nutritive composition of plants. Salicylic acid (SA) is a plant hormone which plays an important physiological role in growth and development of plants (Khan, Prithiviraj & Smith, 2003). Salicylic acid aids plants to tolerate abiotic stress (Janda, Horváth, Szalai, & Paldi, 2007) such as heavy metal toxicity (Choudhary & Panda, 2004), salinity (Yusuf et al., 2008) low temperature (Tasgin, Atici & Nalbantoghu, 2003) and high temperature (He et al., 2005). Hayat, Ali and Ahmad (2007) reported that SA plays key roles in flowers induction, nutrients uptake and ethylene biosynthesis. It has also help in

stomatal movement, photosynthesis (Fariduddin, Hayat & Ahmad, 2003) and several physiological processes including plant growth. Moreover, Farooq et al. (2009) found that rice leaves (*Oryza sativa* L.) treated with SA (100mg L^{-1}) had a positive effect on photosynthesis and plant growth compared to other treatments of 50 and 150mgL-1. This induced better resistance to drought stress than soaking the seeds in the same SA solutions.

Alternaria Blight Disease of Cabbage

Cabbage and leafy vegetables are vulnerable to numerous diseases that may cause serious damage to the crop entirely. While some diseases may only cause insignificant spotting, the quality may be decreased below market standards because cabbage is consumed by the leaves. Alternaria leaf spot is one of the most prominent and destructive disease affecting the yield of cabbage. The disease progression under field conditions is mainly influenced by environmental conditions such as temperature, relative humidity, soil pH, light intensity, wind, etc. (Gunda, Madhu Kiran, Thara & Sree, 2018). A study on alternaria inferred that disease intensity increased with the increasing plant age from 21-71 days old. Inoculum from cultures at 15-35 days was more virulent than older inoculum (Sinha, Rai & Sinha, 2002). Studies on alternaria physiological characters revealed that optimum temperature for the growth of *A. brassicicola* was 25 ^{0}C. For infection and conidial germination in cabbage, an optimum temperature of 25 ^{0}C and 28-31 ^{0}C respectively were needed. The ideal pH for the growth of pathogen was 5.5 and 6. The optimum light intensity that favoured the growth of pathogen was normal day and night condition (20 lux) followed by dark. The growth and sporulation were

however stirred at higher light intensities (Gunda, Madhu Kiran, Thara & Sree, 2018).

Mode of transmission

Alternaria brassicicola may be seed, soil or wind-borne. Seeds may be contaminated by surface borne spores or internally infected by fungus. Spores on the surface of seeds can stay viable for up to 2 years and if the contamination is internal, the fungal mycelium can remain viable for more than 12 years (Dharmendra et al., 2014). The chlamydospores or microsclerotia which serve as the resting spores are the particular sites of survival from year to year. They may be carried also by tools, equipment, people and animals throughout fields.

Types, symptoms and life cycle of alternaria

According to Kumar et al. (2014), production of the vegetable brassicas are mainly affected by *A. brassicicola* and *A. brassicae* while the oleiferous seed crops are mainly affected by *A. brassicae*. The pathogens have a wide spectrum of hosts and can survive saprophytically outside the host and diseased crop debris.

Alternaria brassicicola is noted as a neurotropic fungal pathogen which is highly infective and common than *Alternaria brassicae* and other *Alternaria* spp. The first symptoms of *A. brassicicola* were dark spots ranging in size from 1 cm to 4 cm in diameter. This develops concentric rings within the spots on the lower leaves of cabbage and caused damping off during seedling stage (Dillard, Cobb & Lamboy, 1997). These spots on leaf minimize the plant photosynthetic power as the disease advanced (Kucharek, 2000).

Later, the infection occurs on the reproductive parts of the plant and caused considerable yield losses in cabbage (Doullah, Meah & Okazaki, 2006). Mac Kinnon, Keifer and Ayer, 1999) and Dharmendra et al. (2014) stated that the pathogen appears on leaves and stems of cabbage seedlings and adult plants as well. They found that the disease can also affect the siliquae causing a severe reduction in the amount and the quality of head or seed produced. The cabbage crop can be affected in all stages of its growth. Lesions caused by *A. brassicae* tend to be more circular and develop a tan center as they mature unlike *A.brassicicola* which has typical black spots lesions. Under moist conditions, lesions may develop a sooty black mass of spores. A violet to tan or black spots may develop on seed pods.

Economic impact and importance of alternaria blight of cabbage

Alternaria blight causes leaf spotting, pre-mature defoliation and curd deterioration in cabbage. It has been proved to cause as high as 80 % decrease in seed yield. Valkonen and Koponen (2006) reported that the disease can cause yield losses as high as 50 % by reducing both quality and quantity of the total production. *Alternaria brassicicola* has been reported to cause economic losses in crucifers in several different ways including seeding, vegetative and reproductive stages (Valkonen & Koponen, 2006). *Alternaria brassicae* on the other hand infect the plant at all growth stages. Often lesions are produced on green leaves and during severe attack, pods seeds become shrivel causing early ripening or shattering. The effect of Alternaria on seed are in twofold namely, pre- and post-emergence damping-off leading to stem cankers of the survivors and by affecting the quantity and quality of harvested seeds. On

mature plants, the spots on the head and or outer leaves are significant and this reduces market price as well as the shelf life.

Management of alternaria blight of cabbage

Heavy losses incited yearly by *Alternaria brassicae and brassicicola* on the vegetable Brassicaceae have prompted my search for sources of NPK fertilizer nutrition and the use of salicylic acid against the resultant disease, dark leaf spot. Prevention is key in controlling all diseases affecting crucifers. Some of the controls can be cultural, chemical or combination of them.

Cultural control can be done before planting, during growth and after harvest. It can be achieved through the use of disease-free seeds, practicing proper crop rotation and treating cabbage seeds with hot water at 50 ˚C for 25-30 minutes to minimize the disease incidence after which they are then dried. Chemical control of Alternaria blight is achieved through the application of fungicides. This practice however, increase input cost and also causes environmental pollution. Iprodione has been used as a seed treatment with Captan or thiram as alternatives. In the field, fungicides used against Alternaria leaf spot include chlorothalonil, copper formulations, mancozeb, iprodione and members of the strobilurin group. Many bioagents and or their metabolites have been also studied for their ability to reduce the growth, sporulation, spore germination and toxin production of Alternaria species affecting cabbage and other brassicas, subsequently reducing leaf spot disease.

Different works have been done to estimate the effect of different fungicides concentrations on leaf spot disease of cabbage and other brassica plants as seed treatment or as foliar spraying. Hossain and Mian (2004)

applied four fungicides namely; Rovral 50 WP (Iprodione), Dithane M45 (Mancozeb), Bavistin 70 WP (Carbendazim) and Tilt 250 EC (Propiconazole). They were tested alone or in different combinations to test their efficiency against cabbage Alternaria blight caused by *Alternaria brassicicola*. They found that all the tested fungicides reduced the disease severity and increased seed yield as well as yield components in a field trial. Ayub, Dey, Jahan, Ahmed and Alam (1997) also evaluated four fungicides namely, knowin, Ridomil-MZ 72WP, LirotectM and Rovral 50WP against Alternaria blight of cauliflower *(Alternaria brassicae, Alternaria brassicicola*) in a field experiment. Among the four fungicides tested, Rovral was effective against alternaria blight and maximized seed yield. Pichard and Thouvenot (1999) isolated a strain of Bacillus polymyxa [Paenibacillus polymyxa] and BP1 from cauliflower seeds. It was indicated that the strain has the potential as a biological control agent against Alternaria brassicicola when it was applied to infested seeds.

Role of Nutrition in Controlling Alternaria Blight of Cabbage

There are several factors that can affect the severity of plant disease such as mineral nutrients, seeding date, crop rotation, mulching, organic amendments (manures and green manures), liming for pH adjustment, tillage and seedbed preparation and irrigation (Huber & Graham, 1999). Nutrients are needed for growth and development of plants and microorganisms and are important factors in disease control (Agrios, 2005). All the essential nutrients can affect disease severity. It is thus vital to make them available through the application of fertilizers or alter the soil ecosystem to influence its

availability. In that way, plant diseases are controlled in an integrated pest management system (Huber & Graham, 1999). However, there is no general rule as a particular nutrient can minimize the severity of a disease and maximize the severity of the disease incidence of other diseases or have a completely opposite effect in a different environment (Marschner 1995).

Despite the fact that the importance of nutrients in disease control has been recognized for some of the most severe diseases, the correct management of nutrients in order to control disease in sustainable agriculture has received little attention. Nutrients can affect disease resistance or tolerance (Graham & Webb, 1991). Mineral nutrition does so by affecting plant resistance or susceptibility to pathogens and pests which affects its yield and quality. Agrios (2005) added that though plant disease resistance and tolerance are controlled genetically, the environment and especially the deficiencies and toxicities of soil nutrients do count (Krauss, 1999).

In order to complement disease and pest control methods, it is helpful to know how mineral nutrients affect disease resistance in plants. Altering how plants respond to pest or disease attacks can increase resistance. There are two primary resistance mechanisms that mineral nutrition can affect. One is the formation of mechanical barriers, primarily through the development of thicker cell walls and the synthesis of natural defense compounds such as phytoalexins, antioxidants and flavanoids that provide protection against pathogens.

Öborn et al. (2003) noted that the severances of many diseases can be minimized or controlled using mineral fertilizers coupled with cultural practices by impacting on the pathogen development in its environment. This

is accomplished by the level of nutrients used, the type of nutrient and rate of application and lastly by the form of the mineral nutrient. The level of nutrient used can influence the plant growth and the microclimate by affecting infection and sporulation of the pathogen (Marschner, 1995). Also, the level of nutrients can affect the physiology, biochemistry and particularly the integrity of the cell walls membrane leakage and the chemical composition of the host. For instance, B deficiency can affect the phenolic concentration (Graham & Webb, 1991). Relating mineral nutrient to fungal diseases of which *Alternaria* is one of them, the rates of mineral nutrient have direct influence on the amount of leakage and the composition of what is leaked when thinner weaker cell walls leak nutrients from within the cell to the apoplast (the space between plant cells). This leakage can produce a fertile habitat that triggers the germination of fungal spores on leaf and root surfaces.

The type of mineral nutrient and rate of application have great impact on the controlling of plant diseases. An unreasonable application of nitrogen can cause higher amounts of amino acids and other N-containing compounds in plant tissues. These imbalances in mineral reduce fungal diseases resistance by creating a more conducive environment for pathogens since N is a key component of amino acids (Graham & Webb, 1991). Plant tissues contain and produce a variety of defense compounds which hinder fungal attacks. Boron plays a key role in the synthesis of these compounds. Borate-complexing compounds trigger the enhanced formation of a number of plants defense chemicals at the site of infection. The level of these substances and their fungi static effect also decreases when N supply is too high. Mineral nutrition also affects the formation of mechanical barriers in plant tissue. As leaves ages, the

accumulation of silicon (Si) in the cell walls helps form a protective physical barrier to fungal penetration. Excessively high N levels lower the Si content and increase susceptibility to fungal diseases (Huber & Graham, 1999). Though the above literatures suggest that higher rates of nitrogen triggers pathogen infections and this is only true for diseases caused by obligate parasites such as *Puccinia graminis* and *Erysiphe graminis* and not that caused by facultative parasites such as *Alternaria, Fusarium and Xanthomonas spp*.

Role of nitrogen in controlling alternaria blight of cabbage

When a plant is infected by a pathogen, its physiology is impaired especially nutrient uptake, assimilation, translocation from the root to the shoot and utilization (Marschner, 1995). There are pathogens that can immobilize nutrients in the rhizosphere, the soil surrounding plant roots or in infected tissues such as roots. Others interfere with translocation or utilization efficiency and can cause nutrient deficiency or hyper accumulation and nutrient toxicity (Huber & Graham, 1999). Also, other organisms can utilize a significant amount of nutrients for their growth causing a reduction in the availability of nutrients for the plant and increasing its susceptibility due to nutrient deficiency. One of the most common symptoms of many soil borne pathogens is root infection which reduces the ability of the root to provide the plant with water and nutrients (Huber & Graham, 1999). This effect is more serious when the levels of nutrients are marginal and also for immobile nutrients.

Nitrogen is the most important nutrient for plant growth and there is an extensive literature about the effect of N on diseases because its role in disease resistance is quite easily demonstrated (Marschner, 1995). Despite the fact that N is one of the most important nutrients for plant growth and disease development, there are several reports on the effect of N on disease development that are inconsistent and contradict each other. The real causes of this inconsistency are poorly understood Hoffland, Jeger & van Beusichem, 2000). These differences may be due to the form of N nutrition of the host, the type of pathogen i.e. obligate vs. facultative parasites or the developmental stage of N application. Also, there are no systematic and thorough studies about the effect of N supply on disease resistance on bio control agents' activity and especially on the interaction among nutrient, pathogen, and bio control organisms (Tziros, Dordas, Tzavella-Klonari & Lagopodi, 2006).

In relating these differences to the type of pathogen, when there is high N supply there is an increase in severity of the infection for obligate parasites such as *Puccinia graminis* and *Erysiphe graminis*. However, when the disease is caused by facultative parasites like *Alternaria, Fusarium and Xanthomonas spp.*, high N supply decreases the severity of the infection. The situation is more complex for soil borne pathogens as on the root surface, there are many more microorganisms than in the bulk soil. Also, there is competition between and repression of different microorganisms and there are chemical barriers such as high concentration of polyphenols in the rhizodermis and physical barriers such as silicon depositions on the endodermis (Huber, 1980).

Role of phosphorus in controlling alternaria blight of cabbage

Phosphorus, is the second most commonly applied nutrient in most crops and is part of many organic molecules of the cell (deoxyribonucleic acid (DNA), ribonucleic acid (RNA), adenosine triphosphate (ATP) and phospholipids). Phosphorus is needed in many metabolic processes in the plant and pathogen. However, its role in resistance is variable and seemingly inconsistent. Huber and Graham (1999) noted that phosphorus has been most beneficial when it is applied to control seedlings and fungal diseases where vigorous root development permits plants to escape disease. Numerous researches have shown that phosphorus application can reduce bacterial leaf blight in rice, downy mildew and blue mold, leaf curl virus disease in tobacco, pod and stem blight in soybean, yellow dwarf virus disease in barley, brown stripe disease in sugarcane and blast disease in rice (Potash & Phosphate Institute, 1988). Foliar application of phosphorus can also induce local and systemic protection against powdery mildew in cucumber, roses, wine grapes, mango and nectarines (Reuveni & Reuveni, 1998). However, in other studies, application of P may increase the severity of diseases caused by *Sclerotinia* in many garden plants, *Bremia* in lettuce and flag smut in wheat (Huber, 1980).

Role of potassium in controlling alternaria blight of cabbage

Potassium, as stated by Huber and Graham (1999) can minimize the susceptibility of host plants up to an optimal level for growth, beyond this point, there is no further increase in resistance which can be achieved by increasing the supply of potassium and its contents in plants. The high susceptibility of the K-deficient plant to parasitic disease is due to the

metabolic functions of K in plant physiology. Under K deficiency, synthesis of high-molecular weight compounds (proteins, starch and cellulose) is impaired and there is an accumulation of low-molecular weight organic compounds. Also, potassium may boost the development of thicker outer walls in epidermal cells thus avoiding disease attack. Potassium can also influence plant metabolism as K-deficient plants have impaired protein synthesis and accumulate simple N compounds such as amides which are used by invading plant pathogens. Tissue hardening and stomatal opening patterns are closely related to infestation intensity (Marschner, 1995).

The balance between N and K affects disease susceptibility to plants. Application of K can decrease helminthosporium leaf blight severity and increase grain yields in wheat (Sharma, Duveiller, Basnet, Karki & Sharma, 2005). It has been shown that K fertilization can reduce the intensity of several infectious diseases of obligate and facultative parasites. Example is light gray lesions with a dark border in sugar beet (*Beta vulgaris*) leaves caused by *Cercospora beticola.* It has been observed that K reduces the incidence of various diseases such as bacterial leaf blight, sheath blight, stem rot, sesamum leaf spot in rice, black rust in wheat, sugary disease in sorghum, bacterial leaf blight in cotton, cercospora leaf spot in cassava, tikka leaf spot in peanut, red rust in tea, cercospora leaf spot in mungbean and seedling rot caused by *Rhizoctonia solani* (Sharma, Duveiller, Basnet, Karki & Sharma, 2005).

Role of Salicylic Acid in Controlling Alternaria Blight of Cabbage

Plants have developed many layers of defense response in the face of attack by microorganisms that serve as a threat to their existence. Resistance to pathogen infection can be induced in plants by a wide range of biotic and abiotic agents (Lyon, 2007). Diwaker, Gaurav and Dhirendra (2010) made known that any interaction of plants with phytopathogens is brought about by the generation of various chemical molecules that are absolutely necessary for the activation of their defense machinery. One of these chemicals, salicylic acid (SA) induces systemic acquired resistance (SAR) in plants. The activation of SAR provides a broad-spectrum resistance against a wide range of related or unrelated pathogens. This resulting resistance tends to be broad-spectrum and can be long-lasting but is rarely complete with most inducing agents reducing disease by between 20 and 85%. This induced resistance is a host response thus its expression under field conditions is likely to be influenced by a number of factors such as the environment, genotype, crop nutrition and the extent to which plants are already induced (Dale, Walters, Jaan & Neil, 2013). Walters and Fountaine (2009) also recorded that treatment of plants with various agents including cell wall fragments, plant extracts and synthetic chemicals can induce resistance to subsequent pathogen attack both locally and systemically but Kuc (1982) reported that such induced resistance rarely leads to total pathogen control instead, a reduction in lesion size and or number.

Soil Properties Influencing Cabbage Yield, Quality and Alternaria Blight

Friend, (1992) noted that the soil is one of the primary and important factors influencing plant growth. Kuncoro et al. (2014) also emphasized that a soil is described healthy when it possesses enough air, water, minerals and organic particles. Thus, soil quality alters due to variations of it components and this can be done by measuring its physical, chemical and biological properties (Stamatiadis, Werner & Buchanan, 1999). Also, most root disease outbreak involving soil fungi is brought about by the interplay between fungal growth and the spatial and temporal heterogeneity of the soil environment. Colonization or infection of a root occurs at fine scales with growth and movement of fungal mycelia through soil. Sturz, Carter and Johnston (1997) made known that there are correlations between the outcome of pandemic observed in the field and specific soil properties (such as soil structure, organic matter, moisture, pH, etc.), soil microbial composition or agronomic practices such as continuous cropping, crop rotations or tillage operations.

Soil physical properties influencing cabbage yield, quality and alternaria blight

The soil physical properties which are made of soil structure, texture, porosity and moisture content can be affected by its constituent and component (Doran & Zeiss, 2000). The amount and movement of air, nutrients, porosity and water determines soil temperature, soil texture and structure. McCauley, Jones and Jacobsen (2005) observed that the changes in the soil organic matter drive many of the other changes in soil physical properties. Soil compaction decreases macro porosity and eventually leads to

increase bulk density. Compaction can decrease the plant nutrients specifically nitrogen uptake which may affect the cell wall portions of some plant made of cellulose and lignin (Pettigrew, 2008). Soil temperature and moisture impact significant increase in the breakdown of lignin and cellulose (Thangarajan, Bolan, Tian, Naidu & Kunhikrishnan, 2013). Fageria and Moreira (2011) also observed a curvilinear relationship between the breakdown of cellulose and soil moisture. When moisture increased up from 40 to 60 %, cellulose degradation increased significantly in a curvilinear trend and at higher moisture content. Tuomela, Vikman, Hatakka & Itävaara (2000) determined that the thermophilic phase is fundamental for faster lingo cellulose degradation with increasing temperatures.

In relating plant diseases to the soil physical properties, soil structure had been recorded to have a profound effect on microorganisms/ alternaria by Young and Ritz (2000) when disrupted. Alabouvette, Hoeper, Lemanceau and Steinberg (1996) reported that soils with an unstable soil structure (such as silty soils) compact more easily and are less aerated and generally wetter. These conditions induce diseases caused by Phytophthora spp. or Verticillium. It can also heighten epidemics such as common root rot in peas, crown and root rots in a crop rotation in spring barley and soybean and cereal root rot in humid climates (Sturz, Carter & Johnston, 1997). Abawi and Widmer (2000) stated that soil borne diseases is much intense in soils whose drainage is inadequate, has a poor soil structure, very compacted, low organic matter and soil fertility. Moreover, biopores together with differences in soil physical properties linked with structural heterogeneity such as the availability of water and oxygen, contribute further to the variability in the fungal environment.

Soil chemical properties influencing cabbage yield, quality and alternaria blight

The soil chemical properties comprise of solid, liquid and gas, soluble and insoluble and organic and inorganic substances. The organic groups compose of the decomposition of plant and animal whilst the inorganic are made of N, NH_3, Fe, Ca, Al, etc. elements (Salehi & Maleki, 2012). Li et al. (2013) established that these chemical properties of the soil such as nutrient contents, pH, and salinity can be defined as the presence of the major components dissolved in organic solutes in the soil. These constituents influence soil formation and crop production (Bradl, 2004). Also, cation exchange is a good tool for knowing the type of soil texture. Broders et al. (2009) unveiled that hydrogen ion concentration (pH), Ca, Mg and cation exchange capacity which are components of the soil chemical properties were the primary factors influencing the composition of Pythium in the soil and the severity of disease caused by Pythium.

Nutrient which is one of the chemical properties of the soil was noted by Salehi and Maleki (2012) to have improve plant growth, soil structure and water penetration. Blanchart et al. (2004) also stated that plant nutrient boost soil biological activity, restrain erosion and avoid surface sealing, it is thus an essential element for plants growth, yield and disease control. Wright (1998) also observed that plant nutrition may also play a role in Alternaria leaf spot control. A low rate of nitrogen fertilization resulted in greater lesion area for potato early blight caused by *Alternaria solani* than a high nitrogen rate (MacDonald, Peters, Coffin & Lacroix, 2007). Magnesium has been noted to play a vital role in plant physiology because it is a constituent of chlorophyll.

It also aids in the adsorption and translocation of phosphorus and together with potassium ensures cellular turgidity Mauro (2016). Its effects on plant disease has been known through mineral amendment by comparing Mg concentrations in resistant and susceptible cultivars, concentrations in diseased and healthy cultivars, or correlating conditions affecting Mg availability with disease severity (Jones & Huber, 2007).

The chemical composition within a plant's environs can be ascertained by measuring the pH level present within the soil. Soil's pH level was known to be directly related to its electrical conductivity level Valdes, Miralles, Franco, Sánchez-Blanco & Bañón, 2014). Soil pH is recorded to ease the decomposition of organic matter which intend maximize the presence of phosphorus, manganese and calcium available to plants in the soil. Bradl, (2004) made known that pH value is an indicator of nutrient cycling. As pH increases, the adsorption of minerals follows same trend. Boix-Fayos, Calvo-Cases, Imeson & Soriano-Soto (2001) also stated that soil pH influences the soil physical properties. The higher the pH value, the larger the aggregation of soil particle. Munns and Tester (2008) observed that salinity affected plant growth by controlling the CO_2 absorption rate, slowing plant growth and by this way, minimizing agricultural yield (Amouei, 2013).

The cation exchange capacity of a soil measures the surface electric charge of soil components (Charlet & Schlegel, 1999). The processes of exchange which occur in the soil have a determining impact on the availability of those elements which are adsorbed under cationic form (Ca, Mg, Na and K). A good CEC and appropriate cation balance within the system are vital factors for the chemical fertility of the soil (Mauro, 2016).

Cation exchange was noted to have a positive correlation with organic matter (Bradl, 2004).

The healthier the soil, the more likely a plant will thrive and grow. The electrical conductivity of soil is one of the ways of checking how healthy or suitable the soil and its environment will be for plants growth and quality (Laishram, Saxena, Maikhuri & Rao, 2012). Electrical conductivity actually takes place inside the pores that reside in between soil particles. Because of that, the EC levels can differ based on the soil density and chemical compositions. As different plants require different types of soil physical, biological and chemical properties, knowing a soil's electric conductivity level can aid to measure the essential soil environment for plants. Soil's pH level is directly related to its electrical conductivity level (Valdes, Miralles, Franco, Sánchez-Blanco & Bañón, 2014).

Soil biological properties influencing cabbage yield, quality and alternaria blight

Soils are various systems consisting of highly different microhabitats which form complex organisation of plants in soil microbial communities (Stevnbak et al., 2012). Soil biological properties consist of complex community of microorganisms such as bacteria, fungi, viruses and nematodes with varieties of abiotic constituents. This soil biological properties have a vital role in plant growth and development (Tripathi, Raikhy & Kumar, 2019). Fungi supports soil functions as a plant nutrient source and also impact on plant growth and nutrients uptake. It was also known to have an effect on soil productivity and plant health (Nadeem, Ahmad, Zahir, Javaid & Ashraf,

2014). Nematode and protozoa on the other hand improve plant growth and nitrogen uptake thereby affecting bacterial populations and maximizing the evolution of CO_2 (Reardon et al., 2013). They were also known to increase nitrogen and potassium mineralization (Stevnbak et al., 2012) and substrate utilization and decrease the leaching of phosphate. Moreover, bacteria were confirmed to aid in ecosystem functioning (King, Farrer, Suding & Schmidt, 2012) by providing nutrients for plants, cycling of soil nutrients and organic matter decomposition thereby improving soil health and promoting plant growth (Altieri, 2004). Earthworm was also established to maximize the amount of extractable nitrogen, nutrient availability to plant (Jusselme, Miambi, Mora, Diouf & Rouland-Lefèvre, 2013) thus modifying plant growth and vegetation structure. King, Farrer, Suding and Schmidt (2012) made known that these soil organisms play key role in nutrient transformations but Rønn et al. (2002) reported that though these organisms aid in plant growth, some can also trigger plant diseases.

Soil microbial as presented by Sturz, Carter and Johnston (1997) also had an impact on the incidence of Alternaria. Huber and Graham (1999) decreed that there are pathogens that can immobilize nutrients in the rhizosphere, the soil surrounding plant roots or in infected tissues such as roots, while others interfere with translocation or utilization efficiency and can cause nutrient deficiency or hyper accumulation and nutrient toxicity.

Other Factors Influencing Cabbage Yield, Quality and Alternaria Blight

As a rule, the physical, chemical and morphological properties of the plant species are quite distinct and this may be due to the fluctuation in soil,

climate and few other factors (McGrath, Spargo & Penn, 2014). This effect in one way or another involved the physiological and morphological properties of the plant (cabbage).

Climatic factors

Larcher (2003) observed that climatic elements such as rainfall, sunlight, temperature and humidity and carbon dioxide concentration impact greatly on soil quality and plant growth. Furthermore, climate have greater influence on soil salinity, structure, formation and fertility. Climate was known to determine the type of plant that grows based on the quantity of light, temperature and moisture (Banwart, 2011). This is so because plants are highly sensitive to climate.

Stage of growth and age of plant

Harvesting age is an essential factor that could affect cabbage yield, quality and susceptibility to Alternaria. Sinha, Rai and Sinha (2002) revealed that, disease intensity of cabbage increased with the increasing plant age from 21-71 days old plants while inoculum from cultures 15-35 days was more virulent than older inoculum. Cabbage has nutritive and luxuriant nature which draws a lot of insect pests at various stages of the plant growth (Ninsin, 1997).

Soil management or cultural practices

Ping, Green, Bronson, Zartman and Dobermann (2004) emphasized that there were other factors such as management practices, early stress with subsequent recovery, higher N fertility and different tillage or rotation systems

that may contributes to crop growth, yield and quality. There were other management practices that were noted to also impact on plant growth, quality and yield. For instance, date of planting, green manure crops, irrigation and insect damage (Pettigrew, 2002). Cultural practices such as continuous cropping, water and weed managements etc. adopted had impact on Alternaria disease resistance and tolerance (Sturz, Carter & Johnston, 1997).

Effects of Drought on Cabbage Yield, Quality and Alternaria Blight

Agricultural plants for that reason cabbage, are confronted with uninterrupted war against an array of pathogens and unfavorable environmental constituents which restricts their yield potentials and have been responsible for most devastating famines around the globe (Kumar et al., (2015). Solomon, Manning, Marquis and Qin (2007) recorded that climate change has a latent influence on agriculture which include lower yields in warmer regions due to heat stress, damage to crops by pathogens, soil erosion and inability to cultivate land caused by heavy precipitation events and land degradation resulting from increasing drought.

Grover and Pental, (2003) observed that cabbage cultivation has been hindered by several biotic (diseases, pests etc.) and abiotic factors such as drought, temperature, rainfall, etc. Among biotic stress, one of the main constraints affecting the productivity of crops especially mustard and cabbage is *Alternaria* leaf spot disease caused by *Alternaria brassicae* (Meena, Awasthi, Chattopadhyay, Kolte & Kumar, 2010). Also, drought is one of the key abiotic factors affecting agriculture production by inducing a set of physiological and biochemical reactions in plants. It is thought to curb plant

growth and yield (Khan et al., 2017) and has an effect on an approximately 40 % of the world's available land.

Under drought situations, the photosynthetic rate is decreased as stomatal closure increases due to increasing abscisic acid (ABA) in plant cells, membrane damage and this disturbed activity of various enzymes (Farooq, Hussain, Wahid & Siddique, 2012). Water stress further assists the formation of reactive oxygen species such as hydrogen peroxide (H_2O_2) as stated by Das and Uprety, (2006). Another indicator of membrane damage is the increase of malondialdehyde (MDA) amount, the last product of lipid peroxidation in membranes. Samancıoğlu et al. (2016) recorded that drought leads to lipid peroxidation measured by MDA in plant tissues. Abiotic stress imposed by either drought or salinity also brings about severe growth retardation in many plants. Cabbage, *Brassica oleracea var. capitata* is one of the important vegetable crops contributing to human nutrition and it can be considered as sensitive or moderately tolerant to abiotic stress conditions such as drought. Most of the plants are subject to drought challenges in arid regions (Sahin et al., 2018)

Drought also causes tip burn in cabbage, a non-pathogenic disorder worldwide (Chiang, Chong, Landry & Crete, 1993) This disorder is characterized by necrosis on leaf-margins, edges or tips of cabbage, Brussels sprouts and cauliflower (Guerena, 2006). Brown spots which develop have the tendency to break down during transport and in storage, thereby rendering entry to opportunistic decay causing organisms. It is noted to be caused by deficiency in calcium, rapid growth due to excessive nitrogen, high temperature and water stress. Though tip burn is believed to be a related

disorder caused by localized Ca deficiency of leaves or leaf margins, Saure (1998) however established it to be a stress related disorder. Furthermore, drought conditions and its impact on crops/cabbage diseases varies. In some instances, it will impact on a disease by making the environment more or less conducive for infection, disease development and or disease distribution. In other instances, it may not have effect upon the pathogen at all but may aggravate the damage caused by disease in drought-stressed plants. Though the impact of drought on disease differs, certain diseases of some crops tend to be consistently more or less severe in drought conditions (Sam, Khan, Secor, Gulya and Lamey (2008). They further recorded that drought effects on leaf spots pathogen (Alternaria blight), Oomycete root rots of all crops, Ascochyta blight of pulse crops were less. Meanwhile, very severe or greater cases on fungal root rots causing wilt on many crops, charcoal rot in soybeans, corn etc. and no effects on Rhizoctonia stem canker of potato and Sclerotinia wilt of sunflower. In other diseases like powdery mildew, rusts of most crops, drought may cause different effects under different conditions.

Chapter Summary

Cabbage growth parameters, yield, quality and Alternaria diseases are mostly affected by the soil, climate and cultural practices adapted in its cultivation. Therefore, the nutritional, physiological and morphological characteristics and requirements of the cabbage crop and other processes that boost the crop resistance to diseases, improve yield and quality should be adopted.

CHAPTER THREE

RESEARCH METHODS

This chapter gives a summary of how the project was organized, the research design adopted, the study area and population, the sampling procedures, data collected, instruments and equipment used, materials and processes or procedures used and the type of laboratory analysis undertaken, etc.

Study Area

The experiment was conducted at Adarkabrunso/Adeito located at the western part of the Bosome Freho District, situated within Latitude 6° 00'N and 6° 26'N Longitudes 1° 00 W and 1˚30 W of the Ashanti Region of Ghana. It is characterized by a double maximum rainfall pattern. The major season starts from March to July while the minor season from September to November with annual mean rainfall between 1,600 mm and 1,800 mm. It has fairly high and uniform temperature, ranging between 20°C to 32° C and relative humidity which is fairly moderate but high during the rainy season, ranging between 70 and 80 % (Ghana Statistical Service, 2010). The soils of the study area fall within the Bekwai-Nzima/Oda compound association with a clearly defined topographical sequence. On the summits, upper and middle slopes are found red, well drained (Bekwai series) and brown moderately well drained (Nzima series) in situ developed concretionary silty clay loams. Soils on the middle to lower slopes are made up of brown to yellow brown imperfectly drained silty clays and silty clay loams (Kokofu series) developed from colluvium or hill wash material. The valley bottoms were characterized

by grey poorly drained alluvial loamy sands (Temang series) and clays (Oda series), (Adu, 1992). Because the land has clearly defined topographical sequence, the field experiment was done at the lower slope which has characteristics of Kokofu series with imperfectly to moderately well drain drainage. It has a parent material of colluvial light clay derived from phyllite which is classified as eutric/dystric nitisol with a light vegetation of shrubs and grass particularly spear grass because of continuous cropping.

Population

Apart from cocoa, rice and the staple crops (plantain, maize, cassava and cocoyam), cabbage is the most grown vegetable crop in the Bosome Freho District in the Ashanti region of Ghana. It can be grown in almost all the four (4) zones in the District with the Morontuo zone representing the highest population of about 1/6th of farmers who are into its production (Department of Agriculture, Bosome Freho, 2018). Adarkabrunso/Adeito stretch represent about 60 % of the farmers in the Morontuo zone who are into cabbage production and their livelihood depends solely on it. About 90% of the farmers are mainly males and 5% females with the remaining 5% youth or women supporting in the transplanting, fetching of water, weeding and especially harvesting and carting of the proceeds.

The cabbage is mainly grown on raised beds, mounts and on the flats. Fertilizers used were mainly inorganic with NPK, ammonia and urea dominating in the order. Land is mostly rented, forcing them to do continuous cropping for a longer period of time which has instigated build-up of diseases precisely, Alternaria blight. The farmers were in the age range of twenty-five

(25) to sixty-five (65) years and are mainly middle school, junior and senior high school leavers with very few farmers attaining tertiary education. The growing of cabbage has been their main source of income and have been used to sponsor their wards education for some to become medical doctor and others outside Ghana according to a questionnaire administered prior to the starting of the field experiment. Other essentials are met using the income gotten from the growing of cabbage.

Research Design

The experimental design used was Randomized Complete Block Design (RCBD) with dimension of 6 m x 3 m per bed; inter row distance of 2m and intra row distance of 1 m. The treatments were denoted as follows: NPK (0-0-0) (control), NPK (30-60-60), NPK (60-60-60), NPK (90-60-60), NPK (90-60-60) + 0.25 mM and NPK (90-60-60) + 0.5 mM SA where N denotes nitrogen (N), P represents phosphorus, K stands for potassium and SA for salicylic acid as shown in Table 1.

Table 1 - *Field Layout*

REP 1	REP 2	REP 3
NPK (30-60-60) kg/ha	NPK (90-60-60) kg/ha	NPK (90-60-60) kg/ha + 0.25 mM SA
NPK (60-60-60) kg/ha	NPK (90-60-60) kg/ha + 0.25 mM SA	NPK (0-0-0) kg/ha
NPK (90-60-60) kg/ha	NPK (30-60-60) kg/ha	NPK (60-60-60) kg/ha
NPK (90-60-60) kg/ha + 0.25 mM SA	NPK (90-60-60) kg/ha + 0.5 mM SA	NPK (90-60-60) kg/ha
NPK (90-60-60) kg/ha + 0.5 mM SA	NPK (0-0-0) kg/ha	NPK (30-60-60) kg/ha
NPK (0-0-0) kg/ha	NPK (60-60-60) kg/ha	NPK (90-60-60) kg/ha + 0.5 mM SA

Source: Field data (2019)

Organisation

This project was organised by first administering questionnaires to cabbage farmers in Adeito/ Adarkabrunso in the Bosome Freho District in the Ashanti Region of Ghana to know major challenges confronting them in the cultivation of cabbage. Site was selected with a loamy texture of 48 % sand, 44 % silt and 8 % clay. The soil and water pH were 5.15 and 6.78 respectively. Initial soil major chemical characteristics were N (0.13 %), P (7.57 mg/kg), K (0.3 cmol/kg) OC (1.56 %), OM (1.99 %), Ca (3.62 cmol/kg), Mg (2.34 cmol/kg), Na (0.24 cmol/kg), TEB (6.50 cmol/kg), Ex. Acidity (0.95 cmol/kg), ECEC (7.45 cmolc/kg) and a % Base Saturation of (87.24 %). A recommended cabbage seed (oxylus) was obtained and treated with dress force, a chemical used to treat seeds before planted in the nursery on raised beds. The seedlings were transplanted to the field after forty (40) days of establishment. Twenty-four (24) plots were made with a 6 m×3 m dimensions. An in ter and intra row space of 2 m and 1m was obtained between each plot. Planting distance was 60 cm ×60 cm i.e. 50 plants per bed. Six (6) treatments were administered with four (4) replications and this was done randomly. A balanced fertilizer comprising of NPK 15:15:15 and single fertilizers of urea, muriate of potash and triple supper phosphate were obtained. Also, salicylic acid (SA) with concentrations of 0.25 mM and 0.5 mM were used against the optimum NPK rate. The following were the treatments; NPK (0-0-0) kg/ha, NPK (30-60-60) kg/ha, NPK (60-60-60) kg/ha, NPK (90-60-60) kg/ha, NPK (90-60-60) kg/ha + 0.25 mM SA and NPK (90-60-60) kg/ha + 0.5 mM SA. These treatments were further subjected to same insecticides control (Agoo), watering and weeding, harvesting etc.

Data were collected on leaf length and width (leaf area) on same day before treatments applications and recorded. Leaf area was further recorded weekly for four weeks after transplanting to access the effects of fertilizer and SA application on cabbage leaves. Number of leaves per plant and per plot cum treatment was counted and number of leaves infested with blight disease and pests also recorded. Cabbage leaves which were able to fold and or unfold were also counted and recorded during the cabbage crop establishment. Circumference of heads and fresh weights were harvested excluding the border rows to estimate the yield. Physical appearance/visual observation and grading was done on the various treatments to know which treatment stood tall in terms of quality (disease and pest free) and recorded. Two harvested cabbage samples from each treatment were sent to the laboratory to test for % N, P, Ca, Mg and K nutrients. Post-harvest soil test was also done to know how much fertilizer (nutrient) was consumed by the plants and how much was left in the soil or leached out. Analysis were done using Genstat statistical package to know which treatment was best to improve yield, quality and also suppress Alternaria blight of cabbage.

Cultural Practices

Land preparation

The experimental field was cleared on 19th January, 2019 using cutlass and demarcated into plots using a measuring tape, pegs and garden lines on 31st January, 2019.

Nursery bed preparation

Ten (10) raised beds of about 10 cm high and 2 m × 1 m dimension were prepared and watered on 16th February, 2019. A Bypel insecticide was sprinkled on the beds to cater for all insects pests. Oxylus cabbage seeds from James agro chemical shop (central market-Kumasi) was obtained and treated with dress force, a chemical use for seed treatment. The seeds were spread evenly on the prepared beds. A little water was sprinkled and palm front/branches placed on the beds after planting to prevent excessive heat and to cool the soil. Another watering was done on the third day of planting, 19th February, 2019. Palm fronts were removed on the 5th day of planting, 21st February, 2019 to allow enough sunlight for germination. A first weeding was done using Agil which is a selective weedicide to control weeds thus preventing diseases and pests and also aiding aeration on the nursery bed. Snail pests were picked and destroyed as and when they were seen.

Permanent bed preparation

This was done on 22nd March, 2019 using mattock, pick axe, hoe and cutlass. Site was demarcated into plots using a measuring tape, pegs, garden lines and ropes. Treatments were assigned to the plots randomly. There were 24 plots with a 6 m×3 m dimensions and a planting distance of 60 cm ×60 cm making 50 plants per bed with six (6) treatments and four (4) replications.

Planting

Planting was done on 16th February, 2019. The seeds of cabbage were sown on a raised bed. Healthy seedlings were then transplanted in rows to the

field after 40 days of establishment (28th March, 2019) with bowl of soil to prevent poor root establishment with a plant spacing of 60 cm × 60 cm. They were then watered immediately to prevent shock.

Fertilizer and salicylic acid application

A balanced fertilizer comprising NPK 15:15:15 and single fertilizers of urea, muriate of potash and triple supper phosphate were obtained and calculated to get the various rates of mineral nitrogen, phosphorus and potassium. Salicylic acid with the following concentrations, 0.25 mM and 0.5 mM were used against the optimum NPK rates. These treatments were administered two weeks after transplanting. Salicylic acid and fertilizer applications were calculated as follows;

Summary on salicylic acid rates applied

Salicylic acid 0.25 mM SA = $\frac{500\ ml}{4\ plots} = \frac{125\ ml}{50\ plants}$ = 2.5 ml /plant

0.5 mM SA = $\frac{1000\ ml}{4\ plots} = \frac{250\ ml}{50\ plants}$ = 5 ml/plant.

Summary on fertilizer rates applied

N30---360 g / plot (7.2 g / plant) NPK

P60---360 g NPK and 90 g TSP /plot i.e. 7.2 g NPK plant and 1.8 g TSP / plant

K60---360 g NPK and 117.4 g Muriate of Potash /plot i.e. 7.2 g NPK and 2.348 g K/plant

N60---360 g NPK and 117.4 g Urea /plot i.e. 7.2 g NPK and 2.348 g Urea/plant

N90---360 g NPK and 234.8 Urea / plot i.e. 7.2 g NPK and 4.696 g Urea/plant

Calculations for NPK 30

If 15 kg NPK/ha = 100 kg, then 30 = x = $\frac{3000}{15}$ = 200 kg/ha (4 bags)

Therefore if 10,000 m^2 =200 kg, then 18 m^2 = x kg = $\frac{18 \times 200}{10,000}$ = 0.36 kg or 360 g/ plot (7.2 g/ plant)

Calculations for Urea 30

If 46 kg N/ha = 100 kg, then 30 kg N/ha = U1 = $\frac{(30 \times 100)}{46}$ = 65.2174 kg/ha

Therefore if 10,000 m^2 = 65.2174 kg/ha, then 18 m^2—U1 kg/ha = $\frac{18 \times 65.2174\ kg/ha}{10,000}$ =0.11739 kg (117.4 g/ plot) or 2.348 g /plant

Calculations for Urea 60

46 Kg N/ha=100 kg, then 60 Kg N/ha—U2 = $\frac{(60 \times 100)}{46}$=130.434 kg/ha

Therefore if 10,000 m^2=130.434 kg/ha then, 18 m^2=U2 kg/ha = $\frac{18 \times 130.434 kg/ha}{10,000}$ = 0.2348 kg (234.8 g/ plot) or 4.695 g/plant

Calculations for Muriate of Potash 30

46 kg K_20/ha = 100 kg and, 30 kg K_20/ha = M kg = $\frac{30 \times 100}{46}$ = 65.2174 kg/ha

Therefore if 10,000 m^2 = 65.2174 kg/ha then, 18 m^2 = M kg/ha = $\frac{18 \times 65.2174\ kg/ha}{10,000}$ = 0.11739 kg K_20 (117.4g K_20/ plot) or 2.3478/plant

Calculations for Triple Super Phosphate 30

60 kg P_20_5/ha = 100 kg and 30 kg P_20_5/ ha = T = $\frac{30}{60} \times 100$ = 50 kg/ha

Therefore if 10,000 m^2 = 50 kg/ha then, 18 m^2 = T = $\frac{18 \text{ X } 50 \text{ kg/ha}}{10,000}$ = 0.09 kg

P_2O_5/ plot =90 g TSP /plot or 1.80 g/plant.

Weed control

Weeds were controlled manually. Weeding was done three times. First weeding was done a week after transplanting i.e. 1st April, 2019 prior to administration of treatments. A second one was carried out five (5) weeks after transplanting (29th April, 2019) and a final one eight (8) weeks after transplanting prior to harvesting (13th May, 2019).

Pest control

Pest were controlled using Bypel, two lids (20 ml) per knapsack on the nursery bed and Agoo insecticide (one sachet to a knapsack) on 18th May, 2019 i.e. 53 days after transplanting when signs of pests were seen and snails' pests were handpicked.

Harvesting

Harvesting was done at physiological maturity. Weighing was done using a weighing scale. The figures were recorded in kilograms and the heads finally kept in sacks to facilitate carting and transport. The harvested produce was sorted to know the treatment with the highest quality in terms of appearance, size and weight.

Sampling Procedure

Samples of soil were taken by going diagonal and randomly on the experimental site. Soils from the top to a depth of 15cm were collected and mixed thoroughly and portion bagged in an air tight plastic rubbers and sent to CSIR/SRI laboratory for analysis at Kumasi/Kwadaso in the Ashanti Region of Ghana. Water sample was collected using a 1.5 litre bottle and fetched all particles in the stream for chemical analysis. Two harvested cabbage each from the various treatment were picked randomly after harvesting by eliminating the borders and measuring 3m in between the borders and 3 plants on the column. These were sent to the laboratory via ice chess with ice block to prevent discoloration and deterioration.

Data Collection Procedure

Data were taken on the following parameters: number of leaves per plant on a plot for each treatment, leaf area at week 5^{th} to 8^{th} week after transplanting, number of leaves infested with cabbage blight, number of folded and unfolded leaves, number of leaves infested with pests, fresh weight after harvest and circumference of harvested heads.

Number of leaves

This was done by counting the number of leaves of all plants on a particular treatment at week 5, 6, 7, and 8 after transplanting and the mean number recorded.

Leaf area

The leaf area was taken from 5th to 8th week after transplanting. The leaf area was calculated by measuring the length and breadth of three (3) different leaves taken at the base, middle and the upper portion of three plants from the five sampled plants per plot using the non-destructive prediction models for estimation of leaf area (Yeshitila & Taye, 2016) which is; Leaf area (cm^2) = -260.265 + 27.115 (L (cm) * W (cm)) for cabbage Where L, W, are leaf length, leaf maximum width respectively.

Number of leaves infested with cabbage blight

This was achieved by counting the number of leaves infested as soon as Alternaria blight sets in on each treatment. First sign of Alternaria was on 14th May, 2019 i.e. 35 days or 5 weeks after administering of treatments or 7 weeks after transplanting.

Number of folded and unfolded leaves

This was achieved when the cabbage plants reached the folding stage, 28th May, 2019, i.e. 7 weeks after administering of treatments or 9 weeks after transplanting. This was done weekly afterwards. Leaves that were folded and those who could not fold even after reaching physiological maturity were also counted and recorded.

Number of leaves infested with pests

Leaves which were damaged due to insects pests like diamond backmoth (DBM), snails, grasshoppers, etc. were counted and recorded on

each treatment plot immediately they were noticed. This was experienced on 14th May, 2019 i.e. 5 weeks after administering treatments or 7 weeks after transplanting. This recording was done also at the 8th week.

Fresh weight

The head yield was determined by harvesting 12 heads from selected crops per plot as describe at physiological maturity. The cabbage heads were weighed using a mechanical weighing scale and the reading recorded in kilograms which were later converted to tonnes per hectare.

Circumference of harvested heads

This was done after harvest by measuring the circumference of 12 selected crops per plots of the six treatments whose fresh weights were taken during harvesting using a rope and a ruler.

Soil Chemical Analysis

Soil samples collection and parameters studied

Initial and final soils were taken from a depth of (0-15) cm for each plot with an auger. They were air dried and sent to CSIR/SRI laboratory-Kwadaso for analysis. Parameters analysed included soil texture, pH of soil, OC, OM, N, P, K, Ca, Mg, Na, TEB, Exchangeable Acidity, % Base saturation and ECEC.

Preparation of samples

Moist soil samples from the field were air dried in wooden and enamelled trays for three days. During drying, the trays were numbered and a plastic tag attached to differentiate the various treatments. After drying, the samples were taken to the preparation room. The air-dried samples were grounded with a wooden pestle and mortar so that the soil aggregate is crushed but the soil particles do not break down. After grinding, the entire soil samples from the various treatments were screened through a 2 mm aluminium or plastic sieve except for concretions and pebbles of more than 2 mm. The coarse portions on the sieve were again returned to the mortar for further grinding. This procedure was repeated until all aggregate particles were fine enough to pass through the sieve and only pebbles, organic residues and concretions remained. This process prevented the introduction of a positive bias in the sample as the rejected part may include soil elements with differential fertility. The grounded sample were again mixed thoroughly after passing through the sieve and stored in cardboard boxes in wooden drawers.

Soil texture determination (Bouyoucos 1962)

The hydrometer method was used in this experiment, using 10 % Calgon (15.9g of anhydrous sodium Carbonate and 71.4g of Sodium Hexametaphosphate in l) as dispersing agent. The particle size distribution classes refer to I.S.S.S standards: sand (2 – 0.02 mm); silt (0.02 – 0.002 mm); and clay (< 0.002 mm).

Twenty-five (25) grams of soil were placed in a 250 ml plastic bottle and 10 ml of Calgon and 100 ml of water added. The suspensions were

agitated overnight using mechanical shaker at 120 r.p.m (revolutions per minute). The samples in the bottles were then transferred into 500 ml cylinders and the volume made up to 500 ml. Each cylinder was hand-agitated for 1 minute. Hydrometer readings started 15 minutes later. Each reading was increased by 0.5 to account for meniscus. A second reading was taken 16 hours later. A blank reading was also recorded. The first reading provides the sum of clay and silt (C + S). The second reading was for clay only. Calculations were performed as follows

First hydrometer reading (Clay + Silt) + B1 (blank) 1.5

Second hydrometer reading (Clay) + B2 (blank) 1.5.

Clay % = (2nd read. + Blank 2) × 2, Silt = [(1st read. + B1) – (2^{nd} read. + B2)] x 2

Sand % = ((oven dry soil mass)-(Rsand –RC1))/ (oven dry soil mass) x 100

Clay % = (Rclay-RC2)/ (oven dry soil mass) x 100

Silt % =100- (sand % + clay %)

Soil pH determination

Soil pH was measured with a pH-meter in a 1:2.5 soil/water suspension with distilled water using buffer solutions of pH 4.0, 7.0, 10.0 as reagents. A 10 grams soil from each treatment was placed in a 50 ml plastic beaker together with 25 ml of distilled water and mixed with a glass rod. The soil samples were left for some time and stirred for an hour after which readings were taken. The soil pH reaction was measured after calibrating the instrument with the buffered solutions.

Organic carbon and organic matter

A 1.0 g soil from each treatment was weighed and placed in a 250 ml Erlenmeyer flask. Then, under a fume hood, 10 ml of potassium dichromate was added. The flask was then swirled for the dichromate to wet the soil samples. A 20 ml of concentrated sulphuric acid was added to the samples. The samples were allowed to cool for 3 hours. A 100 ml of deionized water, 10 mls of ortho phosphoric acid with 1 ml of diphenylamine indicator were titrated with 1.0 *N* ferrous sulphate.

A blank reading was determined by titrating 10 ml of dichromate and 20 ml of sulphuric acid with 1.0 *N* ferrous sulphate.

The results were expressed as % organic carbon or as % organic matter.

$$\text{O. C \%} = \frac{(b-a)\text{x } N \text{ x } f \text{ x } (0.39)}{W}$$

Where b = ml of ferrous sulphate used for the blank, a = ml of Mohr's salt used for the sample, N = normality of Mohr's salt, F = normality correction factor and W = weight of the sample $0.39 = 3\times10^{-3} \times 100\ \% \times 1.3$ where 3 is equivalent weight of carbon.

Organic matter (OM) % = O. C. x 1.724.

Total nitrogen determination by kjeldahl

Reagents were concentrated H_2SO_4 (d 1.84), 40% NaOH in water, 0.1 *N* H_2SO_4, 0.1*N* NaOH, mixed indicator: methyl red – blue methylene, 0.1 g of methyl red and 0.05 g of blue methylene dissolved in 100 ml of alcohol (stored in a dark bottle). Digestion was done by using 0.5 g of soil sieved at 2 mm from each treatment which were weighed and put in a digester tube. A tea spoon of copper sulfate pentahydrate and 10 ml of concentrated H_2SO_4 each

were added to the soil in the digestion tube. It was then placed in a digestion block which had been set to a temperature of 420 ^{0}C for a period of 3 hours. A Pale straw colour was obtained after digestion. The sample was left to cool. Distillation was made by using 25 ml of 0.1 *N* H_2SO_4 which was put in a 500 ml Erlenmeyer flask and 200 ml of distilled water and 2-3 drops of mixed indicator were added to each treatment. The Erlenmeyer flask on the distiller was checked to know whether the end of the condensation pipe is covered by the acid. After the distillation, the Erlenmeyer flask with 0.1M NaOH were titrated until the final colour changed from red to green.

Calculation:

$$N\ \% = \frac{(25-a)\ x\ 14}{W(g)}\ x\ 100$$

Where: 25 = ml of 0.1 *N* H_2SO_4 used in the beaker, a = ml of 0.1 NaOH used in the titration, W = weight of the soil in grams, 14 = molecular weight of nitrogen and the results were given to three decimal points.

Available phosphorus determination by Bray and Kurtz's method no.1

A 5g of soil from each treatment were weighed and placed in a 100 ml plastic bottle. A 50 ml of extracting solution were added to each and agitated for 10 minutes in the horizontal shaker. The solutions were filtered and centrifuged to get an adequate amount of extract. A 5 ml of extract were collected with a pipette and placed in test tubes. A 10 ml of colour reagent was added with a pinch of ascorbic acid. The absorbance were measured on the spectrophotometer at 660 nm (lower sensitivity) using the blank as reference. The concentration of phosphorus in the extract was determined

using the calibration curve and then related to the phosphorus in the soil using the following formula:

P (ppm/soil) = abs × 7.603 × $\frac{50}{W(g)}$ x f

Where: W (g) = weight of the sample in grams, f = dilution factor.

Extraction ratio is 50, Equation for gradient of graph is 7.603.

Exchangeable cations (Ca, Mg, K, Na)

Acetic acid (98%), 25% ammonium hydroxide were used as reagents and extracting solutions were 575 ml of acetic acid (98%) and 750 ml of 25% ammonium hydroxide which were made up to 10 litre and pH adjusted to 7.0 ±0.2**.** A 2.5g of soil of the various treatments were placed in 100 ml plastic bottle. Fifty (50) ml of extracting solution was added to each treatment sample and agitated for 1 hour at 160 r.p.m. The extracts then filtered into a test tube. The four macro elements were determined on 1:25 dilution of the extract. Calculations were done by considering a 1:20 extraction ratio (2.5g and 50 ml) and a 1:25 dilution, the following coefficients were obtained:

Potassium meq/100 g = readingin ppm x 1.28, Magnesium meq/100 g = reading in ppm x 4.11, Sodium meq/100 g = reading in ppm x 2.17, Calcium meq/100 g = reading in ppm x 2.50. Where;

1.28 is extraction ratio × dilution ratio/equivalent weight of potassium×10

4.11 is extraction ratio × dilution ratio/equivalent weight of magnesium ×10

2.17 is extraction ratio × dilution ratio/equivalent weight of sodium×10

2.50 is extraction ratio × dilution ratio/equivalent weight of Calsium×10

Exchangeable acidity

A 10 g of soil from each treatment was placed in a 250 ml plastic bottle and a 100 ml of 1 *N* Potassium chloride was added and agitated for an hour. The extract was filtered in an Erlenmeyer flask. Titration of exchangeable acidity was done by transferring 50 ml of filtrate into a beaker and the phenolphthalein indicator added. This was titrated with NaOH until a persistent pink colour was reached. Calculations was made.

Determination of effective cation exchange capacity (ECEC)

ECEC was calculated by summing the exchangeable cations i.e. exchangeable bases and exchangeable acidity.

ECEC (me/100g) = exch. Ca^{2+} + K^{+} + exch. Mg^{2+} + exch. Na^{+} + exch. Acidity.

Cabbage nutrient analysis after harvest

Two harvested samples from each treatment were sent to the laboratory to test for major nutrients like N, P, K, Ca and Mg using same procedure as the soil analysis procedure after the cabbage leaves were chopped and dried.

CHAPTER FOUR

RESULTS AND DISCUSSION

Effects of NPK Fertilizer and Salicylic Acid Treatment on Growth, Yield and Quality Parameters of Cababage

Leaf area

There were significant differences ($p<0.001$) between the treatments with respect to leaf area (Figure 1). Interaction effect however, was not significant ($P=0.308$). Leaf area increased sharply from 5th week after transplanting to 7th week. It also increased steadily from 7th to 8th week. Application of NPK at 60-60-60 kg/ha gave the highest leaf area at week eight (8) followed by those treated with NPK (90-60-60) kg/ha + 0.25 mM SA, NPK (90-60-60) kg/ha + 0.5 mM SA, NPK (90-60-60) kg /ha, NPK (30-60-60) kg/ha and NPK (0-0-0).

Cabbage plots treated with adequate nitrogen (NPK (60-60-60) kg/ha, NPK (90-60-60) kg/ha + 0.25 mM SA and NPK (90-60-60) kg/ha + 0.5 mM SA) produced the best leaf area index of 6.847m^2, 6.584m^2 and 6.414m^2 respectively confirming what Salehi and Maleki, (2012) established. Salehi and Maleki noted that soil nutrients improve plant growth, soil structure and water penetration. Plots treated with higher nitrogen rates gave the highest LA, further confirming the report of Brady (1990) that adequate nitrogen promotes vigorous vegetative growth and also very vital in the formation of chlorophyll and a component of proteins. Nitrogen also affect the production of carbohydrates (Burns et al., 2013) since it is a constituent of the chlorophyll molecule and plays a key role in all metabolic activities of plants thus affecting plant growth and other growth parameters like leaf area. This is

also in line with Hossain, Haque, Abuyusuf, Riad & Iqbal Hussain (2011) who recorded high response of cabbage to nitrogen.

The application of salicylic acid had greater influence on cabbage growth such as leaf area. This might be the cause of higher leaf area on cabbage plots treated with NPK (90-60-60) kg/ha + 0.25 mM SA and NPK (90-60-60) kg/ha + 0.5 mM SA compared to NPK (90-60-60) kg/ha without salicylic acid. This outcome agrees with Fariduddin, Hayat and Ahmad (2003) who stated that salicylic acid aids in stomata movement, photosynthesis and several physiological processes including plant growth (Khan, Prithiviraj & Smith, 2003) since leaf area influences photosynthesis, hence the growth and development of cabbage.

Cabbage plots with no treatment (control) gave the least leaf area. This is because nutrients are needed for growth and development of plants and aid in the activities of microorganisms (Agrios, 2005) which helped to speed the growing processes by working on the soil environment. Plant nutrient were noted by Blanchart et al. (2004) to boost soil biological activity, restrain soil erosion and avoid surface sealing. It is thus an essential element for plants growth, yield and disease control, the more reason the growth of plants on no treatments plots NPK (0-0-0) kg/ha growth was retarded (3.355 m^2) at week 8.

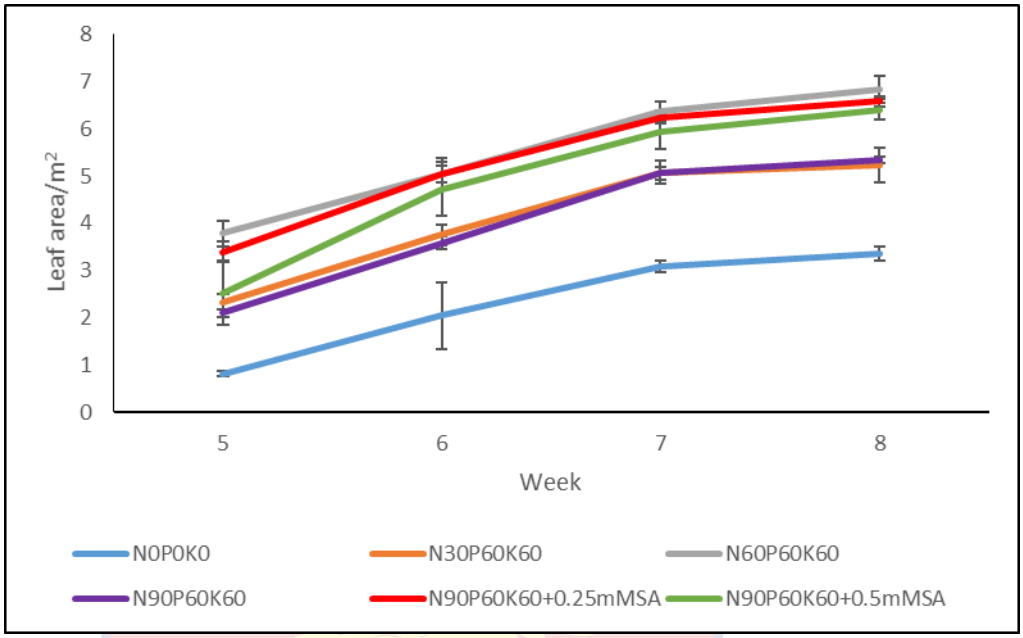

Figure 1: Leaf area as affected under various fertilizer and salicylic acid rates applications. Error Bars represents standard error of difference.

Leaf number

Leaf number was highly significant ($p<0.001$) between the treatments across the period (Figure 2). Number of leaves in each treatment increased steadily from week five to eight after administering treatments. Cabbage plots treated with NPK (60-60-60) kg/ha gave the highest leaf number at week eight (8) followed by those treated with NPK (90-60-60) kg/ha, NPK (90-60-60) kg/ha + 0.5 mM SA, NPK (90-60-60) kg/ha + 0.25 mM SA, NPK (0-0-0) and NPK (30-60-60) kg/ha. These differences in leaf number of the various treatments may be due to the different rates of nutrients applied.

Furthermore, the various rates of nitrogen application impacted significantly on the leaf number because nitrogen is known to influence vegetative growth in plants upon application. Nitrogen was observed by Burns et al. (2013) to affect the production of carbohydrates since it is a constituent of the chlorophyll molecule and play a key role in all metabolic activities of

plants. Thus, by affecting plant growth, nitrogen also influences cabbage growth and number of leaves produced as well.

Also, there was a sharp increase in the number of leaves of the various treatments from week 5-6 after transplanting or 3-4 weeks after treatment application. It can therefore be deduced that cabbage crop makes effective use of nutrients in its early stages of growth because root development was vigorous at this period.

NPK at 60-60-60 kg/ha maintained the highest leaf numbers throughout the four weeks under study. It can therefore be concluded that equal application rates between nitrogen, phosphorus and potassium fertilizer was needed to increase leaf production in cabbage. The higher the leaf number, the higher the absorption of sunlight, hence increase in photosynthesis and carbohydrates assimilation. This support Kumar and Rawat (2002) claim that to improve cabbage production, some factors such as application of adequate fertilizers and disease control methods should be provided.

Also, higher rates of nitrogen application had superior outcome in terms of leaf number over lower rates as inn (Figure 2*)*, treatments with higher N rates (NPK (90-60-60) kg/ha, NPK (90-60-60) kg/ha + 0.5mM SA and NPK (90-60-60) kg/ha + 0.25 mM SA) had initial leaf numbers of 12.45 (5^{th}), 12. 85 (4^{th}) and 13.712 (3^{rd}) respectively at week 5 but came out to be 19.775 (2^{nd}), 19.75 (3rd) and 19.65 (4th) respectively at week 8. This means higher NPK rates are needed to increase cabbage leaf.

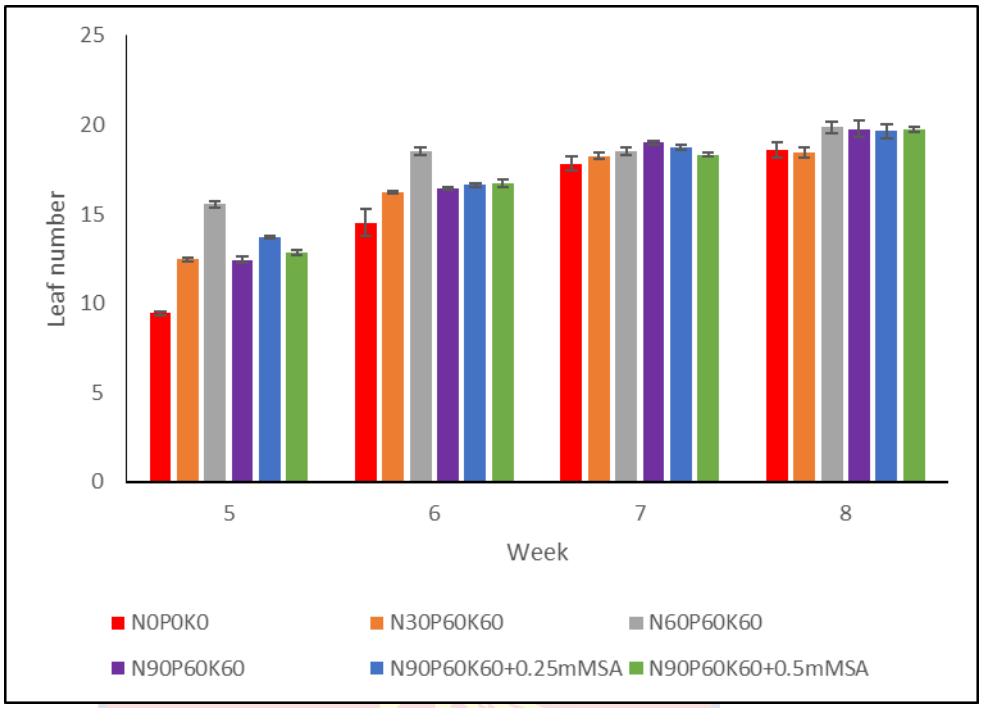

Figure 2: Leaf number as affected under various fertilizer and salicylic acid rates applications. Error Bars represents standard error of difference.

Rates of salicylic acid application must be considered in dealing with cabbage leaf number as treatment with the highest salicylic acid rates application emerged best compare to the lower rate. Treatment NPK (90-60-60) kg/ha + 0.5mM SA was third best at week 5 (12.85) but came out better off than NPK (90-60-60) kg/ha + 0.25 mM SA at week 8 (19.75). Treatment NPK (90-60-60) kg/ha + 0.25 mM SA was 13.712 and 19.65 at week 5 and 8 respectively.

Pests infestation

Pest infestation was not significant ($p=0.981$) under fertilizer and salicylic acid applications, (Figure 3). This shows that the application of salicylic acid and mineral fertilizer did not have significant effects on controlling pest infestation on cabbage fields. These results disagree with

Huber and Watson, (1974) who stated that among the many options to control pests could be a consistent use of mineral fertilizer and salicylic acid. Other factors such as drought and rainfall should be considered as pests were noted after six (6) days period of drought with two (2) days heavy rainfall and another five (5) days of drought. When rainfall was adequate, the incidence of pests and disease minimized. The increase in number of leaves infested with pests on cabbage plots treated with NPK (90-60-60) kg/ha + 0.5 mM SA, NPK (90-60-60) kg/ha and NPK (90-60-60) kg/ha + 0.25 mM SA in week eight may be due to their nutritive and luxuriant nature. This is because cabbage plants draw a lot of insect pests at various stages of the plant growth. Failure to manage insect pests could result in total crop failure (Ninsin, 1997). Also, from the study, insect pest and blight infestation cycles were related as they were both noticed on same day.

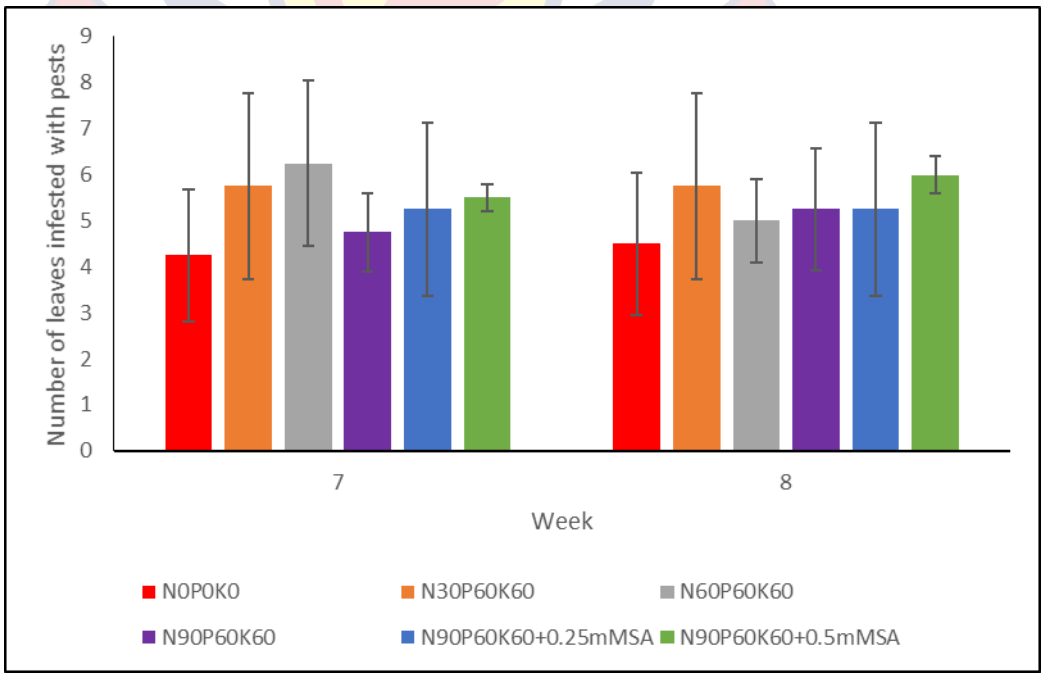

Figure 3: Number of leaves infested with pests under various fertilizer and salicylic acid rates. Error Bars represents standard error of difference.

Blight infestation

Blight infestation on cabbage leaves was not significantly influenced (*p=0.352*) upon fertilizer and salicylic acid applications (Figure 4). This outcome agrees with Meah, Hau and Siddiqua (2002) who concluded that Alternaria blight remains an increasing threat to *Brassicaceae* crops throughout the world and it is one of the major biotic problems which limits cabbage cultivation, quality and shelf life. This is because most Alternaria species are saprophytes and ubiquitous in the environment of which some are plant pathogenic stimulating diseases on a wide variety of economically important crops (Pitt & Hocking, 1997). This was noticed as all treatments were affected.

Though the various treatments were not significant from each other, it can however be deduced that nutrients and its rates of application contributed to cabbage level of resistance or tolerance to Alternaria. Cabbage responses to Alternaria intensity on the various treatments vary depending on the different rates of mineral nitrogen and SA applications. This is in line with Marschner (1995) and Krauss (1999) who stated that though plant disease resistance and tolerance are controlled genetically, they were also affected environmentally and especially by the deficiencies and toxicities of soil nutrients. Zhao et al. (2013) recorded that cotton (*Gossypium hirsutum*) plants with a low rate of nitrogen fertilization resulted in greater lesion area for potato early blight caused by *Alternaria solani* than a high nitrogen rate (MacDonald, Peters, Coffin & Lacroix, 2007). This can be the reason why treatment NPK (90-60-60) kg/ha and NPK (90-60-60) kg/ha + 0.5 Mm SA stood tall in terms of Alternaria blight tolerance than the other treatments.

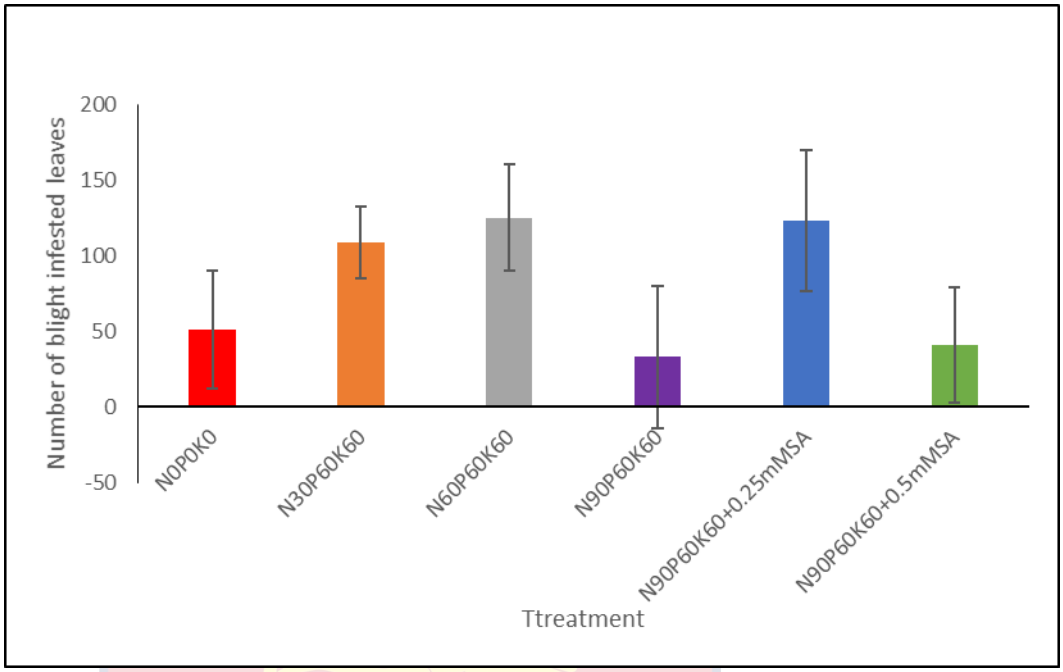

Figure 4: Level of blight infestation under various fertilizer and salicylic acid rates. Error Bars represent standard error of difference.

Huber and Graham (1999) reported that all the essential nutrients can affect disease severity. It is thus vital to make them available through the application of fertilizers or alter the soil ecosystem to influence its availability and in that way, plant diseases are controlled in an integrated pest management system. This may be the key reason why all treatments were affected since the essential nutrients were not adequate as Shika and Doug, (2001) recommended. They exclaimed that optimally, cabbage requires 60 – 85 kg N ha $^{-1}$, 68-80 kg P_2O_5 ha $^{-1}$ and 30-90 kg K_2O ha $^{-1}$. The rates of application for the study were 30-90 kg N ha^{-1}, 60 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}. From this it can be concluded that higher rates of phosphorus and potassium are also vital to prevent plant diseases especially Alternaria blight.

Also, the rate of application of salicylic acid should be taken into accounts in dealing with Alternaria blight resistance as treatment NPK (90-60-60) kg/ha + 0.5 mM SA and NPK (90-60-60) kg/ha + 0.25 mM SA showed

different outcomes interms of blight infestation. This phenomenom further explains what Dale, Walters, Jaan and Neil (2013) reported, that induced resistance is a host response thus its expression under field conditions is likely to be influenced by a number of factors such as the environment, genotype, crop nutrition and the extent to which plants are already induced. Resistance tends to be broad-spectrum and can be long-lasting but is rarely complete with most inducing agents reducing disease between 20 and 85%.

Öborn et al. (2003) stated that the severe ness of many diseases can be minimized or controlled using mineral fertilizers coupled with cultural practices by impacting on the pathogen development in its environment. Cultural practices such as continuous cropping, water and weed managements etc. adopted had impact on cabbage resistance and tolerance to Alternaria disease. Mac, Keifer and Ayer (1999) found that fungus can survive in infested crucifer debris in the soil or on cruciferous weeds and that the chlamydospores or microsclerotia serve as the resting spores on the particular sites for survival from year to year. The site for the field experiment has be cultivated repeatedly and so it is believed the fungi were in the crop debris and soil. The main reason why all treatments were affected.

Also cabbage production requires water management particularly in the dry season. Alternaria blight was noted after six (6) days period of drought with two (2) days heavy rainfall and another five (5) days of drought (Appendix 1 and Figure 5 &6). When rainfall was adequate, the incidence of disease minimized. Shortage of water leads to drought with obvious agricultural and societal impacts (Morrison, Baker, Mullineaux & Davies, 2007). Inability to supply sufficient water during the dry season would result

in total cabbage crop failure. Drought conditions and its influence on crops diseases were taught to vary. In some instances, it will impact on a disease by making the environment more or less conducive for infection, disease development and or disease distribution whilst in other cases, it may not have effect upon the pathogen at all but may aggravate the damage caused by disease in drought-stressed plants. Sam, Khan, Secor, Gulya and Lamey (2008) established that drought effects on leaf spots pathogen (Alternaria blight) of all crops were less. This was not so in my findings as the drought rather triggered the Alternaria blight making all treatments more susceptible. They also noted that many foliar pathogens (fungal/bacteria) were able to infect plants only when leaves were wet and that in drought situations, a lack of free moisture may occur on the leaves which reduces the pathogens' ability to infect plants but this was the opposite.

The Alternaria blight effects on cabbage minimizing after rainfall can attest that, tip burn which is a non-pathogenic disorder was also recorded which is characterized by necrosis on leaf-margins, edges or tips of cabbage. Guerena (2006) believed that to be Ca-related disorder caused by localized Ca deficiency of leaves or leaf margins, but Saure (1998) established it to be a stress related disorder.

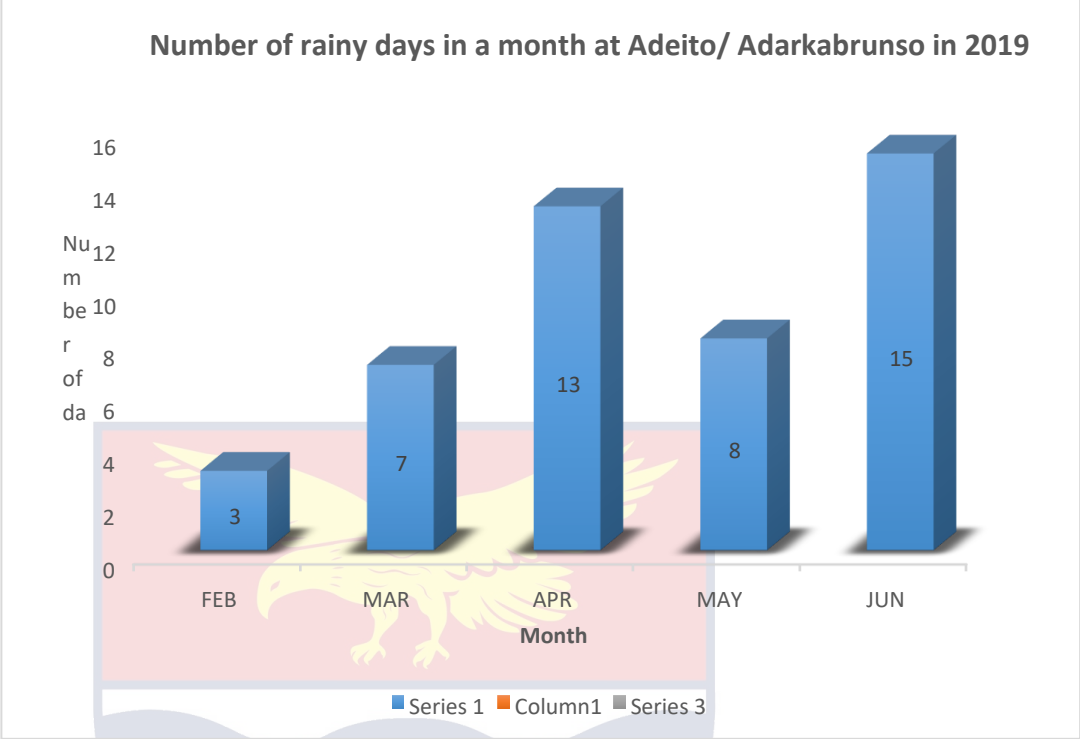

Figure 5: Number of rainy days in a month from Feb-June, 2019 at Adeito/Adarkabrunso.

Source: Adarkabrunso, Bosome Freho District/ A/R.

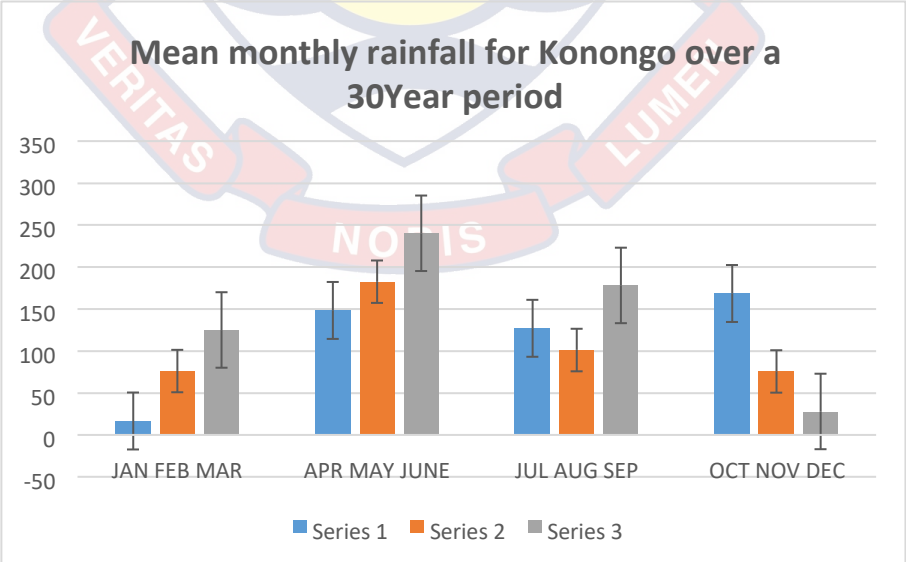

Figure 6: Mean monthly rainfall for Konongo over 30 years period.

The stage of plant growth had influence on the incidence of Alternaria. The disease incidence occurred prior to leaves folding stage and this confirms what Sinha, Rai, & Sinha (2002) revealed. Disease intensity increased with the increasing plant age from 21-71 days old plants. Also, it can also be due to the nutritive and luxuriant nature of cabbage plants which draw a lot of insect pests at various stages of the plant growth. Failure to manage insect pests could result in total crop failure (Ninsin, 1997) and cabbage plants are luxuriant during the leaf folding stage.

Table 2 - Soil Chemical Analysis before Planting

$pH_{(1:2.5)}$	O.C (%)	N (%)	Ca^{2+} ($cmol_{(+)}/kg$)	Mg^{2+} ($cmol_{(+)}/kg$)	K^{+} ($cmol_{(+)}/kg$)	Na^{+} ($cmol_{(+)}/kg$)
5.15	1.56	0.13	3.62	2.34	0.3	0.24

Source: Field data (2019)

Table 2 - *Continued*

T.E. B (cmol $_{(+)}$/kg)	Al^{3+} (cmol $_{(+)}$/kg)	ECEC ($cmol_{(+}$ $_{)}$/kg)	Base Sat. (%)	Avail. P(mg/ kg)	Sand (%)	Silt (%)	Clay (%)	Texture
6.5	0.95	7.45	87.24	7.57	48	44	8	Loam

Source: Field data (2019)

Table 3 - Chemical Analysis on Water Sample

Chemical analysis	$pH_{(1:2.5)}$	EC (µs/cm)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	K^{+} (mg/l)	Na^{+} (mg/l)	Avail. P (mg/l)
	6.78	410	72.14	25.28	-	-	0.47

Source: Field data (2019)

Table 4 - *Soil Chemical Analysis after Harvest*

Treatments	$pH_{(1:2.5)}$	O.C (%)	N (%)	Ca^{2+} ($cmol_{(+)}/kg$)	Mg^{2+} ($cmol_{(+)}/kg$)	K^{+} ($cmol_{(+)}/kg$)	Na^{+} ($cmol_{(+)}/kg$)	T.E. B ($cmol_{(+)}/kg$)
N0P0K0	5.9	1.6	0.1	5.86	2.66	0.34	0.3	9.16
N30P60K60	6.2	1.6	0.1	7.03	2.98	0.38	0.27	10.6
N60P60K60	6.1	1.6	0.1	7.03	2.77	0.39	0.26	10.4
N90P60K60	6.2	1.5	0.1	6.39	2.13	0.52	0.27	9.3
N90P60K60+0.25mMSA	6	1.5	0.1	5.96	2.45	0.31	0.26	8.98
N90P60K60+0.5mMSA	5.9	1.6	0.2	5.96	3.09	0.51	0.3	9.86

Source: Field data (2019)

Table 4 - *Continued*

Treatments	Al^{3+} ($cmol_{(+)}/kg$)	ECEC ($cmol_{(+)}/kg$)	Ca^{2+} ($cmol_{(+)}/kg$)	Mg^{2+} ($cmol_{(+)}/kg$)	Base Sat. (%)	Avail. P (mg/kg)
N0P0K0	0.3	9.46	5.86	2.66	96.8	16.4
N30P60K60	0.15	10.81	7.03	2.98	98.6	24.2
N60P60K60	0.15	10.6	7.03	2.77	98.5	27
N90P60K60	0.15	9.45	6.39	2.13	98.4	20.8
N90P60K60+0.25mMSA	0.2	9.18	5.96	2.45	97.8	25.6
N90P60K60+0.5mMSA	0.3	10.16	5.96	3.09	97	24.2

Source: Field data (2019)

Table 4 - *Continued*

Treatments	Sand (%)	Silt (%)	Clay (%)	Texture
N0P0K0	48	42	10	Loam
N30P60K60	58	32	10	Sandy loam
N60P60K60	44	44	12	Loam
N90P60K60	42	48	10	Loam
N90P60K60+0.25mMSA	46	44	10	Loam
N90P60K60+0.5mMSA	44	48	8	Loam

Source: Field data (2019)

Table 5 - *Nutrient Analysis of Harvested Cabbage Heads*

Treatments	% Ca	% Mg	% K	% P	% N
N60 P60 K60	0.80	0.67	1.52	0.66	2.96
N90 P60 K60	0.72	0.67	1.97	0.74	3.10
N90 P60 K60(0.25mM SA)	0.48	0.62	2.15	0.62	3.07
N30 P60 K60	0.48	0.48	1.36	0.53	2.37
N0 P0 K0	0.80	0.81	1.67	0.64	2.96
N90 P60 K60 (0.5mM SA)	0.72	0.66	2.04	0.78	3.46

Source: Field data (2019)

Circumference of harvested cabbage heads

Circumference of cabbage heads harvested was highly significant (*P<0.001*) under fertilizer and salicylic acid application (Figure 7). Circumference length were in the order NPK (90-60-60) kg/ha + 0.5 mM SA > NPK (90-60-60) kg/ha + 0.25 mM SA > NPK (30-60-60) kg/ha > NPK (90-60-60) kg/ha > NPK (60-60-60) > NPK (0-0-0) kg/ha.

The treatment NPK (90-60-60) kg/ha + 0.5mM SA and NPK (90-60-60) kg/ha + 0.25mM SA gave the widest circumference. This indicates that salicylic acid had significant effect on increasing cabbage heads size (circumference) as established by Raskin (1992). Salicylic acid has a regulatory role in a range of physiological processes such as photosynthesis, transpiration, nutrient uptake, and chlorophyll synthesis and plant development. Salicylic acid was further recognized as an important signaling molecule that potentially influences plant tolerance to water stress because of its influence on the regulation of metabolic and physiological activities during the entire lifespan of the plant, affecting its growth parameters and bio-productivity (Popova, Pancheva & Uzunova, 1997). Salicylic acid was reported by Hayat and Ahmad (2007) to play an important physiological role on growth and development of plants (Khan, Prithiviraj & Smith, 2003). Hayat and Ahmad (2007) further reported that SA plays key roles in flowers induction, nutrients uptake and ethylene biosynthesis. It has also been found to aid in stomatal movement, photosynthesis (Fariduddin, Hayat & Ahmad 2003) and several physiological processes including plant growth (Khan, Prithiviraj & Smith, 2003). The main reason why cabbage circumference increased under highest rate of nitrogen applications with salicylic acid (NPK

(90-60-60) kg/ha + 0.5 mM SA and NPK (90-60-60) kg/ha + 0.25 mM SA) and not the one without SA (NPK (90-60-60) kg/ha).

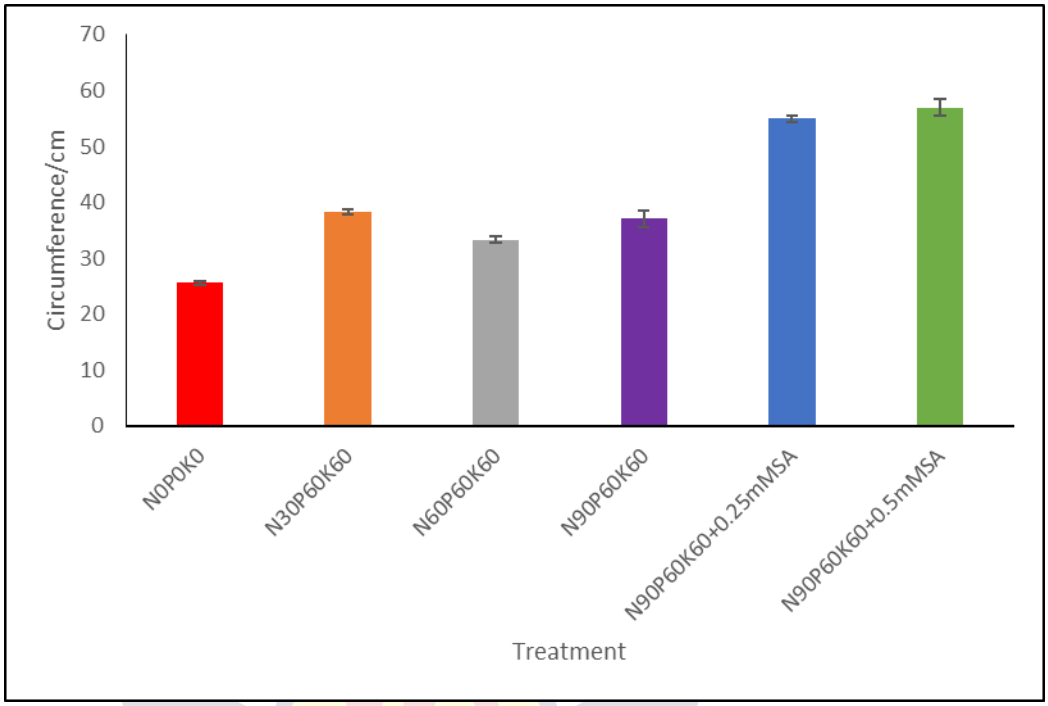

Figure 7: Circumference of cabbage heads after harvest as affected under various fertilizer and salicylic acid rates applications. Error Bars represents standard error of difference.

Moreover, Farooq, Basra, Wahid, Ahmad and Saleem (2009) found that rice leaves (*Oryza sativa* L.) treated with SA (100 mgL^{-1}) had a positive effect on photosynthesis and plant growth compared to other treatments of 50 and 150 mgL^{-1}. This induced better resistance to drought stress than soaking the seeds in the same SA solutions. This may be the reason why NPK (90-60-60) kg/ha + 0.5 mM SA performed better than NPK (90-60-60) kg/ha + 0.25 mMSA. This means that higher rate of application of N and SA is very necessary so far as circumference of cabbage is concern.

Fresh weight of harvested cabbage heads

The yields of harvested cabbage of all treatments were not significant (*P=0.342*) under the application of NPK fertilizer and salicylic acid (Figure 8). Fresh weights of cabbage were in the order: NPK (90-60-60) kg/ha + 0.5 mM SA and NPK (90-60-60) kg/ha > NPK (30-60-60) kg/ha > NPK (0-0-0) kg/ha > NPK (90-60-60) kg/ha + 0.25 mM SA and NPK (60-60-60) kg/ha. The highest yield were recorded on plots treated with the highest NPK and salicylic acid concentrations i.e. NPK (90-60-60) kg/ha + 0.5 mM SA and NPK (90-60-60) kg/ha. This agrees with the findings of Kumar and Rawat (2002) who noted that plant nutrients supply is inevitable in the production of cabbage and to improve its production (yield and quality), some factors such as application of adequate fertilizers and disease control methods should be provided. Hossain, Haque, Abuyusuf, Riad and Iqbal Hussain (2011) also established that nutrient supply is an important input for realizing higher cabbage yield and its nutrient content.

Also, it can be deduced from (Figure 8) that the rate of other soil amendment materials such as SA used influence cabbage yield. This is because, NPK (90-60-60) kg/ha + 0.5 mM SA treated plots were best compare to NPK (90-60-60) kg/ha + 0.25 mM SA treated plots though they possess same level of NPK.

From Table (4), treatment NPK (60-60-60) kg/ha possessed the highest soil available phosphorus (27.03 mg/kg), exchangeable Ca (7.03 cmol/kg) and soil OC (1.67 %), second highest in nitrogen (0.19%) and ECEC (10.60 cmolc/kg) values, third in Mg (2.77 cmol/kg) and also had a moderate potassium value (0.39 cmol/kg) yet recorded the highest disease incidence

(125) and lower yields (39.2 t/ha), (Figure 4) and (Figure 6) respectively. The lowest yield of treatment NPK (60-60-60) kg/ha is in connection with Marschner, (1995) who stated that when a plant is infected by a pathogen, its physiology is impaired especially nutrient uptake, assimilation, translocation from the root to the shoot and utilization. Also, spots caused by *Alternaria brassicicola* fused together on leaf thus minimizing the plant photosynthetic power as the disease advanced. The infection later occurred on the reproductive parts of the plant and caused considerable yield losses in cabbage (Doullah, Meah & Okazaki, 2006). This causes a severe reduction in the amount and the quality of head or seed produced. This shows that disease infestation and yield correlated positively.

Also, fungi were known to have an effect on soil productivity and plant health (Nadeem et al., 2014) thus the yield of cabbage. This was encountered on cabbage crop treated with NPK (60-60-60) kg/ha and NPK (90-60-60) kg/ha + 0.25 mM SA which had the highest Alternaria blight infestation of (125) and (123) respectively, the more reason for their lower yields compare to other treatments.

The similar yields of the various treatments may also be due to same nutrient component (NPK) and soil texture (loam) (Table 4) as established by Tiwari, Singh & Mal (2003) that yield and quality of cabbage were influenced by soil and nutrient status.

Grover and Pental (2003) also observed that cabbage cultivation has been hindered by several biotic (diseases, pests etc.) and abiotic factors such as drought, temperature, rainfall, etc. Among biotic stress, one of the main constraints affecting the productivity of crops especially mustard and cabbage

is *Alternaria* leaf spot disease (Meena, Awasthi, Chattopadhyay, Kolte & Kumar, 2010). Also, drought is one of the key abiotic factors affecting agriculture/ cabbage production by inducing a set of physiological and biochemical reactions in plants and thought to curb plant growth and yield (Khan et al., 2017). This scenario was true in this experiment as there was a severe drought compounded with intermittent heavy rains making all treatments not realizing their optimum yields.

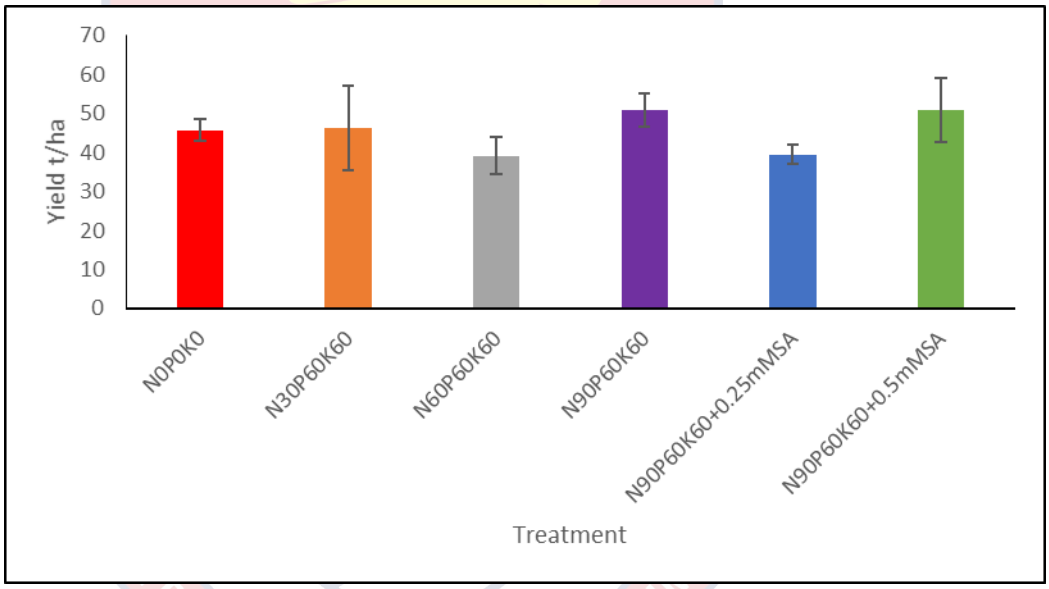

Figure 8: Fresh weights of cabbage heads (yield) after harvest as affected by NPK fertilizer and salicylic acid applications. Error Bars represents standard error of difference.

Number of folded and unfolded leaves

There was no significant difference *(p=0.306)* between the various fertilizer rates and salicylic acid application on number of folded leaves produced (Figure 9). Number of folded leaves increased from 9th to 12th week after transplanting. Number of folded leaves were in the order: NPK (90-60-60) kg/ha + 0.5 mM SA > NPK (90-60-60) kg/ha + 0.25 mM SA > NPK (0-0-

0) kg/ha > NPK (30-60-60) kg/ha > NPK (60-60-60) kg/ha > NPK (90-60-60) kg/ha, (Figure 9).

Salicylic acid played a key role in leaf folding of cabbage as treatments NPK (90-60-60) kg/ha + 0.5 mM SA and NPK (90-60-60) kg/ha + 0.25 mM SA were outstanding interms of number of folded leaves compare to treatment NPK (90-60-60) kg/ha though they were subjected to same NPK rates. This outcome agrees with the report of Khan, Prithiviraj and Smith (2003) that SA aids in physiological growth and development of plants and also help plants to tolerate abiotic stress (Janda et al., 2007) and higher temperatures (He et al., 2005).

Also, the highest number of folded leaves recorded in cabbage crops treated with NPK (90-60-60) kg/ha+0.5 mM SA compare to NPK (90-60-60) kg/ha+0.25 mM SA was due to the role of salicylic acid and its rate of application. Rate of SA applied to a crop was thought to have a correlation on photosynthesis and plant growth (Farooq, Basra, Wahid, Ahmad, & Saleem, 2009).

It can also be concluded that in terms of leaf folding in cabbage, lower levels of nitrogen are also necessary (Figure 9) as lower nitrogen rates (NPK (0-0-0) kg/ha and NPK (30-60-60) kg/ha) were outstanding to higher rates (NPK (60-60-60) kg/ha and NPK (90-60-60) kg/ha) without salicylic acid (Figure 9). Khan, Iqbal, Ahmad, Soomro and Chaudhary (2002) emphasized that cabbage needs nitrogen in optimum amounts but excessive amount of nitrogen may cause loose head formation and internal decay. That may be the reason why cabbage plots treated with NPK (60-60-60) kg/ha and NPK (90-60-60) kg/ha without SA had the least folded leaves levels. They further stated

that in some cases, if nitrogen is not adequate, it will not form heads. This statement however was not so for treatment NPK (0-0-0) kg/ha and NPK (30-60-60) kg/ha as though there was no nitrogen in one and the other had the lowest rate of nitrogen yet attained better leaf folding compared to those with optimum amount of nitrogen (NPK (60-60-60) kg/ha and NPK (90-60-60) kg/ha) without salicylic acid.

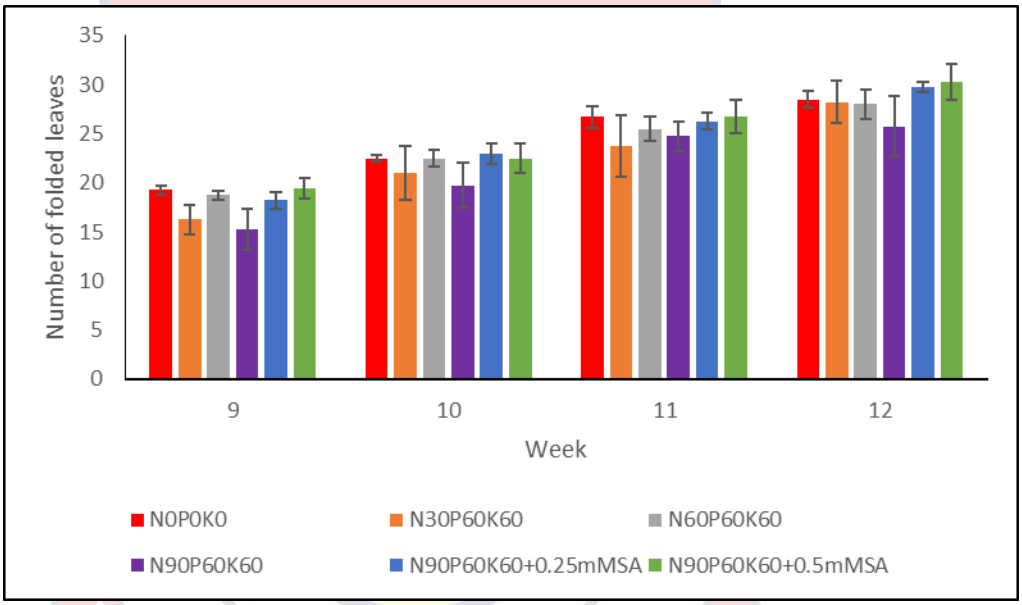

Figure 9: Number of folded leaves as affected under NPK mineral fertilizer and salicylic acid applications. Error Bars represents standard error of difference.

There was also no significant difference ($p= 0.286$) between the various fertilizer and salicylic acid applications on the number of unfolded leaves as shown in Figure 10 below. Number of unfolded leaves decrease gradually from 9th week to 12th week after transplanting. Number of unfolded leaves were in the order, NPK (60-60-60) kg/ha > NPK (90-60-60) kg/ha + 0.25 mM SA > NPK (90-60-60) Kg/ha + 0.5 mM SA, > NPK (90-60-60), > NPK (30-60-60) Kg/ha and NPK (0-0-0) Kg/ha.

From Table 4, it can be concluded that soil phosphorus correlated strongly with number of unfolded leaves of cabbage crop. This is because apart from plots treated with NPK (30-60-60) kg/ha with p-value of (24.24 cmol/kg) which is high, all treatments with higher values of phosphorus had the highest number of unfolded leaves with the least phosphorus value getting the least unfolded leaves as follows. NPK (60-60-60) kg/ha (27.03 cmol/kg), NPK (90-60-60) kg/ha+0.25 mM SA (25.67 cmol/kg), NPK (90-60-60) Kg/ha +0.5 mM SA (24.24 cmol/kg), NPK (90-60-60) (20.8 cmol/kg) and NPK (0-0-0) Kg/ha (16.42 cmol/kg).

It can moreover be deduced that the clay fraction of the soil played a role as the treatment with the highest number of unfolded leaves (NPK (60-60-60) kg/ha) had the highest clay fraction value of 12%. Soil chemical constituents such as higher exchangeable acidity and sodium levels, lower hydrogen ion concentration, phosphorus and calcium levels can be concluded to help reduce number of unfolded leaves in cabbage crop as in Table (4), NPK (0-0-0) Kg/ha with the least number of unfolded leaves had the lowest pH (5.92) which was moderately acidic, had the lowest Ca level of (5.86 cmol/kg) and P (16.42 cmol/kg), highest Na (0.30 cmol/kg) and exchangeable acidity (0.30 cmol/kg) as in Table 6).

Salicylic acid treated plots, NPK (90-60-60) kg/ha+0.25 mM SA and NPK (90-60-60) Kg/ha +0.5 mM SA leading in the number of unfolded leaves in cabbage refute what Janda, Horváth, Szalai and Paldi (2007) established. Salicylic acid was thought to aids plants tolerance to abiotic stress and higher temperatures (He et al., 2005) as severe temperature regimes were experienced during the establishment of the crop. NPK (30-60-60) kg/ha

and NPK (0-0-0) kg/ha attaining least number of unfolded leaves refutes what Khan, Iqbal, Ahmad, Soomro and Chaudhary (2002) established that in some cases, if nitrogen is not adequate, it will not form heads.

All treatments significantly indifferent in unfolded leaves may be due to drought situation experienced prior to leaf folding stage of cabbage as exclaimed by Farooq, Hussain, Wahid and Siddique (2012). Under drought situations, the photosynthetic rate of plants decrease as stomata closure increases due to increasing abscisic acid (ABA) in plant cells, membrane damage and disturbed activity of various enzymes. Water stress further assisted the formation of reactive oxygen species such as hydrogen peroxide (Das & Uprety, 2006). Another indicator of membrane damage is the increase of malondialdehyde (MDA) amount, the last product of lipid peroxidation in membranes. Abiotic stress imposed by either drought or salinity also brings about severe growth retardation in many plants (Sahin et al., 2018).

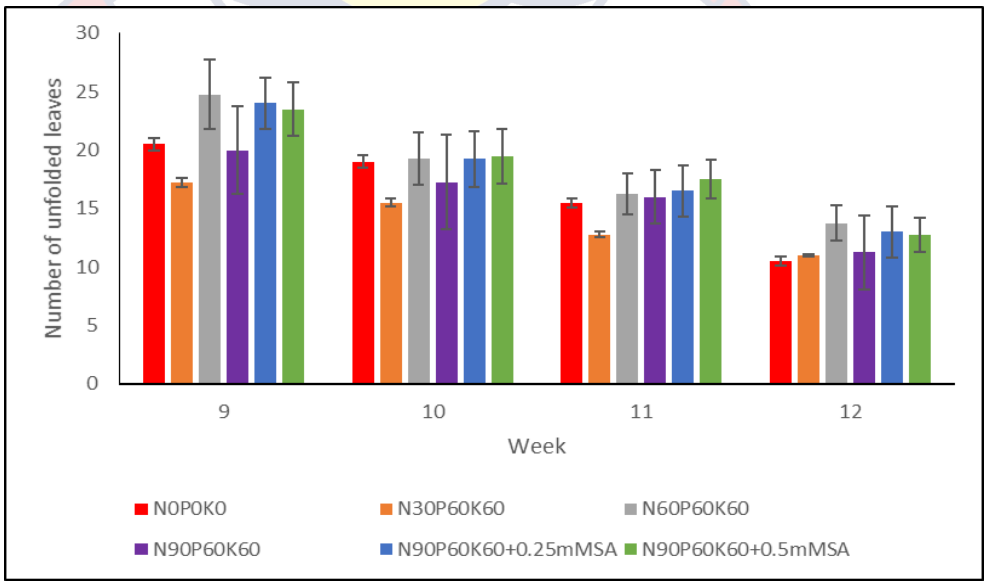

Figure 10: Number of unfolded leaves as affected under NPK mineral fertilizer and salicylic acid applications. Error Bars represents standard error of difference.

Correlation Analysis

There was a weak uphill or positive linear relationship between yield and circumference (0.3455), yield and blight infestation (0.028), yield and pest attack at 7th week after transplanting (0.0832) and yield and pest attack at 8th week. (0.1412). However, a strong uphill or positive linear relationship existed between pest infestation at 7th and 8th week after transplanting (0.8992) whilst a weak uphill or positive linear relationship occurred between circumference and pest attack at 7th week after transplanting (0.0338), circumference and pest attack at 8th week after transplanting (0.0989), blight infestation and pest attack at 7th week after transplanting (0.1135), blight infestation and pest attack at 8th week after transplanting (0.315) and blight infestation and circumference (0.3298).

Table 6 – *Correlations of Parameters Studied*

Correlations	Pest-7WAT	Pest 8WAT	Circumference (cm)	Yield (t/ha)	Blight 6WAT
Pest_7WAT					
Pest_8wat	0.8992				
Circumference_cm	0.0338	0.0989			
Yield_T_ha	0.0832	0.1412	0.3455		
Blight_6WAT	0.1135	0.315	0.3298	0.028	

Source: Field data (2019)

Cost Benefit Analysis

Table 7 - *Cost Benefit Analysis of various Treatment*

Treatment	Cost (GH ₵)	Net income (GH ₵)	Benefit/Cost Ratio (GH ₵)
NPK (30-60-60) kg/ha	4,117.80	42,282.20	10.27
NPK (60-60-60) kg/ha	4,215.60	34,984.40	8.30
NPK (90-60-60) kg/ha	4,313.48	46,586.53	10.80
NPK (90-60-60) kg/ha + 0.25 mM SA	4,713.48	34,386.53	7.30
NPK (90-60-60) kg/ha + 0.5 mM SA	5,013.48	45,586.53	9.09
NPK (0-0-0) kg/ha	3,645.00	19,205.00	5.27

Source: Field data (2019)

Treatment with higher rate of NPK fertilizer without salicylic acid (NPK (90-60-60) kg/ha) was more effective in improving yield, quality and at the same time suppressing Alternaria blight as it is cost effective. Less income was needed to get maximum output and income.

Higher rate of NPK fertilizer with salicylic acid NPK (90-60-60) kg/ha + 0.5 mM SA was effective in improving yield, quality and suppressing Alternaria blight but economically not feasible or best compare to treatment NPK (90-60-60) kg/ha as more income was needed to combat the challenges. Lower income realised in treatment NPK (60-60-60) kg/ha and NPK (90-60-60) kg/ha + 0.25 mM SA may be due to the highest occurrence of blight

disease on these plots which affected it photosynthetic assimilation and yield thus the returns.

From this outcome, it is very important to apply the needed rates in cabbage fields to prevent huge losses in the production of cabbage as treatment NPK (30-60-60) kg/ha even gave best results and income compare to higher rates. Also fertilizer application is inevitable to increase yield, improve quality and stamp down Alternaria blight in cabbage production as the control (NPK (0-0-0) kg/ha) recorded the least output or income.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

At the end of the field study, it was established that fertilizer and salicylic acid application and their rates were very crucial to cabbage leaf growth and development (leaf area). Equal application rates between nitrogen, phosphorus and potassium (NPK (60-60-60) kg/ha) and higher nitrogen rates NPK (90-60-60) + 0.25 mM SA kg/ha), NPK (90-60-60) + 0.5 mM SA kg/ha) and NPK (90-60-60) kg/ha) induced better leaf area than lower nitrogen rates. Also, lower rate of salicylic acid application induced better leaf area than higher salicylic acid application rate.

Moreover, equal application rates between nitrogen, phosphorus and potassium (NPK (60-60-60) kg/ha) and higher nitrogen rates NPK (90-60-60), NPK (90-60-60) + 0.5 mM SA kg/ha) and NPK (90-60-60) kg/ha) + 0.25 mM SA kg/ha) increased leaf number. Higher salicylic acid application rate impacted better than lower rate of SA application.

Control or no treatment cabbage plots (NPK (0-0-0) kg/ha) were more tolerant or resistant to pests than treated plots. Pest occurrence was further influenced by soil and climatic conditions like drought, humidity and temperature as they were seen during some periods of drought (Appendix 1).

Treatments with highest leaf area and highest leaf number (NPK (60-60-60) kg/ha) encountered cabbage blight infestation most. This means cabbage blight disease infestation level has a link to leaf area (LA) and number. Also, higher rate SA (NPK (90-60-60) kg/ha + 0.5 mM SA) treated plots suppressed Alternaria blight better than lower rate of SA (NPK (90-60-

60) kg/ha + 0.25 mM SA) treated plots. The soil, environmental and climatic conditions at the time of cultivation, management practices adopted, site for the field study and plant stages of growth played a key role in the development of the Alternaria blight disease. A six (6) days of drought was experienced with two (2) heavy rains and another five (5) days drought as show in the rainy days/times Table (8) and this triggered the cabbage blight. Alternaria disease occurred prior to leaves folding stage when cabbage crop was very nutritive and luxuriant. Higher nitrogen application with salicylic acid (NPK (90-60-60) kg/ha + 0.5 mM SA) induced better circumferences in cabbage.

Cabbage yield was dependent on the rate of treatments applied. Higher levels of nitrogen treated plots (NPK (90-60-60) kg/ha and (NPK (90-60-60) kg/ha + 0.5 mM SA) gave equal yields of (50.9 t ha^{-1}). Also, higher SA applicate rate gave better yields than lower rates. Alternaria disease influenced cabbage yield as plots with highest diseases infestation (NPK (60-60-60) kg/ha and (NPK (90-60-60) kg/ha + 0.25 mM SA) had the least yields.

Salicylic acid application induced better leaf folding of cabbage. Control and lower nitrogen levels (NPK (0-0-0) kg/ha) and (NPK 30-60-60) kg/ha) ensured better leaf folding in cabbage than higher nitrogen levels without salicylic acid.

Control and lower nitrogen application rate (NPK (0-0-0) kg/ha) and (NPK (30-60-60) kg/ha) controlled unfolded leaves in cabbage than any other treatment. Application of salicylic acid aided more unfolded leaves production in cabbage.

Higher rate of NPK fertilizer without salicylic acid (NPK (90-60-60) kg/ha) was more effective in improving yield, quality and at the same time suppressing Alternaria blight as it is cost effective as less income was needed to get maximum output and income.

Conclusions

From the cabbage field study, it can be established that in relation to yield parameters (leaf area, leaf number, folded leaves, circumference of head and weight of harvested cabbage), highest rates of nitrogen with or without salicylic acid application (NPK (90-60-60) kg/ha + 0.5 mM SA), (NPK (90-60-60) kg/ha + 0.25 mM SA) and (NPK (90-60-60) kg/ha) are very vital and crucial. Yield parameters increased as rates of nitrogen and salicylic acid application increased.

In ensuring higher quality (preventing unfolded leaves, pest and Alternaria blight) in cabbage fields, the control (NPK (0-0-0) kg/ha), NPK (90-60-60) kg/ha) and NPK (30-60-60) kg/ha) are necessary.

To control and stamp down Alternaria blight in cabbage, higher rates of mineral nitrogen only and higher rates of both mineral nitrogen and salicylic acid (NPK (90-60-60) kg/ha) and NPK (90-60-60) kg/ha + 0.5 mM SA) are important.

However, when farmers' target is to increase yield, income and at the same time improve quality, application of higher nitrogen rates without salicylic acid rates NPK (90-60-60) kg/ha is very essential compare to treatment NPK (90-60-60) kg/ha + 0.5 mM SA with salicylic acid as it is very cost effective.

Recommendations

1. It can therefore be recommended that to improve yield, quality and suppress Alternaria occurrence in cabbage fields, higher rates of nitrogen application with or without salicylic acid (NPK (90-60-60) kg/ha SA and NPK (90-60-60) kg/ha + 0.5 mM) should be applied.
2. When cabbage is to be used as salad, NPK (60-60-60) kg/ha and NPK (90-60-60) kg/ha + 0.25 mM SA are recommended.
3. Best NPK and salicylic acid application rate, water management and prevention of continuous cropping on same site are keys to prevent the occurrence of Alternaria blight, improve yield and quality of cabbage heads.
4. Soil chemical analysis prior to cultivation and cost benefit analysis should be done to know the best mineral NPK rates to apply to minimise cost of production and increase income.
5. Future studies should focus on different varieties of cabbage, different rates of organic fertilizers and combination of both organic and inorganic fertilizers.

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APPENDICES

Appendix 1 - *Mean Rainfall Distribution at Adarkabrunso Cabbage Field Demonstration Site*

Date/Month	Rainfall distribution	Remarks
2/2/2019	Light rainfall	First rainfall for the year
4/2/2019	Light rainfall	
6/2/2019	Light rainfall	
Total No. of rainy days for the month		3 times
8/3/2019	Light rainfall	
9/3/2019	Light rainfall	
10/3/2019	Light rainfall	
16/3/2019	Light rainfall	
21/3/2019	Heavy rainfall	First heavy fall of the year
24/3/2019	Heavy rainfall	
28/3/2019	Heavy rainfall	
Total No. of rainy days for the month		7 times
1/4/2019	Light rainfall	
4/4/2019	Heavy rainfall	
5/4/2019	Heavy rainfall	
7/4/2019	Heavy rainfall	
9/4/2019	Heavy rainfall	
14/4/2019	Light rainfall	
16/4/2019	Heavy rainfall	
17/4/2019	Heavy rainfall	
23/4/2019	Heavy rainfall	
24/4/2019	Heavy rainfall	
25/4/2019	Light rainfall	
26/4/2019	Light rainfall	
30/4/2019	Light rainfall	
Total No. of rainy days for the		13 times

month

1-6/5/2019 No rain for 6 days

Date/Month	Rainfall distribution	Remarks
7/5/2019	Heavy rainfall	
12/5/2019	Heavy rainfall	After 5 days drought period
14/5/2019		Incidence of Alternaria seen
15/5/2019	Heavy rainfall	
20/5/2019	Heavy rainfall	
21/5/2019	Heavy rainfall	
23/5/2019	Light rainfall	
24/5/2019	Light rainfall	
25/5/2019	Heavy rainfall	
Total No. of rainy days for the month		8 times
4/6/2019	Light rainfall	
5/6/2019	Heavy rainfall	Visit by supervisors
6/6/2019	Heavy rainfall	
7/6/2019	Light rainfall	
10/6/2019	Heavy rainfall	
11/6/2019		Incidence of Alternaria reduced
14/6/2019	Heavy rainfall	
15/6/2019	Heavy rainfall	
16/6/2019	Light rainfall	
18/6/2019		Harvesting of cabbage
22/6/2019	Heavy rainfall	
24/6/2019	Heavy rainfall	
27/6/2019	Heavy rainfall	In the afternoon
27/4/2019	Heavy rainfall	In the night
28/6/2019	Heavy rainfall	In the afternoon

28/4/2019	Heavy rainfall	In the night
29/6/2019	Light rainfall	
No. of rainy days for the month		15 times

Source: Field data (2019)

Appendix 2 - *Analysis of Variance Leaf Area*

Source of Variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	0.4276	0.1425	0.12	
REP.Subject stratum					
Treatments	5	109.5946	21.9189	18.1	<.001
Residual	15	18.1688	1.2113	18.13	
REP.Subject. Time stratum d.f. correction factor 0.6247					
Time	3	146.3867	48.7956	327.35	<.001
Time.Treatments	15	2.7571	0.1838	1.23	0.308
Residual	54	8.0495	0.1491		
Total	95	285.3843			

Source: Field data (2019)

Appendix 3 - *Analysis of Variance Leaf Number*

Source of variation d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum REP.Subject stratum	3	0.963	0.321	2.1
Treatments	5	79.1804	15.8361	103.72 <.001
Residual	15	2.2903	0.1527	0.46
REP.Subject.Time stratum d.f. correction factor 0.5851				
Time	3	617.8319	205.944	618.69 <.001
Time.Treatments	15	43.7225	2.9148	8.76 <.001
Residual	54	17.975	0.3329	
Total	95	761.9631		

Source: Field data (2019)

Appendix 4 - *Analysis of Variance Pest*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum REP.Subject stratum	3	47.4167	15.8056	0.92	
Treatments	5	11.6667	2.3333	0.14	0.981
Residual	15	257.8333	17.1889	24.27	
REP.Subject.Time stratum d.f. correction factor 1.0000					
Time	1	0	0	0	1
Time.Treatments	5	4.25	0.85	1.2	0.349
Residual	18	12.75	0.7083		

Total	47	333.9167

Source: Field data (2019)

Appendix 5 - *Analysis of Variance Blight*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	17987	5996	0.98	
REP.*Units* stratum					
Treatments	5	37031	7406	1.21	0.352
Residual	15	91951	6130		
Total	23	146969			

Source: Field data (2019)

Appendix 6 - *Analysis of Variance Circumference*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	18.635	6.212	1.9	
REP.*Units* stratum					
Treatments	5	3085.023	617.005	188.42	<.001
Residual	15	49.119	3.275		
Total	23	3152.777			

Source: Field data (2019)

Appendix 7 - *Analysis of Variance Yield*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum					
	3	1158	386	3.29	
REP.*Units* stratum					
Treatments	5	723.1	144.6	1.23	0.342
Residual	15	1760.7	117.4		
Total	23	3641.8			

Source: Field data (2019)

Appendix 8 - *Analysis of Variance Folded Leaves*

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum	3	324.615	108.205	5.13	
REP.Subject stratum					
Treatments	5	139.677	27.935	1.33	0.306
Residual	15	316.198	21.08	7.88	
REP.Subject. Time stratum d.f. correction factor 0.7798					
Time	3	1511.031	503.677	188.31	<.001
Time.Treatments	15	29.781	1.985	0.74	0.7
Residual	54	144.438	2.675		
Total	95	2465.74			

Source: Field data (2019)

Appendix 9 - *Analysis of Variance Unfolded Leaves*

Source of variation d.f.	s.s.	m.s.	v.r.	F pr.
REP stratum 3				
REP. Subject stratum	273.042	91.014	1.25	
Treatments 5	236.5	47.3	0.65	0.666
Residual 15	1091.583	72.772	19.96	
REP. Subject. Time stratum d.f. correction factor 0.8434				
Time 3	1189.875	396.625	108.79	<.001
Time. Treatments 15	67.75	4.517	1.24	0.286
Residual 54	196.875	3.646		
Total 95	3055.625			

Source: Field data (2019)

Appendix 10 - *Field Pictures*


Symptoms of Alternaria blight of cabbage on all the 6 treatments


NPK (90-60-60) kg/ha + 0.25mM SA NPK (90-60-60) kg/ha + 0.5mM SA

NPK (60-60-60) kg/ha

NPK (0-0-0) kg/ha

NPK (30-60-60) kg/ha

NPK (90-60-60) kg/ha.

Cabbage experimental plot at Adarkabrunso/ Adeito, Bosome Freho/Ashanti/Ghana

Appendix 11: *Cabbage at Different Stages of Growth*

Nursed cabbage seedlings

During transplanting

During treatment administration

After treatments administration

After second weeding

At leaf folding

Appendix 12 - *Cost Benefit Analysis of NPK (30-60-60) kg/ha*

Activity/Item	Unit	Quantity	Unit Price	Total
NPK (30-60-60) kg/ha				
NPK fertilizer (30)	bag	4	75	300
Urea	bag	0	0	0
Muriate of Potash (30)	bag	1.304	75	97.8
Triple Super Phosphate (30)	bag	1	75	75
SA			0	0
Oxylus cabbage seeds	sachets	3	300	900
Fungicides (dress force and Bypel)	pc	10	55	550
Insecticides (Agoo)	sachets	25	8	200
Weedicide (Agil)	litres	6	20	120
LAND PREPARATION				
Land clearing	man days	15	35	525
Nursery and Bed preparation	man days	15	35	525
TnT (Anyinase/Adarkabrunso in and out)	personnel and inputs			300
Harvesting	man days	15	35	525
Total cost of production				4117.8
Economic yield/sales	kg	46400	1	46400
Benefit (income)/net return				42282
Benefit cost ratio				10.268

Source: Field data (2019)

Appendix 13 - *Cost Benefit Analysis of NPK (60-60-60) kg/ha*

Activity/Item	Unit	Quantity	Unit price	Total
NPK (60-60-60) kg/ha				
NPK fertilizer (30)	bag	4	75	300
Urea (30)	bag	1.304	75	97.8
Muriate of Potash (30)	bag	1.304	75	97.8
Triple Super Phosphate (30)	bag	1	75	75
SA	ml	0	0	0
Oxylus cabbage seeds	sachets	3	300	900
Fungicides (dress force and Bypel)	pc	10	55	550
Insecticides (Agoo)	sachets	25	8	200
Weedicide (Agil)	litres	6	20	120
LAND PREPARATION				
Land clearing	man days	15	35	525
Nursery and Bed preparation	man days	15	35	525
TnT (Anyinase/Adarkabrunso in and out)	personnel and inputs			300
Harvesting	man days	15	35	525
Total cost of production				4215.6
Economic yield/sales	1kg	39200	1	39200
Benefit (income)/net return				34984
Benefit cost ratio				8.2988

Source: Field data (2019)

Appendix 14 - *Cost Benefit Analysis of NPK (90-60-60) kg/ha*

Activity/Item	Unit	Quantity	Unit price	Total
NPK (90-60-60) kg/ha				
NPK fertilizer (30)	Bag	4	75	300
Urea (60)	Bag	2.609	75	195.68
Muriate of Potash (30)	Bag	1.304	75	97.8
Triple Super Phosphate (30)	Bag	1	75	75
SA	Ml	0	0	0
Oxylus cabbage seeds	sachets	3	300	900
Fungicides (dress force and Bypel)	Pc	10	55	550
Insecticides (Agoo)	sachets	25	8	200
Weedicide (Agil)	Litres	6	20	120
LAND PREPARATION				
Land clearing	man days	15	35	525
Nursery and Bed preparation	man days	15	35	525
TnT (Anyinase/Adarkabrunso in and out)	personnel and inputs			300
Harvesting	man days	15	35	525
Total cost of production				4313.5
Economic yield/sales	1kg	50900	1	50900
Benefit (income)/net return				46587
Benefit cost ratio				10.8

Appendix 15 - *Cost Benefit Analysis of NPK (90-60-60) kg/ha + 0.25 mM SA*

Activity/Item	Unit	Quantity	Unit price	Total
NPK (90-60-60) kg/ha + 0.25 mM SA				
NPK fertilizer (30)	bag	4	75	300
Urea (60)	bag	2.609	75	195.68
Muriate of Potash (30)	bag	1.304	75	97.8
Triple Super Phosphate (30)	bag	1	75	75
SA				400
Oxylus cabbage seeds	sachets	3	300	900
Fungicides (dress force and Bypel)	pc	10	55	550
Insecticides (Agoo)	sachets	25	8	200
Weedicide (Agil)	litres	6	20	120
LAND PREPARATION				
Land clearing	man days	15	35	525

Nursery and Bed preparation	man days	15	35	525
TnT (Anyinase/Adarkabrunso in and out)	personnel and inputs			300
Harvesting	man days	15	35	525
Total cost of production				4713.5
Economic yield/sales	1kg	39200	1	39200
Benefit (income)/net return				34487
Benefit cost ratio				7.3166

Source: Field data (2019)

Appendix 16 - *Cost Benefit Analysis of NPK (90-60-60) kg/ha + 0.5 mM SA*

Activity/Item	Unit	Quantity	Unit price	Total
NPK (90-60-60) kg/ha + 0.5 mM SA				
NPK fertilizer (30)	bag	4	75	300
Urea (60)	bag	2.609	75	195.68
Muriate of Potash (30)	bag	1.304	75	97.8
Triple Super Phosphate (30)	bag	1	75	75
SA				700
Oxylus cabbage seeds	sachets	3	300	900
Fungicides (dress force and Bypel)	pc	10	55	550
Insecticides (Agoo)	sachets	25	8	200
Weedicide (Agil)	litres	6	20	120
LAND PREPARATION				
Land clearing	man days	15	35	525
Nursery and Bed preparation	man days	15	35	525
TnT (Anyinase/Adarkabrunso in and out)	personnel and inputs			300
Harvesting	man days	15	35	525
Total cost of production				5013.5
Economic yield/sales	1kg	50900	1	50900
Benefit (income)/net return				45887
Benefit cost ratio				9.1526

Appendix 17 - *Cost Benefit Analysis for NPK (0-0-0) kg/ha*

Activity/Item	Unit	Quantity	Unit price	Total
NPK (0-0-0) kg/ha				
NPK fertilizer	bag	0	0	0
Urea	bag	0	0	0
Muriate of Potash	bag	0	0	0
Triple Super Phosphate	bag	0	0	0
SA		0	0	0
Oxylus cabbage seeds	sachets	3	300	900
Fungicides (dress force and Bypel)	pc	10	55	550
Insecticides (Agoo)	sachets	25	8	200
Weedicide (Agil)	litres	6	20	120
LAND PREPARATION				
Land clearing	man days	15	35	525
Nursery and Bed preparation	man days	15	35	525
TnT (Anyinase/Adarkabrunso in and out)	personnel and inputs			300
Harvesting	man days	15	35	525
Total cost of production				3645
Economic yield/sales	1kg	45700	0.5	22850
Benefit (income)/net return				19205
Benefit cost ratio				5.2689

Source: Field data (2019)