KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

INCIDENCE AND SEVERITY OF MAJOR FUNGAL DISEASES OF TOMATO (*Solanum lycopersicum* L.) IN THREE DISTRICTS WITHIN FOREST AND FOREST-SAVANNAH AGRO-ECOLOGICAL ZONES OF GHANA

BY

BRIGHT ASANTE OPOKU

(BSc. Hons. Agriculture)

AUGUST, 2012

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A THESIS SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE CROP PROTECTION (PLANT PATHOLOGY) DEGREE

AUGUST, 2012

DECLARATION

I hereby declare that, except for specific references which have been duly acknowledged, this project is the result of my own research and has not been submitted either in part or whole for other degree elsewhere.

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Dr. Charles Kwoseh	…………………………….	………………….
(Head of Department)	Signature	Date

DEDICATION

1 dedicate this work to my parents, Mr. Yaw Opoku and Madam Hannah Agyapomaa, my siblings Opoku Yankyerah and Opoku Acheampomaa, may God bless you all.

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ABSTRACT

Tomato (*Solanum lycopersicum* L) is an important vegetable crop worldwide. Often times, its production is hindered by fungal diseases. The study was carried out in three major tomato growing districts within the forest and forest- savannah agro-ecological zones of Ghana under three main sections. They are; a survey on incidence and severity of fungal diseases in tomato fields, documentation of tomato farmers' knowledge, perceptions and practices on fungal diseases and their control measures and identification of seed-borne fungi associated with farmer-saved tomato seeds, using the blotter method. Calculations on disease incidence and severity were summarized for their mean percentages per district and the results were presented in tables. Data on tomato farmers' knowledge on diseases and their control practices were summarized in percentages and presented in bar charts. Results on seed health test were determined in percentages and presented in tables for districts. Early blight, Septoria leaf spot, Fusarium wilt, Collar rot and Sclerotium rot were the major fungal diseases identified in the study. The incidence of Early blight was 63.9, 43.5 and 38.2 % at Agogo, Offinso North Districts and Techiman Municipality, respectively. The study showed that Early blight and Fusarium wilt were the most common severe diseases in all the districts. The research showed that farmers have knowledge of the diseases because of losses that these diseases caused. However, their knowledge on control practices was poor and, therefore, contributes to the high incidence and severity of the identified fungal diseases. Twenty-two species of fungi from 12 genera were identified as seed-borne pathogens of tomato on farmer-saved tomato seeds. *Fusarium oxysporum, Alternaria* sp., and *Fusarium* spp., were seed-borne pathogens identified on the tomato seeds to associate with field diseases of Fusarium wilt, Early blight and Collar rot, respectively.

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LIST OF ABBREVIATIONS

FAO…………………. Food and Agricultural Organization

PPMED………………..Policy Planning, Monitoring and Evaluation Department

MoFA…………………Ministry of Food and Agriculture

IFPRI-PBS**................** International Food Policy Research Institute-Programme for Biosafety Systems

GSSP…………………..Ghana Strategy Support Programme

CSIR …………………..Council for Scientific and Industrial Research

SRID…………………..Statistics Research and Information Directorate

PDA…………………….Potato Dextrose Agar

GIPC………………… Ghana Investment Promotion Centre

MIS…………………….Management and Information Service

Cm …………………….Centimeter

g………………………gram

mm……………………millimeter

mg…………………….milligram

kcal……………………kilocalorie

Mt……………………..metric tonne

Ha……………………hectare

°C……………………Degree Celsius

GH¢…………………Ghana cedi

% ……………………Percentage

CHAPTER ONE

1.0 INTRODUTION

Tomato (*Solanum lycopersicum* L.), known to be a nightshade crop, belongs to the family of *Solanaceae* and is consumed in diverse ways, including raw, as an ingredient in many dishes, sauces and in drinks (Alam *et al*., 2007). The fruit of tomato, classified as a vegetable in trade, is a very strong "protective food" (Alam *et al*., 2007). Many Ghanaian dishes have tomatoes as a component ingredient (Tambo and Gbemu, 2010). Tomatoes are very rich in vitamins B and C and also contain good amount of potassium, iron, and phosphorus (Wener, 2000). Also the modest levels of beta-carotene and gamma-carotene in tomato products, makes it rich in the supply of vitamin A to the body. The presence of lycopene in tomato acts as antioxidant, to fight free radicals that interfere with normal cell growth and activity (Giovannucci, 1999). According to Filippone (2006), eating tomato prevents cancer, heart disease and premature aging. Tomato is the most popular vegetable grown in the world. It is the second most important vegetable crop next to potato (Srinivasan, 2010). Presently, it is estimated to be grown on more than 5 million hectares with a production of nearly 129 million tonne worldwide (FAO, 2006). In 1987, tomato contributed about 130,000 tonnes to total agricultural production and about GH¢ 1.3 million in revenue to the Ghanaian economy (PPMED, 1991). High yields of tomato result in high incomes to farmers, especially in areas such as Akomadan, Tuobodom, Agogo, where it is cultivated almost three to four times per year and Mankessim, Navrongo in the lean season. In Ghana, area planted to tomato was 44000.1 sq.km which was higher than other vegetable crops recording 19000.4 sq.km (SRID – MoFA Report, 2009). Tomato serves as a cash crop for many farmers in the guinea savannah, coastal savannah, forest and forest-savannah agro ecological zones (MoFA, 2002).

In recent years, domestic tomato production has intensified across Ghana, but local production is not able to meet the domestic high demand hence tomatoes are often imported mainly from Burkina Faso (Horna *et al.*, 2006). This situation is due to lots of constraints, particularly diseases and pests (Villareal, 1980). Worldwide, several pathogens affecting tomato have been reported. Among the economically important are of fungal, nematode, viral and bacterial aetiology (Jones *et al.,* 1991; Chupp and Sherf, 1960). Fungal diseases of tomato such as early blight, late blight, Septoria leaf spot, Fusarium wilt, Collar rot, Sclerotium rot and damping-off have been reported in Ghana (Offei *et al.*, 2008; MoFA, 1995; Clerk, 1974). These infections are declining the importance of tomato cultivation in the major growing countries (Shankara *et al*., 2005; Agrios, 2005). In Ghana, such fungal diseases affect crop growth, reduce yields and critically affect farmers' livelihoods (IFPRI-PBS 2006; GSSP Report, 2010). In major tomato producing areas such as Akomadan, Tuobodom-Techiman and Agogo tomato cultivation continues to serve as employment to about 80 % of the populace (Sinnadurai, 1992). In Ghana, quantitative information of fungal disease incidence, farmers' knowledge on diseases and diseases level of losses to tomato production are scanty. Observations however, on farmers' fields show that severe disease pressure has led to farmers' abuse and overdependence on chemicals and other strategies to control diseases but they may be ineffective if the plant is already infected. The untimely application of high dosages of available fungicides is gradually affecting the environment, human health and making some of the fungi develop resistance to the chemicals fungicides (IFPRI-PBS, 2006; GSSP Report, 2010). This arises from the fact that a great number of these fungal diseases are seed-borne. According to Clottey *et al.* (2009), seed recycling is a common practice especially to Ghanaian farmers. Farmers obtain seed either from their own fields, from neighbours and friends (Clottey *et al.,* 2009). This recycling has a negative effect on seed quality, giving way to build-up and multiplication of seed-borne fungal pathogens (IFPRI – PBS, 2006; GSSP Report, 2010). Seed-borne fungi are of considerable importance due to their influence on the overall health, and final crop stand in the field (Richardson, 1983; Suryanarayana, 1978; Neergaard, 1977). Infected seeds also play a role in the dissemination of plant pathogens and disease establishment (Agarwal, 1981). Therefore, the control of seed-borne pathogens is the first step in any agricultural crop production and protection programme (Van Gastel *et al*., 1996; Schwin, 1994).

To help develop an appropriate fungal disease control measures, a better understanding of the disease situation in major tomato growing areas of Ghana must be known. This project is an attempt to document the actual field diseases situation of tomato with the aim that results obtained can be depended on to develop appropriate control measures. The main objective of the study was to determine the incidence and severity of fungal diseases and pathogens of tomato and the famers' management practices for these infections in three districts within the forest and forest-savannah zones of Ghana. The specific objectives were to;

(i). determine the incidence and severity of the identified fungal diseases and other pathogens of tomato,

(ii). determine the knowledge, perceptions and practices of tomato farmers on fungal diseases and their control measures,

(iii). identify seed-borne fungi associated with farmer-saved tomato seeds.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1.0 Biology of the tomato plant

The modern cultivated varieties of tomato are thought to have originated from the wild tomato with common name such as vine-like herb of the nightshade family (Pardee, 2009). It is native to the Andean regions of the coastal strip of western and southern America (Cox, 2000). Tomato was first domesticated in Mexico in mid-16th century (Paran and van der Knaap, 2007). It was widely then distributed as a wild plant in the tropics and subtropics. Tomato is widely grown in the Central, East and West Africa particularly, in Ghana and Nigeria (De Lannoy, 2001; Tindall, 1988).

The Stem growth habit ranges between erect and prostrate. It grows to a height of 2-4 m (Shankara *et al*., 2005). The leaves are spirally arranged, 15-50 cm long and 10-30 cm wide. Inflorescence is clustered and produces 6-12 flowers. The plant is mostly self-pollinated but partly also cross pollinated (Shankara *et al*., 2005). The fruit is fleshy berry, globular to oblate in shape and 2-15 cm in diameter. The immature fruit is green and hairy. Ripe fruits range from yellow, orange to red. Tomato has numerous seeds, which are kidney or pear shaped. They are hairy, light brown 3-5 mm long and 2-4 mm wide. The embryo is coiled up in the endosperm. Approximate weight of 1000 seeds is 2.5 – 3.5 g (Shankara *et al*., 2005).

2.1.1 Varieties of tomato

Various varieties of tomato available worldwide have been classified, based on shape and colour of the fruit, height of the tomato plant, days to maturity, disease resistance and other growth characteristics which are usually determinate or indeterminate (Norman, 1992). Some foreign varieties include Big boy, Beefmaster, and Goliath, all from Canada. Tomato F1 No.7 and Tomato F1 Tyking 5 are from Vietnam. Tomato Red Cherry, Tomato Floradade, Tomato jam Roma and Royal sluis are from U S A. Starke Money maker and Starke Heinz 1370 are from South Africa. The available cultivars in West Africa include, Pectomech EEC, Pectomech CEE, Burpee Roma VF and Tomato Roma VF (www.growtomatoes.com). According to IFPRI-PBS (2006) and GSSP (2010) Reports, most tomato varieties used in Ghana for commercial production are introduced varieties, which are not well adapted to local conditions. Some local varieties highly cultivated include 'Ashanti', 'Caterpillar', 'Cocoaba', 'Power', 'Burkina', 'Akoma' and 'Rando' (Khor, 2006).

According to sources from the Ministry of Food and Agriculture (2008), the recommended varieties of tomato in Ghana are the Roma VF, Pectomech, Pectomech VF, Tropimech, Rio Grande, Cac J, Wosowoso and Laurano 70. The main sources of seeds of farmers are reputable seed dealers. Robinson and Kolavalli (2010a) described the Pectomech variety as suitable for processing and preferred by consumers to achieve a premium price over the local varieties. Clottey *et al.* (2009) reported that major tomato varieties in Vea (Upper East region), Ghana, are Pectomech, Tropimech and Roma. Adubofour *et al*. (2010) also cited two varieties of tomato grown in Ghana as Bolga and Ashanti. Robinson and Kolavalli (2010c) mentioned varieties such as Rasta, Power, Power Rano, and Wosowoso, grown under rain-fed conditions with Power Rano often preferred due to its high tolerance and resistance to diseases. Ellis *et al*. (1998) described the 'Power' variety as the predominant variety for cultivation in Ghana.

2.1.2 Uses and nutritional value of tomato

Tomato can be used as vegetable served with rice and salads. Its principal use in Ghana is in soups and stews (Tambo and Gbemu, 2010). They abound with essential nutrients such as vitamins and minerals (Bradley, 2003). According to Giovannucci (2002), of the 14 carotenoids found in human serum, tomato and tomato products contribute to nine and are the predominant source of about one-half, including lycopene (Cox, 2001; Di Macio *et al*., 1989). According to the USDA National Nutrient Database (2010), the nutritional content of an average 123 g red, ripe raw tomato are follows; alpha carotene: 124 mcg, beta-carotene 552 mcg, calcium: 1.2 mg, carbohydrate: 4.7 mg, Copper: 0.073 mg, dietary fibre: 1.5 g, Energy: 22.14 kcal, fat: 0.2g, folate (dietary folate equivalents DFE): 18 mcg, iron:0.33 mg, IU Vitamin A: 1025, lutein + zeaxanthin: 151 mcg, lycopene: 3165 mcg, magnesium: 1.4 mg, manganese: 0.140 mg, moisture content: 116.26 g, niacin: 0.731 mg, pantothenic acid: 0.109 mg, phosphorus: 3.0 mg, potassium: 292 mg, protein: 1.0 g, RAE Vitamin A: 52, riboflavin: 0.023 mg, sodium: 6 mg, thiamin: 0.046 mg, total choline: 8.2 mg , total monosaturated fatty acids: 0.038 g, total polyunsaturated fatty acids: 0.102 g, total saturated fatty acid: 0.034 g, total sugars: 3.23 g, vitamin B-6: 0.098 mg, vitamin C (total ascorbic acid): 16.9 mg, vitamin E - alpha-tocopherol: 0.66 mg, vitamin K (phyloquinone): 9.7 mcg and Zinc: 0.21 mg. The nutrient value changes based upon the type of tomato (USDA National Nutrient Database, 2010; Beecher, 1998).

2.1.3 Economic importance and production levels of tomato worldwide

Tomato was second to pepper, producing an average yield of 7.5 Mt/ha in 2009 when compared with other vegetable crops (SRID – MoFA Report, 2009). Also, total land area for tomato production increased from 28400 ha in 1996 to 37000 ha in 2000 (GIPC, 2001). However, import of tomato paste in Ghana increased from 3300 metric tons in 1998 to 24740 tonne in 2003 (FAO, 2005). According to ghanaweb.com report (2006), the European Union exported 27, 000 metric tons of preserved tomatoes to Ghana in 2003. Ghana's import volume of tomato paste increased by an average of

23 % from this trend. Aryeetey (2006) confirmed that Ghana is second only to Germany as the largest importer of tomato paste, consuming an average of 25,000 tonne of tomato paste in a year at a total cost of about $25 million. In the U S, it is grown in an area of 175,000 ha, producing about 11.5 million mt annually (FAOSTAT. 2008). Tomato production has been reported for 144 countries (www.growtomatoes.com). The highest producing country is China, in both hectares of harvested production (1, 625,435.05 hectares) and weight of fruit produced (39,938,708 Mt) (FAOSTAT Database, 2008). In Africa, Egypt, Nigeria, Tunisia and Morocco are the leading producers (FAOSTAT. 2008)

2.1.4 Climatic requirements for tomato production

Tomato is a warm-season plant. It requires a relatively cool, dry climate for high yield. However, it is adapted to a wide range of climatic conditions from temperate to hot and humid tropical (Green *et al.*, 1989). The optimum temperature for most varieties is between 21 and 24 °C. The plant tissues are damaged below 10 °C and above 38 °C (Rice *et al.*, 1993). Light intensity affects the colour of the leaves, fruit set and fruit colour. Water stress and long dry periods will cause buds and flowers to drop off, and the fruits to split. However, if rains are too heavy and humidity is too high, the growth of mould will increase and the fruit will rot (Shankara *et al.*, 2005).

2.1.5 Soil requirements for tomato production

Tomato will grow in a variety of soils, provided such soils are warm, have high water-holding capacity, good aeration, and are free of salt. The soils must contain a readily available supply of plant food and a pH of 5.5 to 6.8 (Green *et al.*, 1989). In general, sandy loam soils prepared in deep friable condition is important for the development of a strong root system (Shankara *et al.*, 2005).

2.1.6 Areas of tomato cultivation in Ghana

In Ghana, a wide range of locations are suitable for tomato production. It is grown in the forest, transitional savannah and other agro-ecological zones (Norman, 1992). Tomato is cultivated especially in the Northern, Upper East and around southern Volta Regions of Ghana (Clottey *et al.* 2009). It is the most lucrative crop in the Upper East Region and it is more profitable than rice, maize, groundnuts, yam, pepper and dairy. Close to 90 % of the two million people living in these areas cultivate tomato (Robinson and Kolavalli, 2010b). Tomato production is also a vibrant economic activity at Offinso North, Agogo and Techiman Districts. Cooperative farming is concentrated around Mankesim, Swedru, Agogo, Nsawam, Amasaman, Sege and Dodowa (Norman, 1992). Also, at Akomadan, Nkenkaasu, Afrancho, Tuobodom, Wenchi, Techiman, Accra, Somanya, Keta, Navrongo and around the Volta Lake, individual farmers cultivate it on large scale as their main occupation (Ellis *et al*., 1998).

2.1.6.1 Characteristics of the area surveyed

The study was carried out in three major tomato growing Districts that lie within the forest and forest- savannah agro-ecological zones of Ghana. The Offinso North District of Ashanti is located in the moist semi-decideous forest zone and lies between latitudes 6˚45 N and 7˚25 S with longitudes1˚65 W and 1˚45 E as part of Offinsoman territory of Ashanti. The district has mean annual rainfall ranging between 700 mm and 1200 mm (MIS Office - MOFA, Offinso-North District). Relative humidity for the area ranges from 70 to 90 % with the mean monthly temperature ranges from 27 to 30 ^{0}C. The soils take the characteristics of sandy-loam developed from parent materials of varied rock type of different geological origin (MIS Office - MOFA, Offinso-North District).

The Agogo District and the study communities of Techiman Municipality lie within the forest-savannah agro-ecological zones. The Agogo District is surrounded by the moist open forest and wooded savannah vegetations. The District lies between latitude 6.8˚ North and longitude 1.08˚ West. It has wet semi-equatorial type of climate with mean annual rainfall ranging between 1200 and 1500 mm (MIS Office - MOFA, Asante Akim-North District). Relative humidity for the area ranges from 80 to 90 % with the mean monthly temperature ranges from 26 to 30 ^{0}C. The soils are the product of parent rocks and climate conditions and take the characteristics of savannah ochrosol (MIS Office - MOFA, Asante Akim-North District).

The study areas of Techiman Municipality are surrounded by Guinea-Savannah woodland and Transitional vegetations. The Municipality lies between longitudes 10˚ 49 E and 20˚ 30 W with latitudes 80˚ 00 N and 70˚ 35 S (MIS Office - MOFA, Techiman Municipality). The Municipal experiences both semi-equatorial and tropical conventional or savanna climates characterized by moderate to heavy rainfall annually with a mean annual rainfall ranging between 1250 and 1650 mm. Relative humidity for the area ranges from 75 to 80% with the mean monthly temperature ranges from 27 to 30 ^{0}C (MIS Office - MOFA, Techiman Municipality). The soils take the characteristics of the Damango-Murugu-Tanoso Association, the Bediesi-Bejua Association; and the Kumasi-Offin Association (MIS Office - MOFA, Techiman Municipality).

2.1.7 Constraints to tomato cultivation

In Ghana, tomato production per farmer per hectare is very low, compared with developed countries. This can be attributed to several reasons such as high cost of labour (land preparation, transplanting and harvesting) which represent more than 50

% of total production costs (Clottey *et al.,* 2009). Drought and high rainfall create periods of abundance and scarcity, which affect and create unstability in market prices (Robinson and Kolavalli, 2010a). High cost of inputs, transportation from farm gates, and inadequate storage and processing facilities are also major constraints (Robinson and Kolavalli, 2010d).

The most important among these is the vulnerability of tomato crop to various diseases including fungal, viral, bacterial and nematode diseases (Horna *et al.,* 2006). Tomato plants are susceptible to several fungi, bacteria and viruses. Fungi and bacteria cause foliar (leaf), fruit, stem or root diseases. Damage caused by diseases can result in considerable yield losses to farmers (Shankara *et al*., 2005). Like other pathogens, fungi also give more problems because some species may live in soil and seed. They are only noticed when their disease severity is high and yield reduction also increases (Shankara *et al*., 2005). Synthetic insecticides and fungicides are generally expensive for the average farmer to use, and represent about two per cent of production cost (GSSP, 2010; IFPRI- PBS, 2006 Report).

2.1.8 Fungal diseases of tomatoes, their characteristics and management

Plant diseases constitute a major constraint to crop production (Lucas *et al*., 1987). This often result in a great degree of crop losses and may range from slight to 100 % (Agrios, 2005). Tomato plants are subjected to attack by numerous diseases wherever the crop is grown. Fungal pathogens such as *Alternaria solani* (Ellis and Martin) Jones and Grout, the causal agent of early blight disease and *Fusarium oxysporum f. sp. lycopersici*, the causal agent of wilt disease are considered as major agents of yield reduction to the crop (Stone *et al.,* 2006; Awad, 1990). Early blight disease is a three - phase disease, which produces leaf spots, stem canker and fruit rot. Fungal diseases responsible for significant economic losses sustained by tomato producers each year in most parts of the world where the crop is grown are shown in Appendix 1. Fungal infection is often caused by fungal spores that land on leaves, germinate there and penetrate the plant tissue through its stomata, wounds, or sometimes even directly through the plant's skin (Shankara *et al*., 2005). The filaments develop at an increasing rate in the affected plant tissue, from which they extract nutrients and into which they may excrete substances that are toxic to the plant (Agrios, 2005). The affected plant tissue usually dies off. The harmful effects of the fungus are usually limited to the affected area, but there are some types of fungi (such as *Fusarium* and *Verticillium* spp.) that invade the plant's vascular tissues (xylem) and thus, spread throughout the plant (Agrios, 2005). The most obvious symptoms of fungal diseases are leaf spots. These spots are normally round or oval, but they can also be polygonal or spindle-shaped with pointed ends. In an early stage of fungal infections, moist areas may be noticeable on the leaves, where the leaf will later die off. At a later stage of some infections, the leaf spots have a dead brown centre and are surrounded by a light or dark-coloured halo. Concentric rings of different shades of brown or grey may form around the centre (Shankara *et al*., 2005).

2.1.8.1 Early blight of tomato and its management

Early blight of tomato caused by *Alternaria solani* is one of the most common and destructive diseases of tomato in areas of heavy dew, rainfall and relative humidity (Norman, 1992). *Alternaria* sporulates best at about 27 ºC when abundant moisture (as provided by rain, mist, fog, dew, irrigation) is present. The fungus survives in infected plant debris in or on the soil for at least one and perhaps several years (Nash and Gardner, 1988). It can also be seed-borne. The spores can be transported by water, wind, insects, other animals including man, and machinery. The fungus can cause disease on foliage (leaf blight), stem (collar rot / stem cankers), seedlings (damping-off), and fruit (fruit rot). It can result in severe damage during all stages of plant development (Nash and Gardner, 1988). The leaf blight phase, commonly referred to as early blight, is the most important phase of the disease and can result in complete loss of the crop when incidence is severe (Kallo and Banerjee, 1993). Under irrigated conditions, susceptible hybrids can be severely damaged by early blight incurring a loss of 50 to 80 % (Mathur and Shekhawat, 1986).

The control of tomato early blight disease has been almost exclusively based on the application of chemical fungicides. Several effective fungicides have been recommended for use against this pathogen, but they are not considered to be long term solutions, due to concerns of expense, exposure risks, fungicide residues and other health and environmental hazards. Use of clean seed saved from disease-free plants, practicing three-year crop rotation with non-susceptible crops and the use of resistant or tolerant varieties are possible control measures (Norman, 1992).

2.1.8.2 Fusarium wilt of tomato and its management

Fusarium wilt is a disease caused by the soil-borne fungus, *Fusarium oxysporum f. sp. lycopersici*. Plants infected by this soil-dwelling fungus show leaf yellowing and wilt (http/www.hort.iastate.edu). The fungus works its way up through the plant's roots, clogging water-conducting tissue in the stem to prevent water from reaching branches and leaves, starving the plant (Lucas *et al*., 1987). Interior of main stem when split shows discoloured streaks from plugged water-conducting tissue (Mark *et al*., 2006). Affected plants produce very few tomatoes. Often, the entire plant dies.

The disease can attack at any stage in a tomato plant's growth. The fungus is favoured by temperatures between 21° and 32° C and wet weather. Tomato crops in poorly drained soil are more susceptible to infection than those in well-drained soil (Mark *et* *al*., 2006). Wet soil allows the fungus to multiply which allows it to spread more easily. Fusarium wilt is more serious when root knot nematodes are present in the soil.

There is no chemical control available. To minimize losses from Fusarium wilt is to plant disease-free seed or transplant in well drained, disease-free soil, rotate at least four years away from tomatoes to reduce populations of the fungus in soil, and remove and destroy infected plant residue. Disinfest soils, seed-beds and greenhouses with fumes of fungicides (www.extension.iastate.edu/store).

2.1.8.3 Southern blight / Sclerotium rot of tomato and its management

Southern blight caused by *Sclerotium rolfsii* Sacc. affects a wide variety of crops, including tomato, potato, pepper, and eggplant (Lucas *et al*., 1987). It is found in warm climates worldwide (Bachi and Seebold, 2008). A close inspection at the base of the stem reveals brown lesions covered with a white fungal mat and mustard-size sclerotia. The disease causes sudden wilting of the foliage, followed by yellowing of the leaves and browning of stems (Bachi and Seebold, 2008). Wilting and plant death result from a decay of the stem or crown at the soil line (Bachi and Seebold, 2008).

The fungus is spread by infested soil or cultivating tools, infected transplants, running water, and as sclerotia mixed with seeds. It is soil-borne and control is by sanitization such as removal of infected plants, burying of crop debris to a depth of 24 cm, and avoiding dense plant population (Bachi and Seebold, 2008). According to avrdc publication (2005), fields well drained, rich in humus, and not too acidic, help to control the infection. Also, fungicide application at the time of planting, crop rotation with non-host crops such as maize, sorghum, small grains, or cotton reduces it. Disease levels have been reduced by application of ammonium nitrate either before planting or as three-phase side dressing at monthly intervals (www.isuagcenter.com).

2.1.8.4 Septoria leaf spot of tomato and its management

Septoria leaf spot is caused by a non-soil-borne fungus *Septoria lycopersici* (Speggazzini), but can survive in debris, perennials and weeds for at least three years. Round, yellow or water-soaked spots appear on undersides and tops of leaves which turn black or brown with tiny black dots in the centre. Heavily infected leaves turn completely yellow, and then brown, and fall. Spotting works its way up the plant and can infect stems (www.plantpath.iastate.edu). It can attack tomato plant at any point in the season. It is most common in humid weather and often affects tomato plants after a period of heavy rainfall. Septoria leaf spot does not display characteristic concentric spots seen in early blight. Control is by fungicide application, growing resistant varieties, and practicing crop rotation (Mark *et al*., 2006).

Other fungal diseases of tomato include late blight caused by *Phytophthora infestans* (Mont.) De Bary, Verticilium wilt caused by *Verticilium albo-atrum* Reink & Berthier. Powdery mildew caused by *Leveillula taurica* (Lev.) Arnaud, Leaf mould caused by *Cladosporium fulvum* Cook, Collar rot which can be caused by either *Alternaria* sp. *or Fusarium* sp. and damping off soil-borne pathogens (Chupp and Sherf, 1960). Also, Cercospora (black) leaf mold caused by *Cercospora fuligena* Roldan, fruit rot caused by various fungal species and anthracnose diseases caused by several fungal species in the genus *Colletotrichum*, including *C. coccodes* (Wallr.) Hughes, *C. dematium* (Pers. ex Fr.) Grove, *C. gloeosporioides* Penz. (Jones *et al.*, 1991).

2.1.9 Seed-borne fungi

Seed-borne diseases cause crop losses which may be of economic importance to many nations all over the world (Neergaard, 1977). The term seed-borne describes the state of any micro-organisms being carried with, on, or in the seed (Agarwal and Sinclaire, 1997; Agarwal, 1981). Seed may either be infected or contaminated (Agarwal and Sinclaire, 1987). Seed-borne diseases have received great attention, especially in Europe and North America (Mathur *et al.*, 2003). Diseases and injuries to seeds are caused by fungi, viruses, bacteria, and nematodes. Among the parasitic organisms, the fungi are frequently encountered on seeds (Neergaard, 1977). Seed-borne pathogens of tomato are known to cause serious field diseases of tomato and could cause diseases in other plants (Odebunmi-Osikanlu, 1989; Agrios, 1988). *Cladosporium fulvum* causes the leaf mould of tomato (Jones, 1973). *Alternaria solani* and *Fusarium oxysporum* are seed-borne fungi of tomato and cause blight, root rot and wilt of tomato, respectively (Sherf and Macnab, 1986**).** Inoculum carried by the seeds into the field may act as a source of primary inoculum for pathogens attacking other crops (Neergaard, 1977).

In countries such as Ghana and Nigeria where mixed cropping is the usual practice, novel pathogens are introduced into new crops and new localities (Emechebe, 1981). This contributes to the development of disease severity on cultivated field and the susceptible host plant (Danquah *et al.*, 2004). Some seed-borne fungi are non-pathogenic, but could cause diversity of seed losses (Richardson, 1990).

Seed-borne *Fusarium oxysporum f. sp. lycopersici* is one of the most devastating fungal diseases of tomato (Singh *et al*., 1980). *Fusarium oxysporum* causes post-harvest rot on tomato fruit (Abu Bakar *et al.,* 2012) and produce decayed water soaked with white or pinkish mould growth lesions. Also, seed-borne *Cladosporium* spp. produce black lesions on tomato fruits (Ramsey and Heiberg, 1952) with maximum storage rot at 30 °C (Shersingh *et al.,* 1983).

2.2 Seed infection by fungi

Seed infection establishment is complicated. Many factors, including environment, the host and the pathogen's physiological conditions, may work together to bring infection (Mathur *et al.*, 2003). Routine seed health testing during the Capacity Enhancement Project (CEP) mycology phase in Ghana revealed high levels of infections of maize, rice and cowpea seeds by *Fusarium verticillioides* (Saacardo) Neremberg, *Bipolaris oryzae* (Breda de Haan) Shoemand *Phoma sorghina* (Saac.) Boerema, Dorenbosch & van Kest, respectivelly, which adversely affected the farmers' yield (Danquah *et al.*, 2004). Danquah (1973) and Addison (1971) earlier had recognized the importance of plant diseases transmitted through seeds in Ghana. Clear (1992) isolated *Alternaria brassicicola* (Schw.) Wiltshiremore frequently than *Alternaria raphani* (Groves & Skolko) from canola seeds in Canada.

In India, Chahal and Kang (1979) obtained 3 to 59 % infection of *Alternaria brassicicola* in mustard seed samples. In Scotland, Richardson (1970) found that 10 % Brassica seed samples were infected by *A. brassicae* (Berkeley) Saccardo, carrying 1 to 39 % seed infection. Fungal infections cause both quantitative and qualitative damage to seeds, and, subsequently, reduce the size and weight of seeds. Fungi are responsible for deterioration of food resources in the seed.

Deterioration of protein in cowpea seeds is caused by *Aspergillus flavus* Link (Neergaard, 1977). Seeds are infected by different types of fungi before and after harvest, causing damage in the form of discoloration (Miles and Wilcoxson, 1986; Gopinath 1984). Seed infection by pathogenic fungi is undesirable because infected seeds often have reduced germination, poor seedling vigour and may transmit the fungus to the seedlings (Chirappa and Gambogi, 1986).

2.3 Methods of isolating seed-borne fungi

Seed-borne fungi could be incubated using the following methods; the standard blotter test, agar plate test, the freezing method and the water agar method. The type of isolation method depends on the type of seed being tested, the pathogen to be isolated, the species of pathogen concerned and the availability of the test method (Neergaard, 1979).

According to Neergaard (1979), although the blotter method has some limitations, it is internationally recognized by International Seed Test Association. This is because it is extremely useful for routine seed health test and provides quick identification of fungal habit characters such as the form, length and arrangement of conidiospores, the size, septation, colour, chain formation of conidia, appearance of spore masses, character of mycelium and density of colony. Also, it is applicable to all kind of seeds including cereals, vegetables, ornamentals and forest seeds. The method is a hybrid between the moist chamber procedure in plant pathology and the germination test used in seed technology (Neergaard, 1979).

Filter/blotter papers in blotter method have the ability to absorb and hold moisture for long periods. This gives the required moisture for the growth and sporulation of seed-borne fungi. Also, the filter/blotters are made with cellulose, complex carbohydrates that cannot be degraded by fungi for nutrition, there-by forcing the fungi to utilize the seed nutrients to grow and emerge from the seed (Neergaard, 1979). However, the cost of filter/blotter paper in developing countries is expensive and any replacement of blotter/ filters could be of substitute advantage.

2.4 Pathogenic soil-borne fungi of tomato

The genera of plant pathogenic fungi such as *Pythium, Phytophthora, Rhizoctonia, Sclerotium, Sclerotinia, Fusarium and Verticillium* have been reported to survive in the soil for many years due to the production of resilient survival structures in the form of melanized mycelium, chlamydospores, oozspores, zoospores and sclerotia (Watanabe, 2002). Soil-borne plant pathogens can significantly reduce yield and quality of vegetable crops such as tomato (Watanabe, 2002). Disease complex may arise from simultaneous infections of multiple soil-borne pathogens which could highly damage crops. Many diseases caused by soil-borne pathogens are difficult to predict, detect, and diagnose because the soil environment is extremely complex (Koike *et al*., 2003). The soil organisms that have the potential to be plant pathogens include fungi, bacteria, viruses, nematodes and protozoa. Some pathogens of the leaves and stems survive in the soil at various stages in their life cycles (Koike *et al*., 2003). The soil serves as a reservoir of inoculum of these pathogens, the majority of which are widely distributed in agricultural soils (Watanabe, 2002). Therefore, a soil phase of a plant pathogen may be important, even if the organism does not infect roots. A detrimental interaction between a soil organism and a plant is often highly specific (Koike *et al*., 2003). Highly specialised interactions between soil organisms and plants can kill seedlings and even adult crops (Koike *et al*., 2003).

2.5 Management of tomato fungal diseases and pathogens

Good and bad disease management practices pertain in most African countries. Such practices originate from the farmers' knowledge, others being cultural practices and also fungicidal control measures (Norman, 1992). According to Chupp and Sherf (1960), fungicides such as maneb, zineb, ziram, captan or dyrene can be sprayed on tomato fields four to six weeks after planting at repeated application interval of seven to ten days to treat various fungal diseases of tomato such as early blight, septoria leaf spot and other *Alternaria* infections. Control by exclusion mechanism can also be used to manage diseases of plants (Kahn, 1991).

According to Norman (1992) and Sinnadurai (1992), Diathane M45 (mancozeb) at 8 kg/ha has proved quite effective in giving a fair measure of control when sprayed 14 days after planting, thereafter at weekly intervals. Also, *Stemphylium solani* G.F.Weber, causal agent of gray leaf spot on tomato in Florida, Texas and Illinois, was controlled by fungicides (Norman, 1992)). Phoma rot of fruit, stem and leaf blight of tomato reported in England, West Indies and other tomato growing areas of the world caused by *Phoma destructiva* Plowr. and *Phoma* spp.can be controlled by these fungicides following the spraying procedures outlined for control of early blight disease and hot water seed treatment (Norman, 1992). Planting of resistant tomato varieties is the only effective means of controlling Fusarium wilt. Other fungal infections such as Phoma rot, Pleospora fruit rot, Cladosporium leaf mould and Cercospora leaf mould can be controlled with resistant cultivars. Also, adopting land and crop rotational systems provides effective control to majority of soil-borne fungal pathogens (Shankara *et al*., 2005).

2.6 Tomato farmers' knowledge, practices and perceptions on plant diseases

The farmers' knowledge, practices and perceptions being indigenous or modern could be a significant resource to contribute to efficiency, effectiveness, and sustainability of plant disease management process. According to Agrios (2005), disease incidence and severity may vary with variety, location, time of year, season, land-usage, and time of control measure, cultural practices and the cropping system.

2.6.1 Effect of seed treatment on incidence and severity of tomato fungal diseases

Hot water seed treatment may reduce the *Fusarium* pathogens in seed (Manners, 1992). It has been proven to control Septoria leaf spot and some species of *Alternaria* pathogens (Manners, 1992). Also, *Cercospora fuligena* Roldan which causes Cercospora leaf mold on tomato reported in Mexico, Japan, China, Philippines and other tropical countries, was found to be controlled by seed treatment and early spraying of tomato seedlings with fungicides such as ziram, ferban, maneb, and captan (Chupp and Sherf, 1960). According to Manners (1992), seeds, cuttings or bulbs may be treated physically with hot water to kill the pathogen and not the host. Cereal seeds have been treated from *Ustilago nuda* (Jens.) Kellerm.et Swingle the causal agent of loose smut by submerging in water at a temperature enough to kill the pathogen but not the cereal (Manners, 1992).

2.6.2 Effect of nursery/seed bed treatment on tomato fungal diseases' incidence and severity

Control methods such as seed bed sterilizations has been reported to be of little value to control Fusarium wilt infections but is effective to control Septoria leaf spot infection (Chupp and Sherf, 1960). However, seed-bed sterilizations are effective to reduce the incidence and severity of *Alternaria* infections (Chupp and Sherf, 1960). According to Harry and Febry (1986), composts materials such as treebark and sewage sludge have been used to control diseases caused by species of *Phytophthora and Rhizoctonia.* The principal controlling factor is the heat developed from composting.

2.6.3 Effect of land and crop rotations on incidence and severity of tomato fungal diseases

Long intervals of land rotations are useful to control majority of fungal diseases of most vegetable crops. At least four-year land rotations are required for effective control of Septoria leaf spot, Fusarium wilt and early blight (Chupp and Sherf, 1960). Crop rotations, weed eradications, proper amounts of fertilizer application and cautious watering help to reduce the spread of *Alternaria* infection (Manners, 1992). Rotating crops of different family reduces disease incidence and severity. Incidence of Fusarium wilt of banana caused by *Fusarium oxysporum f.sp.cubense* was found to reduce from 40 to 5 % in Taiwan by two to three year break during which rice was grown (Manners, 1992). However, crop rotations and similar practices fail to reduce the prevalence of Fusarium wilts of tomato (Chupp and Sherf, 1960). *Stemphylium botryosum* Waltr., causative of fruit rot of tomato, has been reported from all parts of the world to affect many vegetable crops and can be control with crop rotation practices and good seed treatment.

2.6.4 Effect of stage of crop growth and time of fungicide application on incidence and severity of fungal diseases

The growth stage of a crop (host) is a contributing factor towards disease incidence and severity (Manners, 1992). The stage could be favourable for the pathogen to enhance its infection. Fungicide should be applied at appropriate time for effective disease control. If applied too early after planting, it may not persist for long enough and, if applied too late after transplanting, the pathogen may have entered the host before the fungicide is applied. This renders the treatment useless (Manners, 1992). According to Chupp and Sherf (1960), fungicide spraying at two-four weeks after planting and seven to ten days intervals till early fruiting reduces the severity of ripe rot of anthracnose caused by *Colletotrichum* spp. Spraying at seedling stage reduces the spread of Septoria leaf spot, and Pleospora fruit rot caused by *Septoria lycopersici* and *Stemphylium* spp., respectively.

2.7 Incidence and severity of plant disease

Plant disease is measured by measuring the incidence of the disease. The number or proportion of plant units (leaves, stems, and fruit) that show disease symptoms in relation to the total number of units examined is incidence (Agrios, 2005). However, the severity of the disease is the proportion of leaf area or amount of plant tissue that is diseased and the yield loss caused by the disease (Bachi and Seebold, 2008). Measuring disease incidence is relatively quick in epidemiological studies to measure the spread of a disease through a field, region, or country (Jones *et al*., 1980). The level of disease damage, at which control costs just equal incremental crop returns is the economic threshold of the disease (Sherf and Macnab, 1986). This varies with the tolerance level (damage threshold) of the crop, which depends on the growth stage of the crop when attacked, crop management practices, environment, shifts in pathogen virulence, and new control practices (Agrios, 2005; Manners, 1992).

According to Manners (1992), a disease is epidemic when the percentage incidence and severity of the infection increases rapidly from a low level to a high one. In an endemic disease by contrast, the disease level remains fairly constant. The development of disease severity depends on the level of interaction between the host, the pathogen and the environment (Norman, 1992; Park, 1990).

Diseases such as cereal smuts, neck blast of rice, brown rot of stone fruits, and the vascular wilts of annuals have disease incidence that has a direct relationship to the severity of the disease and yield loss because each diseased plant or fruit is a total loss

(Agrios, 2005), whereas diseases such as most leaf spots, root lesions, and rusts in which plants are counted as diseased whether they are exhibiting a single lesion or hundreds of lesions, disease incidence may have little relationship to the severity of the disease or to yield loss.The yield loss is the difference between attainable yield and actualyield (Agrios, 2005).

2.7.1 Effect of temperature and season on incidence and severity of fungal diseases

Pathogens differ in their preference for higher or lower temperatures. Some fungi grow much faster at lower temperatures than others and there may be significant differences among races of the same fungus (Park, 1990). Temperature affects the number of spores formed in a unit plant area and the number of spores released in a given time period (Agrios, 2005). The effects of temperature on disease development are varied. Temperatures away from the optimum delay the germination of pathogen spores and germ tube growth, reduce the rate of vegetative growth or multiplication within the host, increase the latent period and decrease the rate of spore production (Manners, 1992).

As a result, many diseases develop best in areas, seasons, or years with cooler temperatures, whereas others develop best where and when relatively high temperatures prevail. Thus, the late blight pathogen, *Phytophthora infestans*, is most serious in the northern latitudes whereas in the subtropics, it is serious only during the winter (Agrios, 2005). Many diseases, such as the brown rot of stone fruits caused by *Monilinia fructicola* (Winter) Honey are favoured by relatively high temperatures and are limited to areas and seasons in which such temperatures are prevalent (Agrios, 2005). Several diseases, such as Fusarium wilt and anthracnose caused by

Colletotrichum, are favoured by high temperatures and are limited to hot areas; the subtropics and tropics (Agrios, 2005).

2.7.2 Effect of relative humidity and moisture on incidence and severity of fungal diseases

Moisture influences the initiation and development of infectious plant diseases in many interrelated ways. It may exist as rain or irrigation water on the plant surface or around the roots, as relative humidity in the air, and as dew (Ayres and Boddy, 1986). Moisture is indispensable for the germination of fungal spores and penetration of the host by the germ tube. The occurrence of many diseases in a particular region is closely correlated with the amount and distribution of rainfall within the year (Agrios, 2005). Rainfall determines not only the severity of the disease, but also whether the disease will occur in a given season and such periods are, therefore, frequently used in disease prediction systems (Agrios, 2005).

In many fungal epidemics, moisture affects the liberation of spores from the sporophores, as in apple scab caused by *Venturia inaequalis* (Cooke) Wint., can occur only in the presence of moisture (Jones *et al*., 1980). The severity of *Pythium* damping off infection of seedlings and seed decays is influenced by soil moisture (Agrios, 2005). Soil pathogens, including *Phytophthora*, *Rhizoctonia*, *Sclerotinia*, and *Sclerotium*, usually cause their most severe symptoms on plants when the soil is wet. Several other fungi such as *Fusarium solani* (Mart.) Apple & Wollen, which is the cause of dry root rot of beans, *Fusarium pallidoroseum* (Cooke) Saac., the cause of seedling blights, and *Macrophomina phaseoli* (Maulb.) S.F.Ashby, the cause of charcoal rot of sorghum and of root rot of cotton, grow fairly well in dry environments whereas vascular wilts caused by the fungus, *Verticillium*, are significantly more severe when the plants suffer from water stress (Agrios, 2005).

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study comprised a survey to identify major fungal diseases of tomato and score for their incidence and severity, administering questionnaire to document tomato farmers' knowledge and practices towards management of fungal diseases and isolation of seed-borne fungi associated with farmer-saved tomato seeds, using the blotter method.

3.1.1 Documentation of incidence and severity of fungal diseases of tomato

A survey was conducted in some selected communities in the following major tomato growing districts; Offinso North District (Nkenkaasu, Akomadan, Afrancho), Techiman Municipality (Tuobodom, Tanoboase and Bonomanso) and Agogo District (Agogo township, Nyantokro and Abrewapon) between August and November, 2011. Incidence and severity of fungal diseases of tomato were documented. Survey on tomato farms were conducted at the flowering stage for all districts. The distance between the selected farms in a community was 0.5-1 km apart.

In each District, 30 farms were randomly selected and screened. On each farm, 30 tomato plants were randomly selected on a diagonal direction across the farm and were examined for incidence and severity. The tomato farms selected for scoring were of 0.40 - 0.80 ha in size. The distributions of farms screened are presented in Table 1.

Plate 1: A farm infected by wilt and blight diseases at Akomadan in Offinso North District

Table 1: Distribution of farms screened for disease incidence and severity

Municipal/District	Town	Number of farms surveyed
Offinso North	Nkenkaasu	10
	Akomadan	10
	Afrancho	10
Techiman	Tuobodom	18
	Tanoboase	7
	Bonomanso	5
Agogo	Agogo township	10
	Nyantokro	10
	Abrewapon	10
Total		90

Fungal disease severity was scored, based on a 1-5 scale (CSIR- Crops Research Institute Kumasi, Ghana); Anonymous (2008) as follows:

1→ No disease symptom expression on tomato plant

2 → Disease symptom expression on leaf of tomato plant to cover 5-25 % of the total leaf (s) area

3→ Disease symptom expression on leaf greater than 25-50 % of the total leaf (s) area of tomato plant

4→ Disease symptom expression on leaf and tissues greater than 50-75 % of the total leaf (s) area of tomato plant where at most a single fruit is assessed as yield

5→ Disease symptom expression on leaf and tissues greater than 75-100 % of the total leaf (s) area causing complete death of tomato plant to the point of no recovery or no yield attained.

Final disease incidence and severity were calculated using the formula recommended by CSIR- Crops Research Institute Kumasi, Ghana as below:

Disease incidence = [Number of infected plants / Total plant scored] x 100

$$\text{Disease severity} = \frac{\sum \text{(Number of plants scored for each rating x the rating value)}}{\text{Total plants scored}}$$

The data collected included fungal disease (s) incidence per farm/district and fungal disease (s) severity per farm/district (Appendices 2, 3 and 4). In addition to fungal diseases, plants were scored for the presence of tomato yellow leaf curl disease (TYLCV). Samples of diseased tomato seedlings, the causal agent of which could not be identified on farm as well as samples of fungal diseased tomato plants that were scored for disease incidence and severity were collected into an ice chest and studied further in the laboratory. Also, farmer-saved tomato seeds were collected from farmers into sterilised envelopes for seed health test.

3.1.2 Documentation of farmers' knowledge, perceptions, and disease control practices

Questionnaire (Appendix 8) comprising structured and unstructured questions were administered to document tomato farmers' knowledge, perceptions and control practices on tomato diseases. The data collected included;

i. farmers' knowledge and perceptions on the identified fungal diseases of tomato,

ii. farmers' control measures to the identified fungal infection,

iii. farmers' practices on seed treatment for storage,

iv. farmers' sources of tomato seeds,

v. farmers' nursery practices,

vi. tomato varieties cultivated and their susceptibility to the identified infections

vii. seedling infections of tomato,

viii. gender, age and educational level of tomato farmers,

ix. number of years of respondents in tomato production and

x. cost of tomato production and yield attain per 0.4 ha with disease and no disease effect.

3.2 Identification of fungi infecting tomato seedlings and unknown tomato disease

Samples of diseased tomato seedlings collected during the field surveys were labeled as A- leaf yellowing, B - wilting, C – black spots on leaves and stem of tomato, D – basal stem canker and E- damping off. Isolations of fungal pathogens were done at the Plant Pathology laboratories of Faculty of Agriculture, KNUST and CSIR -Crops Research Institute, Kumasi, to identify the causative organisms of the infections.

Small pieces of the infected stems and leaves (2-5 mm sq) were cut from the edges of infections of the plants using a sharp scaple blade and a pair of laboratory scissors. The equipments were sterilized periodically in the process by flaming. The cut pieces were sterilized for 3 min in 10 % sodium hypochlorite solution and rinsed in five changes of sterilized distilled water. The infected pieces were dried on sterilized filter paper under lamina flow bench and placed on a prepared potato dextrose agar (PDA). The inoculated plates were incubated at 27 ºC for seven to fourteen days during which pure cultures of microbial growth were established for identification. The fungal Identification was carried out under a compound microscope and with the aid of fungi descriptions manuals (Mathur and Kongsdale, 2003; Barnett and Hunter, 1972). The PDA was prepared as follows; tubers of potato were washed, cut into pieces and 200 g of the material was weighed and boiled with 1000 ml distilled water. Upon cooking, the pieces were mashed and strained through three layers of chese cloth. 20 g of agar and 500 g of antibiotics (tetracycline) were added to the filtrate. The mixture was then sterilized by autoclaving at 121 ºC (141bin = : 0.98 kg cm-2 pressure) for 15 minutes in Erlenmeyer flasks. After cooling, the medium was poured into autoclaved petri dishes at the rate of 15 ml per plate and was allowed to solidify under sterile condition.

3.3 Determination of seed-borne fungi associated with farmer-saved tomato seeds

A total of 68 farmer-saved tomato seed samples were collected from the tomato producing areas during the surveys. The number of farmer-saved tomato seed lots collected at each locality for each district varied, depending on availability: Offinso

North District (Nkenkaasu (8), Akomadan (8), Afrancho (7), Techiman Municipality (Tuobodom (13), Tanoboase (5), Bonomanso (4), Agogo District (Agogo township (10), Nyantokro (7), and Abrewapon (6). Information on seeds collected were; name of farmer, Agro-ecological zone, village/community, variety, seed type, date of harvest and storage period. These were subsequently, registered and stored in the cold room at CSIR-Crops Research Institute, Kumasi, during the seed health tests.

Table 2: Number of tomato seed samples and working seeds tested / District

Municipality/District	Number of seed samples	Number of working seeds
Offinso North	23	4600
Techiman	22	4400
Agogo	23	4600
Total	68	13600

The 68 farmer-saved tomato seed samples collected were plated, using the blotter method (ISTA, 2005; Mathur and Kongsdal, 2003). The plating was done using Complete Randomized Design with 200 seeds per sample and 25 tomato seeds per plate. The plated seeds were arranged in seed trays and incubated at 20 ±2 ºC under alternating cycles of 12/12h of near ultraviolet light (NUV or florescent light) and darkness for seven days to enhance sporulation of seed-borne fungi. Four replicates of each sample were incubated. Plates were examined for fungal growth, using stereomicroscope. Fungi found growing on seeds were carefully examined and identified, based on habit characters (Mathur and Kongsdal, 2003).

Also, some fungi found growing on seeds on blotters were further cultured on PDA and Microscopic characteristics such as spore or conidia shapes and other reproductive structures produced on PDA by fungi isolates were also depended on for identification (Mathur and Kongsdale, 2003; Barnett and Hunter, 1972). The percentage infections of seed-borne fungiidentified on seeds were calculated per district. Also, the incidence of seed-borne fungi was determined on number of seed-samples collected for each District.

The percentage occurrence or percentage infection of seed-borne fungi on farmer-saved tomato seeds was calculated using the formula recommended by Neergaard (1979) and CSIR- Crops Research Institute Kumasi, Ghana) as follows:

$$\% \text{ infection of seed-borne fungi on seeds} = \frac{\text{Sum of infected seeds}}{\text{Total number of seeds tested}} \times 100$$

$$\% \text{ infection of seed-borne fungi on seed lots} = \frac{\text{Number of seed samples infected}}{\text{Total number of seed samples tested}} \times 100$$

3.4 Analysis of Data

Calculations were done on data for each disease incidence and severity. They were summarized for their mean percentages per municipality/district and the results were presented in tables. Data on tomato farmers' knowledge and perceptions on diseases and their control practices were summarized in percentages and presented in bar charts. Results on seed health tests were determined in percentages and presented in tables for municipality/districts. Data on socio-demographic characteristics of tomato farmers (respondents) were also determined in percentages and presented in table and pie chart.

CHAPTER FOUR

4.0 RESULTS

The results of the studies are presented in Tables 3 to 10, Figures 1 to 9 and Appendices 2 to 7. The results cover the incidence and severity of identified fungal diseases of tomato, farmers' knowledge, perceptions and control practices towards the management of identified fungal diseases of tomato, and the incidence of seed-borne fungi associated with farmer-saved tomato seeds.

4.1.1 Major fungal diseases of tomato identified in the studied districts

A total of five tomato fungal diseases were identified in the study areas. The diseases were Early blight, Septoria leaf spot, Fusarium wilt, Collar rot, and Sclerotium rot. (Plates 2- 6 indicate symptom expressions of these diseases).

Plate 2: Early blight of tomato (Symptoms arrowed)

Plate 3: Fusarium wilt of tomato (Symptoms arrowed)

Plate 4: Collar rot of tomato (Symptoms arrowed)

Plate 5: Septoria leaf spot of tomato (Symptoms arrowed)

Plate 6: **Sclerotium rot of tomato (Symptoms arrowed)**

Respectively, the pathogens isolated from these diseased plants were *Alternaria solani* (Ellis and Martin) Jones and Grout, *Fusarium oxysporum f. sp. lycopersici*, *Fusarium* spp. and *Sclerotium rolfsii* Sacc. The pathogen that causes Septoria leaf spot of tomato (Plate 5) coud not be isolated.

Early blight was found in all the districts with the highest incidence of 63.9 % occurring in Agogo, followed by 43.5 % in Offinso-North Districts (Table 3). Fusarium wilt was found in all the districts, with highest incidence of 45.2 % occurring in Agogo District (Table 3).

The highest incidence of Sclerotium rot recorded was 36.8 % in Offinso North District, but was not recorded in Agogo District (Table 3). Incidence of Septoria leaf spot was recorded in all the districts with 34.0 % most prevalent in Offinso North District. Incidence of collar rot was 37.5 % most prevalent in Agogo District (Table 3). Generally, all the major fungal diseases of tomato were encountered in all the study areas.

Table 3: Incidence of major fungal diseases of tomato in the studied districts

District or Municipality	Mean % disease incidence /District or Municipality				
	Early blight	Septoria leaf spot	Fusarium wilt	Collar rot	Sclerotium rot
Agogo	63.9	19.1	45.2	37.5	0.0
	(0-90)*	(0-82)	(0-83)	(0-73)	(0.0)
Offinso North	43.5	34.0	41.6	32.9	36.8
	(0-73)	(0-80)	(0-83)	(0-77)	(0-80)
Techiman	38.2	21.9	24.9	14.3	19.1
	(0-63)	(0-67)	(0-70)	(0-60)	(0-60)

** Values in brackets are % range of fungal diseases incidence*

4.1.2 Severity of major fungal diseases of tomato in the studied districts

Early blight and Fusarium wilt recorded the highest severity score of 2.0 in Agogo District (Table 4). The least severity of Septoria leaf spot recorded was 0.6 and this was in Agogo District (Table 4). In the Offinso-North District, Fusarium wilt and Sclerotium rot recorded the highest severity of 2.0 (Table 4). The least severities of collar rot recorded were 1.1 and 0.5 in Offinso North and Techiman Districts, respectively (Table 4). Sclerotium rot was not found in Agogo Districts. Generally, the severity of the fungal diseases identified from the study areas was as high as 25 %. This indicates that incidence of fungal disease caused 25 % damage to tomato crops in the study areas.

Table 4: Severity of fungal disease of tomato in the studied districts

District or Municipality	% Mean severity score (scale 1-5)* of fungal diseases / District or Municipality				
	Early blight	Septoria leaf spot	Fusarium wilt	Collar rot	Sclerotium rot
Agogo	2.0	0.6	2.0	1.3	0.0
Offinso North	1.5	1.1	2.0	1.1	2.0
Techiman	1.3	0.7	0.8	0.5	0.7

**Scores representing means of severity measured on a 1-5 scale are defined below:*

1→ No disease symptoms

2 → Disease symptoms to cover 5-25% of the total leaf (s) area

3→ Disease symptoms to cover 25-50% of the total leaf (s) area

4→ Disease symptoms to cover 50-75% of the total leaf (s) area where at most a single fruit is assessed as yield

5→ Disease symptom expression on leaf and tissues to cover 75-100% of the total leaf (s) area

4.2 Tomato farmers' knowledge and perceptions on fungal diseases identified

The results showed that majority (76 – 99 %) of the farmers knew the infections as diseases and reported that these diseases occurred at all stages of plant growth (Fig.1). They perceived the causes of these infections to be the soil and low temperature conditions. Most (97 %) farmers perceived Early blight damage as leaf yellowing of seedlings, to yellowing, spotting and falling of leaves. Upon severe infection, yellowing of leaves causes death of plants. Also, they reported that there is formation of small fruits and fruit rot at the advance stage (Fig.1). Also, 80 to 99 % farmers reported damage caused by Fusarium wilt as wilting and dying of tomato crops in greenish state at three weeks after transplanting. They also reported that Collar rot produces basal stem canker on tomato plants and seedlings on the nursery. Total tomato plant population wilt at two to three weeks upon high incidence of collar rot disease and plants that are able to manage the disease produce small, few and rotted fruits similar to Fusarium wilt when infection occurred at fruiting stage (Fig.1).

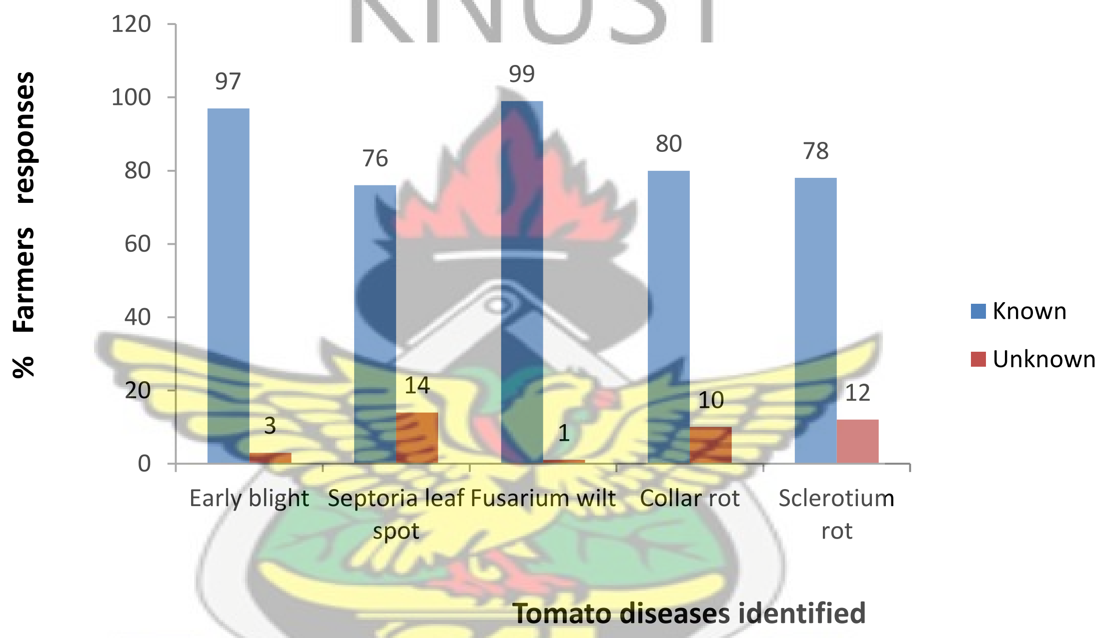

Fig. 1: Farmers response to knowledge and perception on fungal diseases of tomato identified

4.3 Tomato Farmers' control measures against the fungal diseases identified

The results showed that apart from Sclerotium rot, the majority (72 – 98 %) of the farmers implemented a control measure (Fig. 2). Application of fungicides, according to the farmers, was the only strategy employed for the management of diseases. The commonly used fungicides include Dithane M-45 (Mancozeb); Topsin (Thiophanate – methyl); Kocide (Copper Hydroxide); Ridomil Plus (Mefenoxam); Funguran (Copper

Hydroxide); and Champion (Copper Hydroxide). However, 52 % of farmers do not implement control measure to Sclerotium rot (Fig. 2). Also, 60 % of farmers who implemented control measure reported that these fungicides were not effective in controlling the diseases, especially Fusarium wilt, Collar rot and Sclerotium rot (Fig.2).

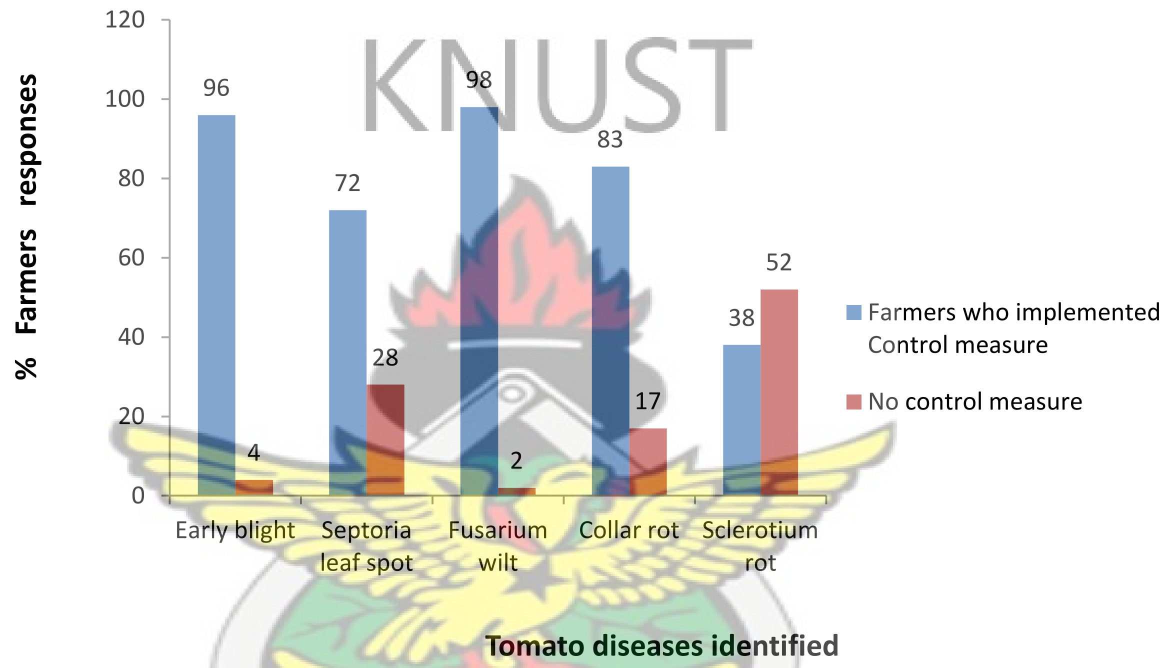

Fig. 2: Farmers' response to control measure on fungal disease of tomato identified

4.4 Disease management practices by the tomato farmers

4.4.1 Seed treatment practices

Only 14 % of the farmers interviewed treated their seeds (Fig.3). The chemical seed treatment methods reported by them include mixing the seeds with lambda super 2.5 EC (lambda- cyhalothrin), Dithane M-45 powder or Dithane M-45 solution (80 % mancozeb) air dry before storage. Others mixed the seeds with Furadan (carbofuran 3 % G), Cobox or Funguran (Copper hydroxide) and kept in paper for storage. The majority of tomato farmers (86 %) stored their seeds without any treatment (Fig.3).

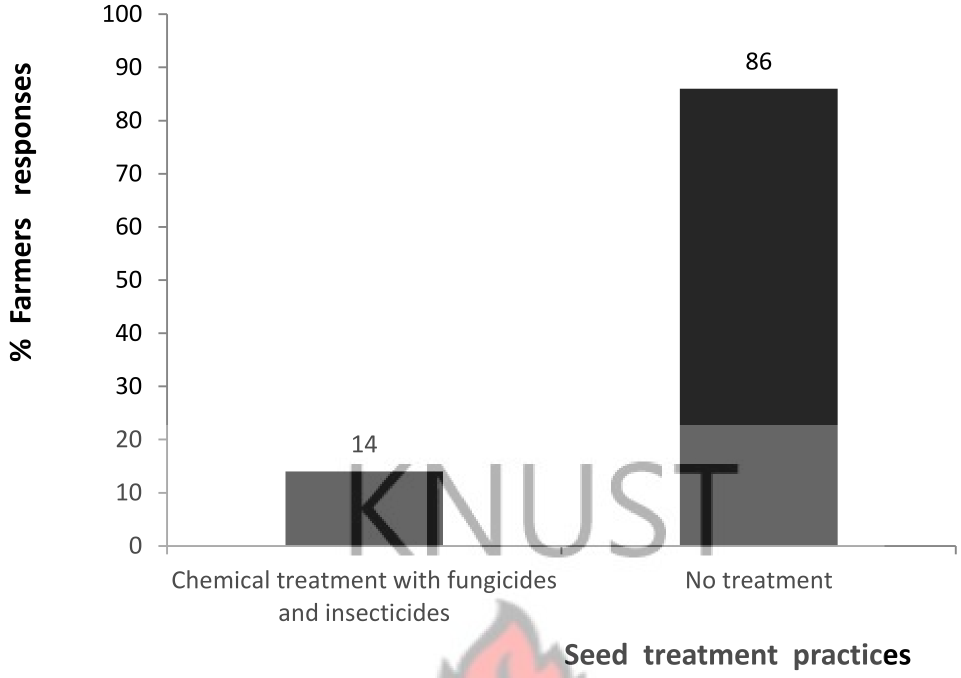

Fig. 3: Tomato farmer's responses to seed treatment

4.4.2 Seedling and nursery bed practices

Majority (62 %) of the farmers reported burning of dried weeds (stubble) on the nursery bed prior to sowing of seeds as their soil treatment practice against pathogens and pests (Fig. 4). Only 30 % farmers treated their nursery beds with chemicals against pathogens and pests (Fig. 4). The identified seedlings and nursery bed chemical treatments practiced by the Farmers included: application of Funguran on nursery-bed prior to sowing, mixing of Ridomil Plus with seeds or sprayed on bed and at seedling emergence. Dithane M-45 is sprayed on seedlings upon emergence and Furadan is broadcast on the nursery bed followed by watering. Also, a mixture of Furadan + Dithane M-45 is applied on nursery bed. Spraying of Lambda super 2.5 EC to seed bed before sowing. Others reported of Ridomil Plus and Sunpyrifos 48 % EC (Chlorpyrifos-ethyl) application immediately after germination.

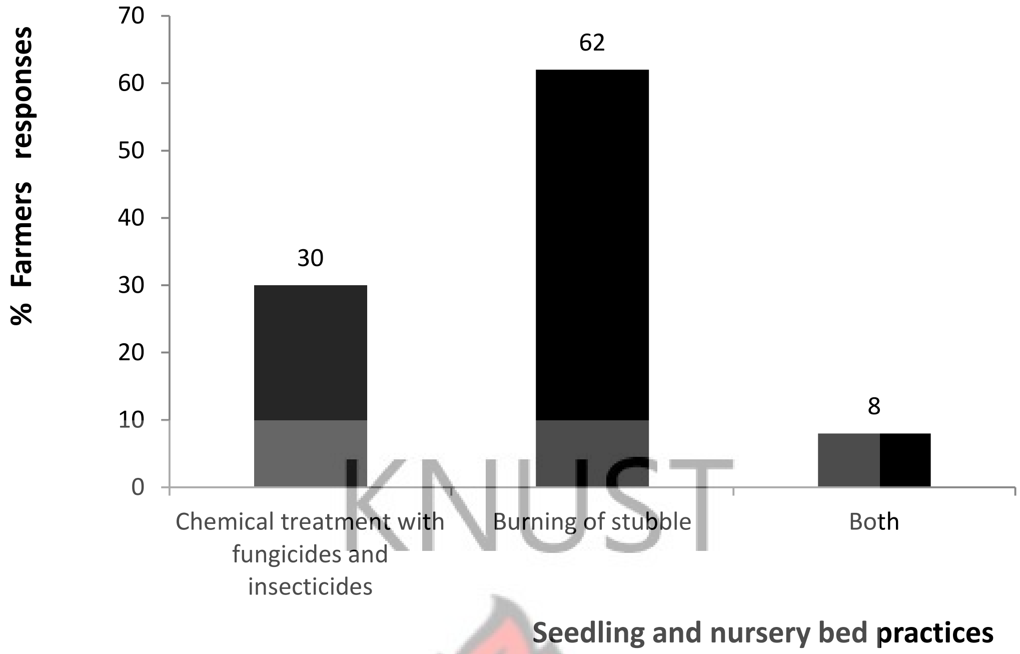

Fig . 4: Tomato farmers' seedling and nursery bed practices

4.4.3 Source of tomato seedlings

Most (79 %) of the tomato farmers raised their own seedlings on prepared beds on their fields meant for the seasonal tomato production, while 10 % farmers patronised seedlings raised by their friends far away from their cultivated fields (Fig.5). The remaining 11 % of the farmers obtained their seedlings from their own and their friends' nursery.

Fig. 5: Farmers source of tomato seedlings

4.4.4 Source of seeds

Eighty-six percent of the farmers utilised Farmer –saved tomato seeds. Nine per cent of responded farmers patronised certified seeds imported, and only 5 % of farmers patronised both sources (Fig.6).

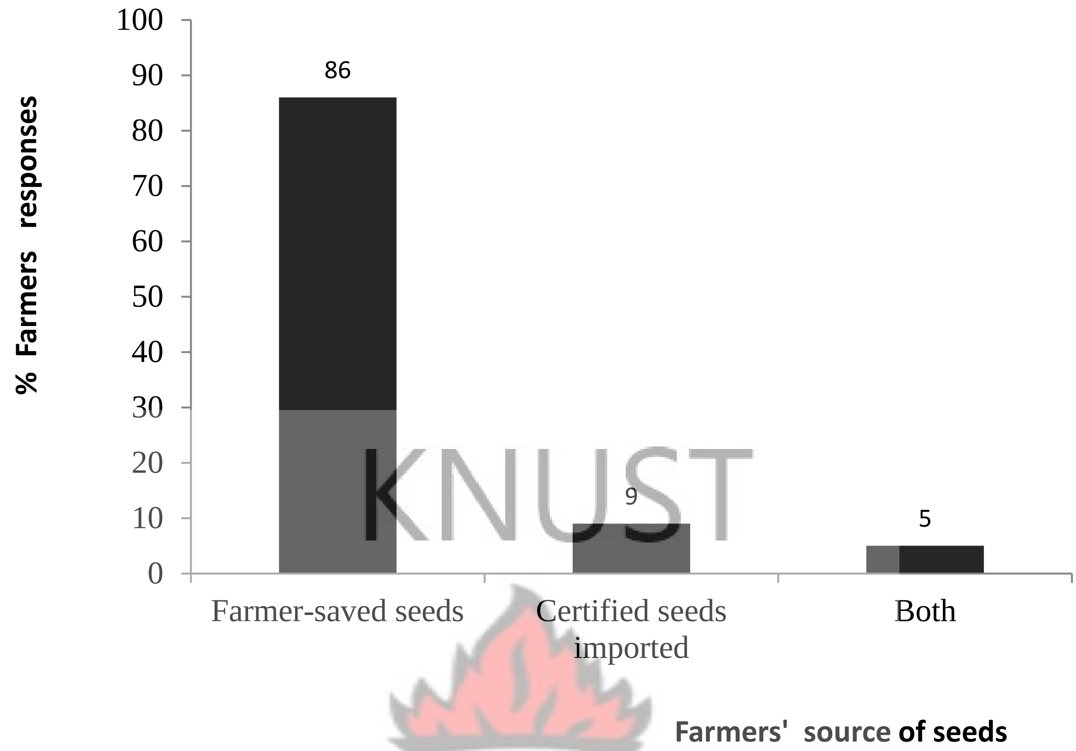

Fig. 6: Farmers source of tomato seeds

4.4.5 Tomato varieties grown by Farmers

Majority (97 % - 100 %) of farmers grow Pectomech ("Pecto" or "Pectofake") and Power-Rano ("Abonkruwa" or "Rano"). Only 26 % of farmers grow Power ("Caterpillar" or "Rasta"), whereas 31 % of the farmers cultivated "Akoma" variety. Most of the farmers reported that none of these varieties is able to withstand disease attack, except Power-Rasta (Fig.7).

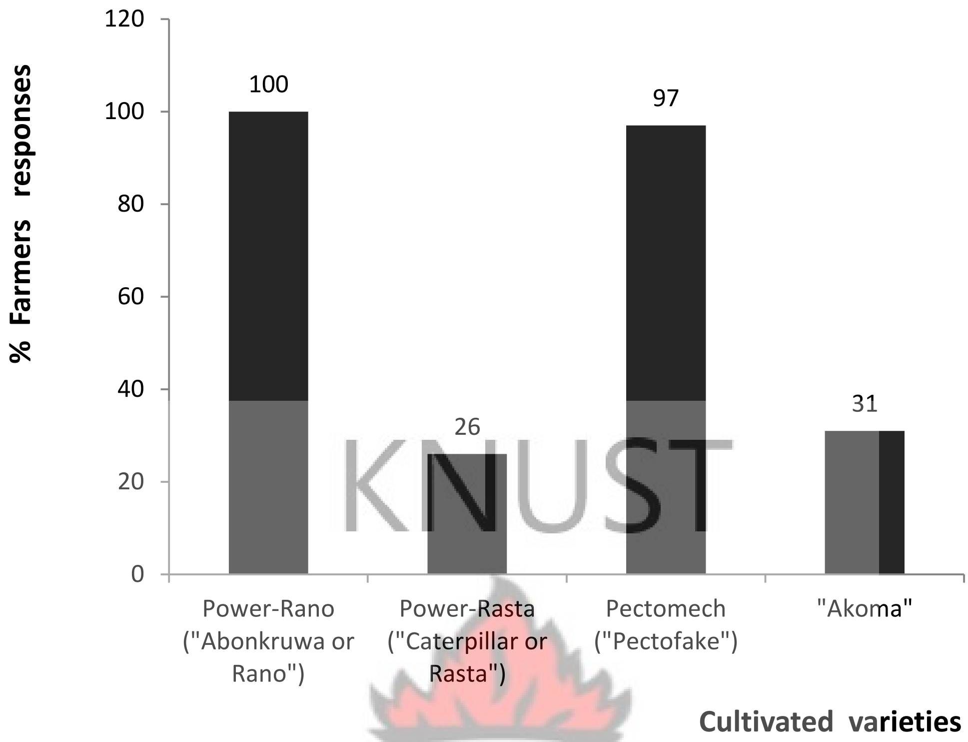

Fig. 7: Tomato varieties cultivated by farmers

4.5 Socio – Demographic Characteristics of Respondents

4.5.1 Gender, age and educational level of tomato farmers

Out of the 90 tomato farmers interacted with; there was a clear dominance of male (83.3 %) as against female (16.7 %) producers (Table 5). Majority (74.4 %) of the farmers were within the age range of 31 – 50 years while, 5.6 % constituted those above 50 years. Additionally, only 20.0 % had secondary education as the highest level, while the rest 36.7, 31.1 and 12.0 % had basic, non formal education and no education, respectively (Table 5).

Table 5: Percentage distribution of tomato farmers based on gender, age, and level of Education in Agogo, Offinso North Districts and Techiman Municipality

Variable	% Tomato farmers
A. Gender	
Male	83.3
Female	16.7
B. Age	
20-30 years	20.0
31-40 years	35.5
41-50 years	38.9
Above 50 years	5.6
C. Educational level	
No education	12.0
Non formal	31.1
Basic	36.7
Secondary	20.0

4.5.2 Number of years of respondents in tomato production

Farmers' experiences in years of tomato cultivation varied. From the survey, 22 % of the farmers have been producing tomatoes for more than 20 years (Fig. 8). 27 % of farmers have been in it for 15 years while, 31 % farmers have been in tomato production for 10 years.

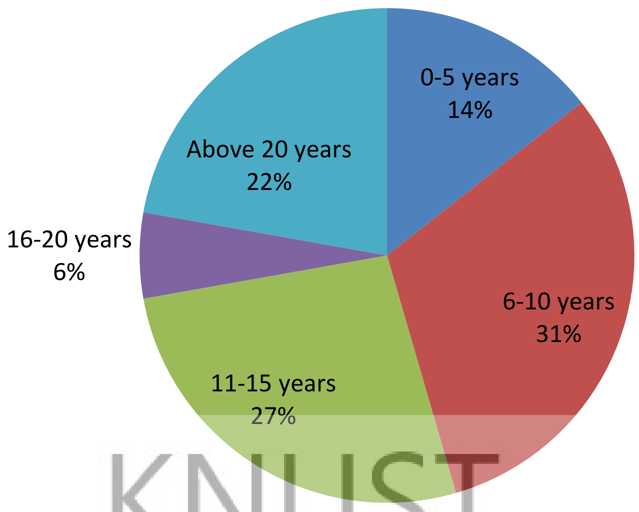

Fig. 8: Experience of respondents in tomato production in the studied districts

All the farmers reported diseases as the major hindrance to tomato production. Plate 1 confirms fungal diseases as major problem to tomato farmers at Akomadan in the Offinso-North District. Other factors mentioned were: inadequate rainfall, transportation difficulty, low prices for their produce and inadequate funding.

4.5.3 Cost of tomato production and yield attained per 0.4 ha with diseased and no diseased effect in the studied districts

According to the farmers, they spent GH¢ 400-500, excluding the cost of their personal effort, and GH¢ 800-1000 including the cost of their personal effort, on 0.4 ha of tomato production and can obtain 100-135 crates of tomatoes / 0.4 ha under good farming management practices and without disease incidence (Table 6). However, if no control measure, incidence of diseases reduced yield to 1-20 crates / 0.4 ha of tomato farm, depending on the type of infection (Table 6).

Table 6: Cost of tomato production and yield attained per 0.4 ha with disease and no disease effect in the studied districts

Variable	Attainable yield / crate	% Tomato farmers
A. Famers' cost of production GH¢		
400-500 excluding farmers effort	100-135	100
800-1000 including farmers effort	100-135	100
B. Disease effect		
Incidence of disease	1-20	100
Absence of disease	100-135	100

4.6 Seedling infections of tomato identified in the studied districts

By symptom expression, black spots on leaves and stems, basal stem canker, wilting, damping-off and leaf yellowing were seedling infections observed and reported by farmers (Fig. 9). Most (77 %) farmers described wilting as a serious nursery infection of tomato with no control (Fig. 9). Farmers (57 %) reported black spots on leaves and stems locally called "nkateyadie" as serious seedling infection (Fig. 9). Additionally, 51 % of farmers reported basal stem canker locally called "Akwekwee" as major nursery infection and that can also occur on the field after transplanting (Fig. 9). Wilt and basal stem canker were identified as Fusarium wilt and Collar rot, respectively, due to *Fusarium* spp. isolated (Appendix 5). Also, *Alternaria* sp. and *Bipolaris* sp. were isolated from seedlings of leaf yellowing symptom. No organism was isolated from damping-off seedlings however; *Curvularia pallescens* was isolated fom seedlings of black spots symptoms (Appendix 5). Plates 7 and 8 show some of the seedling infections of tomato identified.

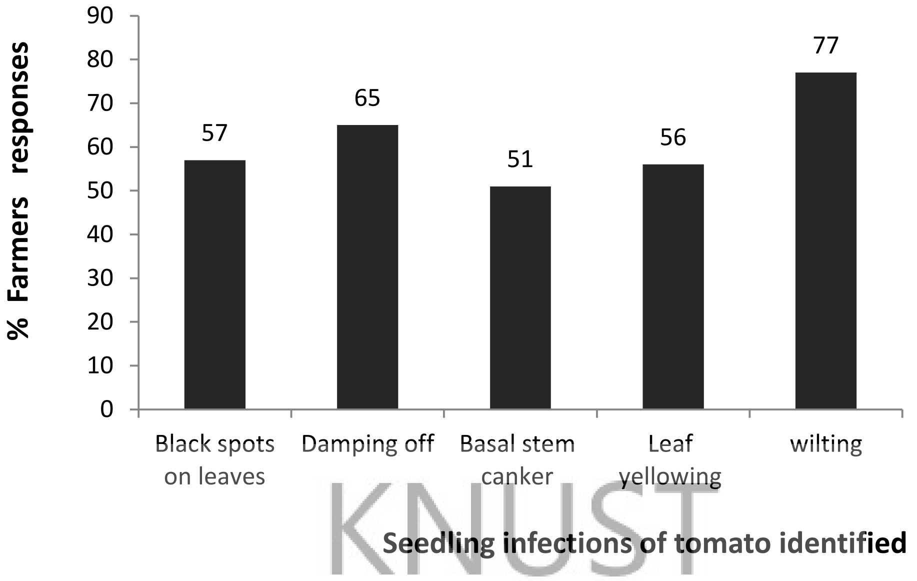

Fig. 9: Farmers' response to tomato seedling infections identified

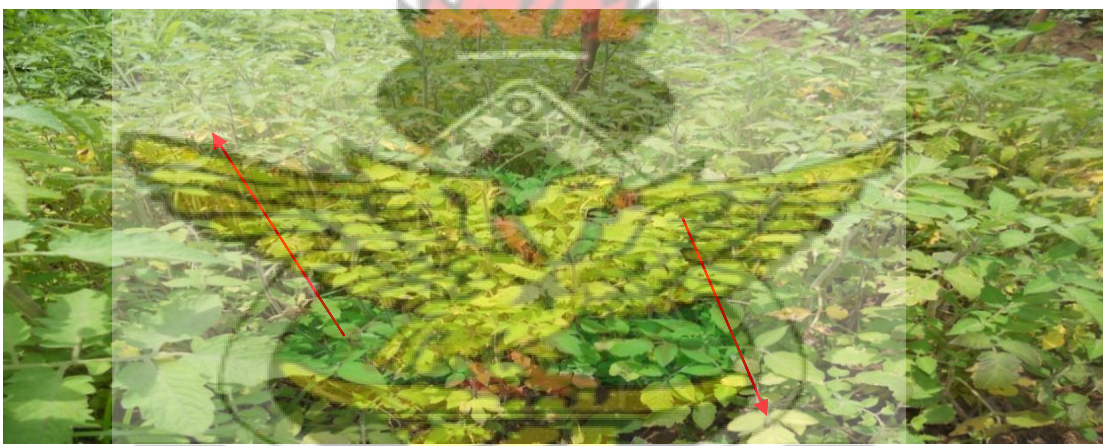

Plate 7: Leaf yellowing infection of tomato seedlings (Arrowed)

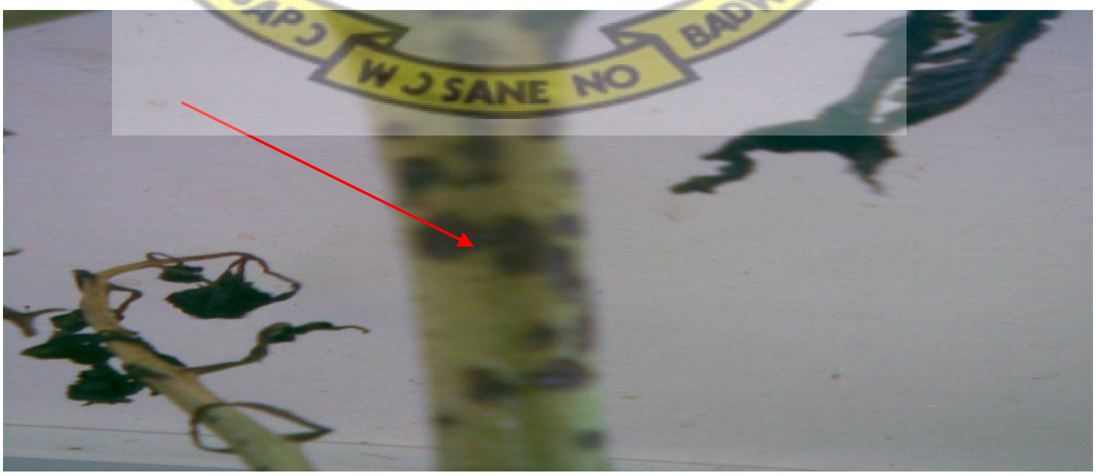

Plate 8: Black spots and lesions infection on stem of tomato seedling (Arrowed)

4.7 Seed-health test: Incidence of seed-borne fungi on farmer-saved tomato seeds

Out of the 68 farmer-saved tomato seed samples tested for seed-borne fungal pathogens, a total of 22 species of fungi from 12 genera were identified (Table 10). The mean percentage infections of seed-borne fungi of tomato seeds recorded in the study are presented in Tables 7 to 10. Important seed-borne pathogenic fungi recorded were *Alternaria* sp., *Cercospora* sp., *Colletotrichum* sp., *Curvularia lunata* (Wakk.) Boedijn, *Curvularia pallenscens* Boedijn, *Fusarium culmorum* (W.G Smith) Sacc., *Fusarium equiseti* (Corda) Sacc., *Fusarium oxysporum f. lycopersici* (Saccardo) Snyder and Hansen, *Fusarium pallidoreseum* (Cooke) Sacc., *Fusarium poae* (Peek) Wollenweber, *Fusarium verticillioides, Phoma exigua* Desmaz., *Phoma sorghina* (Sacc.) Boerema Dorenbosch & van Kest, *Phoma* sp. and *Rhizoctonia solani* Kuhn (Tables 7, 8, and 9).

4.7.1: Incidence of seed-borne fungi associated with farmer-saved tomato seeds from Agogo District

The results showed that apart from *Cercospora* sp. and *Rhizoctonia solani*, the seed-borne fungi isolated from Agogo seeds recorded a mean percentage infection of 10.5 % (Table 7). The storage fungi *Rhizopus* sp., *A. flavus, Penicillium and A. niger* recorded the highest percentage infection of 38, 33.4, 27.0 and 20.5 %, respectively. However, with the exception of *F. oxysporum,* the pathogenic fungi isolated recorded the least percentage infections, respectively. The pathogenic fungi *Alternaria* sp. and *F. oxysporum* recorded 2.0 and 26.5 %, respectively (Table 7).

Table 7: Percentage infection of seed-borne fungi on farmer-saved tomato seeds from Agogo District in the Forest and Forest-Savannah agro-ecological zones of Ghana

Fungi Identified	Number of seed samples	Number of seeds tested	Number of seeds infected	% Incidence of seed-borne fungi
Alternaria sp.	23	4600	92	2.0
Aspergillus flavus	23	4600	1536	33.4
Aspergillus niger	23	4600	943	20.5
Aspergillus sp.	23	4600	322	7.0
Bipolaris sp.	23	4600	115	2.5
Cercospora sp.	23	4600	0	0.0
Colletotrichum sp.	23	4600	23	0.5
Curvularia lunata	23	4600	230	5.0
Curvularia pallescens	23	4600	322	7.0
Fusarium culmorum	23	4600	115	2.5
Fusarium equiseti	23	4600	322	7.0
Fusarium oxysporum	23	4600	1219	26.5
Fusarium pallidoreseum	23	4600	23	0.5
Fusarium poae	23	4600	92	2.0
Fusarium verticillioides	23	4600	368	8.0
Melanospora zamiae	23	4600	23	0.5
Phoma exigua	23	4600	46	1.0
Phoma sorghina	23	4600	874	19.0
Phoma sp.	23	4600	23	0.5
Penicillium sp.	23	4600	1242	27.0
Rhizopus sp.	23	4600	1748	38.0
Rhizoctonia solani	23	4600	0	0.0
% Mean infection	-	-	-	10.5

4.7.2: Incidence of seed-borne fungi associated with farmer-saved tomato seeds from Offinso North District

In the Offinso North District, apart from *Bipolaris* sp., *Colletotrichum* sp., *F. culmorum, F. equiseti, F. pallidoreseum, Melanospora zamiae* and *Rhizoctonia solani*, the seed-borne fungi isolated from seeds of Offinso-North District recorded a mean percentage infection of 9.1 % (Table 8).

Table 8: Percentage infection of seed-borne fungi on farmer-saved tomato seeds from Offinso North District in the Forest and Forest-Savannah agro-ecological zones of Ghana

Fungi Identified	Number of seed samples	Number of seeds tested	Number of seeds infected	% Incidence of seed-borne fungi
Alternaria sp.	23	4600	69	1.5
Aspergillus flavus	23	4600	1541	33.5
Aspergillus niger	23	4600	322	7.0
Aspergillus sp.	23	4600	506	11.0
Bipolaris sp.	23	4600	0	0.5
Cercospora sp.	23	4600	69	1.5
Colletotrichum sp.	23	4600	0	0.0
Curvularia lunata	23	4600	322	7.0
Curvularia pallescens	23	4600	1472	32.0
Fusarium culmorum	23	4600	0	0.0
Fusarium equiseti	23	4600	0	0.0
Fusarium oxysporum	23	4600	851	18.5
Fusarium pallidoreseum	23	4600	0	0.0
Fusarium poae	23	4600	115	2.5
Fusarium verticillioides	23	4600	161	3.5
Melanospora zamiae	23	4600	0	0.0
Phoma exigua	23	4600	115	2.5
Phoma sorghina	23	4600	115	2.5
Phoma sp.	23	4600	23	0.5
Penicillium sp.	23	4600	759	16.5
Rhizopus sp.	23	4600	1978	43.0
Rhizoctonia solani	23	4600	0	0.0
% Mean infection	-	-	-	9.1

The storage fungi *Rhizopus* sp.and *A. flavus* recorded the highest percentage infection of 43.0 and 33.5 %, respectively, while the pathogenic fungi *Alternaria* sp. recorded the least percentage infection of 1.5 %. However, *Curvularia pallescens*, and *F. oxysporum,* were high compared to *F. verticillioides*, *Phoma exigua* and *P. sorghina* (Table 8).

4.7.3: Incidence of seed-borne fungi associated with farmer-saved tomato seeds from Techiman Municipality

In the Techiman Municipality, apart from *Alternaria* sp., *Bipolaris* sp., *Cercospora* sp., *Colletotrichum* sp., *Curvularia lunata*, *Fusarium pallidoreseum* and *Melanospora zamaie*, the seed-borne fungi isolated from Techiman seeds recorded a mean percentage infection of 9.1% (Table 9).

The storage fungi *A. flavus*, *A. niger*, *Penicillium* sp. and *Rhizopus* sp. recorded the highest percentage infection of 33.2, 25.5, 20.0, and 19.5 %, respectively. The pathogenic fungi *F. oxysporum,* recorded the highest percentage infection of 28 % among the *Fusarium* species followed by 12 % *Curvularia pallescens* infection. *Phoma* spp. recorded the least percentage infection (Table 9).

Table 9: Percentage infection of seed-borne fungi on farmer-saved tomato seeds from Techiman Municipality in the Forest and Forest-Savannah agro-ecological zones of Ghana

Fungi Identified	Number of seed samples	Number of seeds tested	Number of seeds infected	% Incidence of seed-borne fungi
Alternaria sp.	22	4400	0	0.0
Aspergillus flavus	22	4400	1461	33.2
Aspergillus niger	22	4400	1122	25.5
Aspergillus sp.	22	4400	286	6.5
Bipolaris sp.	22	4400	0	0.0
Cercospora sp.	22	4400	0	0.0
Colletotrichum sp.	22	4400	0	0.0
Curvularia lunata	22	4400	0	0.0
Curvularia pallescens	22	4400	528	12.0
Fusarium culmorum	22	4400	176	4.0
Fusarium equiseti	22	4400	440	10.0
Fusarium oxysporum	22	4400	1232	28.0
Fusarium pallidoreseum	22	4400	0	0.0
Fusarium poae	22	4400	308	7.0
Fusarium verticillioides	22	4400	396	9.0
Melanospora zamiae	22	4400	0	0.0
Phoma exigua	22	4400	110	2.5
Phoma sorghina	22	4400	44	1.0
Phoma sp.	22	4400	110	2.5
Penicillium sp.	22	4400	880	20.0
Rhizopus sp.	22	4400	858	19.5
Rhizoctonia solani	22	4400	66	1.5
% Mean infection	-	-	-	9.1

4.7.4: Incidence of seed-borne fungi on number of farmer-saved tomato seed samples from Agogo, Offinso-North Districts and Techiman Municipality

The results further showed 100 % incidence of *A. flavus* on seed samples collected from Offinso North District and Techiman Municipality. Seed samples collected from Techiman recorded the highest percentage incidence (54.6 %) of *A. niger*, followed by Agogo District (Table 10). With exception of *Bipolaris* sp. and *Melanospora* sp., the non-pathogenic fungi recorded the highest percentage incidence for all the districts with 68.2 and 65.2 % incidence of *Penicillium* sp. at Techiman Municipality and Offfinso North District, respectively. However, seed lots collected from Techiman Municipality recorded the lowest incidence (31.8 %) of *Rhizopus* sp. (Table 10).

The pathogenic fungi such as *Aternaria* sp. recorded 8.7 % incidence on Agogo and Offinso North Districts farmer-saved tomato seed lots. Among the *Fusarium* species isolated, incidence of *F. oxysporum* was 56.5 % high for seed lots from Offinso North District followed by Techiman Municipality (50 %). Seed lots from Techiman Municipality recorded high incidence of *F. culmorum, F. equiseti, F. poae, and F. verticillioides* (Table 9). Also, Offinso North District recorded the highest incidence of *Curvularia pallescens* (73.9 %) and *C. lunata* (21.7 %) whereas a high incidence of *Phoma sorghina* (21.7 %) was recorded on Agogo District seed lots. Generally, Agogo District seed lots recorded the highest number (20 species) of isolated fungi, followed by Offinso North District (16 species) (Table 10). Appendices 6 and 7 show photos of the various fungal species isolated from the seeds.

Table 10: Incidence of seed-borne fungi on number of farmer-saved tomato seed samples collected from Agogo, Offinso North Districts and Techiman Municipality in the Forest and Forest-Savannah agro-ecological zones of Ghana

% Incidence of seed-borne fungi on seed lots of tomato / District or Municipality

Fungi Identified	Agogo	Offinso North	Techiman
Alternaria sp.	8.7	8.7	0.0
Aspergillus flavus	91.3	100.0	100.0
Aspergillus niger	47.8	17.4	54.6
Aspergillus sp.	8.7	13.0	9.1
Bipolaris sp.	8.7	4.3	0.0
Cercospora sp.	0.0	8.7	0.0
Colletotrichim sp.	4.3	0.0	0.0
Curvularia lunata	8.7	21.7	0.0
Curvularia pallescens	26.1	73.9	31.8
Fusarium culmorum	8.7	0.0	13.6
Fusarium equiseti	17.4	0.0	22.7
Fusarium oxysporum	43.5	56.5	50.0
Fusarium pallidoreseum	4.3	0.0	0.0
Fusarium poae	13.0	8.7	18.2
Fusarium verticilliodes	17.4	13.0	27.3
Melanospora zamiae	4.3	0.0	0.0
Phoma exigua	4.3	8.7	13.6
Phoma sorghina	21.7	8.7	4.6
Phoma sp.	4.3	4.3	9.1
Penicillium sp.	43.5	65.2	68.2
Rhizopus sp.	52.2	52.2	31.8
Rhizoctonia solani	0.0	0.0	9.1

Sixty-eight (68) farmer-saved seed lots with 23/Agogo, 23/Offinso North and 22/ Techiman Districts were tested

CHAPTER FIVE

5.0 DISCUSSION

The discussion cover, the incidence and severity of identified fungal diseases of tomato, incidence of seed-borne fungi identified on farmer-saved tomato seeds, tomato farmers' knowledge & perceptions on fungal diseases as well as their practices on the management of tomato diseases.

5.1 Incidence and severity of fungal diseases of tomato in the studied districts and municipality

Early blight, Septoria leaf spot, Fusarium wilt, Collar rot and Sclerotium rot were the major fungal diseases identified from the study. Although the mean incidence of diseases recorded appeared to be low, the range of incidence (Table 3) and values recorded per district (Appendices 2 to 4) were quite high in disease situation to cause crop losses at all stages of growth to farmers. This is inline with the report by Manners (1992), Nash and Gardner (1988) that disease incidence can occur at any stage of plant growth to cause losses. According to Agrios (2005), for many diseases in which plants are counted as diseased, whether they are exhibiting a single lesion or hundreds of lesions, disease incidence and severity reduce yield to cause losses.

Also, mean disease severity appeared to be low (Table 4) but in some fields high disease severity were recorded. For example, severity score of 3 was recorded for Fusarium wilt in some fields in Offinso North District (Appendix 3). Since the Offinso North District falls in the forest zone, favourable conditions can enhance the development of the disease to cause crop losses. The severity score of 3 means damage to tomato plant by Fusarium wilt was within 25-50 %. This means when factors for full expression of disease reported by Mark *et al*. (2006) become available, severity will be high and disease could be devastating. Agrios (2005) reported that factors such as favourable temperature range, humidity, pH of soil and other soil available nutrients could positively affect the growth and development of fungal pathogens to cause infection. These situations may exist in certain seasons and may be responsible for high application of chemical fungicides depended on by farmers in the studied areas.

Results from the survey, observations in the fields and discussion with farmers indicated that very high incidence and severity of these infections cause severe losses in tomato production. This confirmed the reports of Kallo and Banerjee (1993); Mathur and Shekhawat (1986) on 50 to 80 % crop losses caused by Early blight.
The study showed that Early blight, Septoria leaf spot and Fusarium wilt were the most frequently occurring and highly severe diseases in all the districts. This is in line with Norman (1992) and Leather (1959) who identified early blight as prevalent foliar seed-borne disease of tomato in Ghana, especially in the warm and humid environments of the Ashanti region. Agogo and Offinso North Districts were in the forest transitions of Ashanti to experience such favourable conditions for the development of the diseases.

5.2 Farmers' knowledge and control practices on fungal diseases in the studied districts

The results from the survey indicate that a high percentage of farmers had perceived knowledge of the fungal diseases of tomato because of losses that these diseases caused. Even though they had knowledge of diseases, their knowledge on control practices was poor. At least 96 % of the farmers controlled diseases using chemicals, but indications from the study showed that farmers suffered severe losses in yield, despite the over dependence on chemicals. It appeared that the farmers' main solution to every disease situation was application of chemicals. Acccording to Wolff (1999), tomato farmers spent more money on chemicals to control diseases. It could be obvious that this reason may be the cause of chemical abuse on vegetables in the country (Robinson and Kolavalli, 2010c; Clottey *et al.*, 2009). Situations that could not be controlled by chemical application were even given chemical treatment. This requires a critical education of farmers in the knowledge of application of appropriate disease control measures.

Eighty-six per cent farmers utilised farmer–saved tomato seeds with the reasons that it is easily affordable, resistant to diseases and pest, and adaptable to their climatic conditions. Nine per cent of responded farmers patronised certified seeds imported based on the reason that in dry seasons, they withstand diseases, produce high yield and have long storage span. Some tomato farmers patronised seedlings raised by their friends, thereby facilitating movement of pathogens from one field to another. This implies that farmers contributed to the spread and build-up of diseases on their farms. These agree with Agrios (2005), Manners (1992) and Park (1990) that the use of seed, nursery stock, and other propagative material that carry various pathogens increase the amount of initial inoculum within the crop and favours the development of epidemics greatly.

The study also showed that farmers grow Powerasta (Caterpillar or Rasta) because it is the most disease resistant variety, even though it has poor market value due to it softness. Also, it easily gets rotten and develops cracks at maturity when harvesting delays. Majority (97 - 100 %) of the farmers who grow Pectomech (Pecto or Pectofake) reported that it has good market price, but cannot withstand drought and needs intermittent watering. Power-Rano variety was said to be adaptable to all climatic conditions for growth and has good market price. These benefits could be improved with disease resistant traits as an attempt to manage fungal diseases and reduce huge losses (Mark *et al.,* 2006). The ineffectiveness of the available fungicides to control these fungal diseases reported by the farmers who control diseases could be attributed to wrong time of application, mode of application, and the poor dosage of fungicide application. This is in line with Norman (1992), Bachi and Seebold (2008) that for some of the infections that are seed and soil-borne, control measure must be implemented on seeds and at seedling and soil bed preparation time before transplanting.

It was observed from the study that farmers start to implement control measures to these fungal infections when they begin to notice symptom expression on the field and also at two weeks after transplanting. This is inline with the report by Norman (1992) that farmers implement control measures to diseases at the wrong time. This indicates that the fungal pathogens could start the development of the infection (latent infection) and to the point of economic damage as reported by (Shankara *et al.*, 2005) prior to the farmers control measure. This confirmed seedling infections of tomato identified and reported by farmers during the survey.

5.3 Gender, age and educational level of tomato farmers in the studied districts

The results showed that tomato production is dominated by male farmers and young adults within the age of 20-40 years. This could be attributed to the intensive labour involved in tomato production reported by Clottey *et al*. (2009). Also, only 20 % of the youth are involved in tomato production and this could be attributed to the losses they encounter because of diseases. This indicates that the future of tomato production looks unhopefull; hence, effort should be made to manage fungal disease situations to minimize crop losses. About 80 % of tomato farmers were of low level of education and this confirmed their perceived knowledge on poor disease control and seed treatment practices.

5.4 Seed-health of farmer-saved tomato seeds from Techiman Municipality, Agogo and Offinso North Districts

Different fungal species were identified on farmer-saved tomato seeds collected from the studied districts. According to Richardson (1990; 1983), *Alternaria* sp., *Cercospora* sp., *Colletotrichum* sp., *Fusarium oxysporum, F. verticillioides, Phoma exigua, Rhizoctonia solani* and *P. sorghina* are known to cause serious field diseases of tomato.

In Agogo District, incidence of *Fusarium oxysporum*on seeds was as high as 26.5 %. *F.oxysporum* incidence on seeds in Offinso North District was 18.5 %. In Techiman Municipality, incidence of *F.oxysporum* was 28 %. Although seeds collected from Offinso North District recorded the least incidence of *F. oxysporum*, as high as 56.5 % incidence of the pathogen was also recorded on the total number of seed samples collected from the District. *Fusarium oxysporum* is responsible for wilt disease in tomato and the incidence recorded are high enough to cause huge losses when the environmental conditions favourable for thriving by this pathogen persist. According to Sherf and Macnab (1986), *F. oxysporum* causes root rot and wilt of tomato.

Abu Bakar *et al*. (2012) reported *Fusarium oxysporum* to cause post-harvest rot on tomato and produce decayed water-soaked lesion with white or pinkish mould growth. Species of *Fusarium* pathogen such as *F.culmorum* and *F.equiseti* were also recorded on seed samples. Incidence of *Fusarium verticillioides* was 27.3 % higher on seed samples from Techiman and 13 % lower on seed samples from Offinso North Districts, respectively. These *Fusarium* species could be responsible for the cause of Collar rot disease and basal stem canker infection on tomato seedlings reported by the farmers. Seed-borne, *Fusarium moniliforme* has been found to cause collar rot and reduced crop germination (Mantecom *et al.*, 1984).

Fusarium wilt and Collar rot diseases caused by *Fusarium oxysporum* and *Fusarium* spp., respectively, are seed-borne diseases. Therefore, if farmers are to apply control on the field when the diseases become profound without early seed treatment, then the high yield losses observed during the survey and also reported by the farmers is possible to take place.

Knowledge in seed treatment, using appropriate fungicides, can eliminate most of the seed-borne pathogens. From this study, most farmers did not control seed-borne pathogens. The high incidence of diseases reported by farmers and the high losses they experienced was the result of their poor knowledge in seed treatment.

Early blight incidence was high. In some places, incidence was as high as 64 %. The farmers intimated that in some seasons, early blight caused huge losses to them. Species of *Alternaria* that causes this disease was identified on seed samples from Agogo and Offinso North Districts. *Alternaria solani* can cause extensive defoliation, leading to a reduction of economic fruit yield of tomato (Stone *et al.*, 2000; Spletzer and Enyedi 1999; Awad, 1990). The occurrence of this disease on farmers' field could also be reduced if farmers practiced seed treatment with appropriate fungicides.

Storage fungi (saprophytes), for example, *Aspergillus flavus*, *A. niger* and *Penicillium* sp. were found to be predominant on farmer-saved tomato seeds from all districts and municipality. Similar findings have been reported by Orlova *et al*. (1982), Marcinkowska (1982), Huang and Sun (1982) who found *A. flavus*, *A.niger* and *Fusarium oxysporum* to be predominantly associated with tomato seeds. The high incidence of storage fungi could be attributed to the result of farmers' pre-treatment and storage condition of their seeds. Majority of the farmers' seed samples collected were found to be wet. High temperatures and humid conditions were their storage conditons. Seeds were found to be in bottles and tin containers. The high infection rates recorded in the tomato seeds by these storage fungi can be of significance to seed contamination due to heating, discolouration and production of toxins, since they are great producers of mycotoxins (Christensen and Kaufmann, 1965; Christensen and Lopez, 1963).

From this study, farmer education on appropriate disease identification and their appropriate methodologies particularly, seed treatment, would be essential in ensuring effective disease management in all three districts studied. This observation may be relevant in most tomato producing areas of Ghana.

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

The result of the study revealed that Early blight, Fusarium wilt, Sclerotium rot, Septoria leaf spot and Collar rot were the major fungal diseases of tomato devastating crop yields and declining the importance of tomato cultivation at Techiman Municipality, Agogo and Offinso North Districts within the forest and forest-savannah agroecological zones of Ghana. Early blight, Fusarium wilt and Sclerotium rot were the most severe fungal diseases of tomato identified in the studied areas. The incidence of Early blight was 63.9 % at Agogo higher than Offinso North and Techiman communities recording 43.5 and 38.2 %, respectively. The severity of Early blight was higher at Agogo District than Offinso North District and Techiman Municipality.

The incidence of Fusaruim wilt was 45.2 % at Agogo. It was higher than Offinso North and Techiman communities, respectively, yet Offinso North District recorded the highest severity of Fusarium wilt disease.

Agogo District recorded the highest incidence (37.5 %) of Collar rot, whereas a high incidence (36.8 %) and severity of Sclerotium rot was recorded in Offinso North District. Apart from Septoria leaf spot, incidence and severity of other diseases were low in Techiman Municipality.

Farmers had perceived knowledge of the diseases because of losses that these diseases caused. Despite their knowledge of the diseases due to losses, the knowledge on control practices is poor. The farmers, therefore, contributed to the high incidence and severity of the identified fungal diseases.

Tomato production is dominated by male and also old adult farmers and this make the future of tomato production look bright.

The result of the farmer-saved tomato seed health test has confirmed that *Alternaria* sp., *Aspergillus flavus, A. niger, Bipolaris* sp., *Cercospora* sp., *Colletotrichum* sp., *Curvularia lunata, C. pallenscens, Fusarium oxysporum, F. verticillioides, F. culmorum, F. equiseti, F. pallidoreseum, F. poae, Melanospora* sp., *Penicillium* sp., *Phoma exigua, P. sorghina, Rhizoctonia solani* and *Rhizopus* sp. are seed-borne fungi of tomato.

Fusarium oxysporum, Alternaria sp. and *Fusarium* spp.were seed-borne fungi identified on the tomato seeds and were found to be associated with field diseases such as Fusarium wilt, Early blight and Collar rot, respectively. The highest number of seed-borne fungi was isolated from Agogo District farmer-saved tomato seeds.

RECOMMENDATIONS

Based on the results obtained, the following recommendations are proposed:

- Educational programme should be conducted with all stakeholders in the tomato industry, especially tomato farmers and the Ministry of Food and Agriculture, on the awareness and appropriate control strategies for tomato fungal diseases and seed treatment practices prior to storage and sowing to prevent seed and seedling infection and also, some field diseases.

- Further study should also be conducted in the Northern and Guinea-savannah agroecological zones of Ghana to identify the incidence and severity of major fungal diseases of tomato.

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APPENDICES

Appendix 1

List of Fungal diseases of Tomato

No.	**DISEASES**	**CAUSAL ORGANISM**
1.	Alternaria stem canker	*Alternaria alternata f.sp. lycopersicii*
2.	Anthracnose	*Colletotrichum cocodes* *Colletotrichum dematium* *Colletotrichum gloeosporioides* *Glomerella cingulata* (teleomorph)
3.	Black mold rot	*Alternaria alternata* *Stemphylium botryosum* *Pleospora tarda* (telemorph) *Stemphylium herbarun (telemorph)* *Pleospora herbarun* *Pleospora lycopersici* *Ulocladium consortiale* *Stemphylium consortiale*
4.	Black root rot	*Thieolaviopsis basicola* *Chalara elegans*
5.	Black shoulder	*Alternaria alternata*
6.	Buckeye fruit and root rot	*Phytophthora capsici* *Phytophthora dreshleri* *Phytophthora nicotianae var. parasitica* *Phytophthora parasitica*
7.	Cercospora leaf mold	*Pseudocercospora fuligena* *Cercospora fuligena*
8.	Charcoal rot	*Macrophomina phaseolina*
9.	Corky root rot	*Pyrenochaeta lycopersici*
10.	Didymela stem rot	*Didymella lycopersici*
11.	Early blight	*Alternaria alternata*
12.	Fusarium crown and root rot	*Fusarium oxysporum f.sp. radicis-lycopersici*
13.	Fusarium wilt	*Fusarium oxysporum f.sp. lycopersici*

14.	Grey leaf spot	*Stemphylium botryosum f.sp. lycopersici* *Stemphylium lycopersici* *Stemphylium floridamin* *Stemphylium solam*
15	Grey mold	*Botrytis cinerea* *Botryotinia fuckeliana* (teleomorph)
16.	Late blight	*Phytophthora infestans*
17.	Leaf mold	*Fulvia fulva* *Cladosporium fulvum*
18.	Phoma rot	*Phoma destructive*
19.	Powdery mildew	*Oidiopsis siculla* *Leveillulab taurica* (teleomorph)
20.	Pythium damping off and fruit rot	*Pythium alphanidermatum* *Pythium arrhenomanes* *Pythium debaryanum* *Pythium myriotylum* *Pythium ultimum*
21.	Rhizoctoria damping-off and fruit rot	*Rhizoctonia solani* *Thanatephorus cucumeris* (telemorph)
22.	Rhizoplus rot	*Rhizopus stolonifer*
23.	Septoria leaf spot	*Septoria lycopersici*
24.	Sour rot	*Geotrichum candidum* *Galactomyces geotrichum* *Geotrichum klebahnii*
25	Southern blight	*Sclerotium rolfsii* *Athelia rolfsii*
26.	Target spot	*Corynespora cassiicola*
27.	Verticillium wilt	*Verticillium albo-atrum* *Verticillium dahliae*
28.	White mold	*Sclerotinia sclerotiorum* *Sclerotinia minor*

Source: Tomato diseases (Fact sheets and information Bulletins), the Cornel Plant Pathology. Vegetable Disease Web page
http//:www.growtomatoes.com/world.production.statistics
http//:www.worldseed.org/isf/seed- health testing.html

Appendix 2

Disease incidence and severity for thirty farms at Agogo District (Nyantokro, Abrewapon, Agogo)

Diseases →	Early blight		Septoria leaf spot		Fusarium wilt		Collar rot		Viral infection I		Viral infection J	
% DI and DSI →	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**
Farms↓												
1	90	2.17	0	0	70	2.07	60	2.27	0	0	53	1.90
2	63	2.46	50	1.87	0	0	0	0	57	1.57	0	0
3	60	1.90	60	1.90	67	2.30	73	2.87	0	0	53	1.93
4	90	2.50	0	0	83	2.70	60	1.87	73	2.00	0	0
5	57	2.20	0	0	0	0	0	0	50	2.76	0	0
6	77	1.83	0	0	60	1.97	73	2.70	0	0	63	2.03
7	60	1.60	0	0	50	1.57	0	0	60	1.9	0	0
8	60	1.87	0	0	60	2.30	63	2.10	0	0	0	0
9	73	2.17	82	2.30	0	0	0	0	49	1.87	0	0
10	0	0	0	0	60	2.10	45	1.20	0	0	53	1.93
Mean	**62.9**	**1.87**	**19.2**	**0.61**	**45.0**	**1.50**	**37.5**	**1.29**	**28.9**	**1.01**	**22.0**	**0.80**
11	70	2.03	43	1.50	67	2.25	67	2.10	0	0	50	1.90
12	63	1.90	0	0	63	2.70	70	2.33	59	1.93	0	0
13	53	1.80	48	1.43	0	0	67	2.47	63	2.03	50	1.13
14	57	1.77	57	1.70	63	2.20	0	0	57	1.87	0	0
15	63	1.90	0	0	0	0	0	0	0	0	67	2.57
16	63	2.07	0	0	70	2.30	0	0	50	2.90	0	0
17	60	1.90	34	1.50	0	0	43	2.03	0	0	73	2.27
18	63	1.97	0	0	63	2.57	0	0	60	2.03	0	0
19	90	1.97	0	0	67	2.17	70	2.43	0	0	0	0
20	57	1.83	0	0	67	2.13	67	1.83	0	0	0	0
Mean	**63.9**	**1.90**	**18.2**	**0.61**	**46.0**	**1.62**	**38.5**	**1.33**	**28.9**	**1.08**	**24.0**	**0.82**
21	53	2.03	67	2.30	60	1.73	57	1.70	50	2.90	0	0
22	70	1.90	0	0	57	1.57	0	0	60	2.10	0	0
23	30	1.10	0	0	50	1.80	0	0	0	0	53	2.10
24	60	1.87	0	0	53	1.73	57	1.87	63	1.83	0	0
25	63	2.03	80	2.07	0	0	0	0	67	2.43	0	0
26	60	2.07	0	0	57	1.87	0	0	47	1.87	0	0
27	67	2.36	0	0	50	2.10	63	2.23	0	0	43	1.70
28	90	2.53	53	1.87	0	0	70	1.97	0	0	53	1.73
29	80	2.30	0	0	57	1.97	53	1.70	0	0	43	1.73
30	77	1.16	0	0	63	1.50	65	2.93	0	0	37	1.50
Mean	**64.9**	**2.03**	**20.0**	**0.62**	**44.5**	**1.43**	**36.5**	**1.29**	**28.7**	**1.11**	**23.0**	**0.88**
AV.%DI	63.9		19.1		45.2		37.5		28.9		23.0	
AV.DSI		1.90		0.61		1.52		1.29		1.07		0.83

Disease incidence = [Number of infected plants / total plant scored x 100] or [area infected / total area planted x 100] or [% of the 30 plants infected or expressing symptoms].

$$\text{Disease severity} = \frac{\sum \text{(Number of plants scored for each rating x the rating value)}}{\text{Total plants scored}}$$

(CSIR- Crops Research Institute Kumasi, Ghana)

Appendix 3

Disease incidence and severity for thirty farms at Offinso North District (Nkenkaasu, Akomadan, Afrancho)

Diseases →	Early blight		Septoria leaf spot		Fusarium wilt		Collar rot		Sclerotium rot	
% DI and DSI →	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**
Farms↓										
1	0	0	63	1.73	70	2.60	0	0	77	3.50
2	62	1.87	0	0	70	2.27	60	2.23	0	0
3	60	2.70	0	0	0	0	0	0	0	0
4	0	0	60	1.83	83	3.13	63	2.20	50	2.13
5	57	1.73	63	2.13	0	0	77	2.57	54	2.40
6	0	0	80	2.30	90	3.93	0	0	0	0
7	53	2.03	0	0	50	2.03	60	1.76	0	0
8	73	2.40	53	1.97	63	1.80	0	0	63	3.27
9	57	2.03	0	0	0	0	67	2.73	70	2.70
10	63	2.23	32	1.53	0	0	0	0	53	2.20
Mean	**42.5**	**1.49**	**35.1**	**1.15**	**42.6**	**1.57**	**33.0**	**1.11**	**36.7**	**1.62**
11	63	2.13	57	1.93	0	0	67	2.47	0	0
12	57	2.13	73	2.03	80	3.57	77	2.20	0	0
13	67	2.07	53	1.97	77	2.90	0	0	80	3.43
14	63	2.10	60	1.90	60	3.10	0	0	70	3.77
15	57	2.07	0	0	67	2.67	0	0	60	3.17
16	53	2.13	0	0	53	2.07	67	2.17	0	0
17	0	0	50	1.93	0	0	63	1.80	57	2.77
18	50	1.73	0	0	47	2.10	0	0	54	1.50
19	0	0	50	1.44	25	0.69	0	0	57	2.50
20	34	1.37	0	0	0	0	55	1.97	0	0
Mean	**43.6**	**1.57**	**34.3**	**1.12**	**40.9**	**1.71**	**32.9**	**1.10**	**37.8**	**1.71**
21	67	2.37	0	0	83	1.97	67	2.30	0	0
22	0	0	27	1.3	0	0	54	2.13	0	0
23	0	0	0	0	57	2.20	77	2.20	73	2.73
24	64	1.83	50	1.83	63	3.10	0	0	77	2.70
25	63	2.03	63	1.73	0	0	0	0	67	3.17
26	53	1.53	67	1.87	0	0	60	2.40	0	0
27	57	1.63	53	1.67	67	2.67	70	2.23	0	0
28	73	2.77	0	0	80	3.57	0	0	0	0
29	0	0	0	0	0	0	0	0	63	3.53
30	67	2.10	67	2.70	63	2.90	0	0	80	2.70
Mean	**44.4**	**1.43**	**32.7**	**1.11**	**41.3**	**1.64**	**32.8**	**1.13**	**36.0**	**1.50**
AV.%DI	43.5		34.0		41.6		32.9		36.8	
AV.DSI		1.49		1.13		1.64		1.11		1.61

Disease incidence = [Number of infected plants / total plant scored x100]

$$\text{Disease severity} = \frac{\sum \text{(Number of plants scored for each rating x the rating value)}}{\text{Total plants scored}}$$

(CSIR- Crops Research Institute Kumasi, Ghana)

Appendix 4

Disease incidence and severity for thirty farms at Techiman District (Tuobodom, Tanoboase, Bonomanso)

Diseases →	Early blight		Septoria leaf spot		Fusarium wilt		Collar rot		Sclerotuim rot		Black spots on leaf and stem		Viral infection I	
% DI and DSI →	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**	**% DI**	**DSI**
Farms↓														
1	53	1.73	67	1.70	0	0	57	1.77	0	0	57	1.83	50	1.60
2	50	1.87	0	0	43	1.40	0	0	53	2.10	0	0	47	1.60
3	47	1.53	50	2.0	0	0	0	0	0	0	77	2.0	43	1.60
4	50	1.63	0	0	0	0	0	0	60	2.27	50	1.50	53	1.93
5	53	1.63	0	0	60	1.60	0	0	0	0	0	0	43	1.80
6	0	0	0	0	53	1.53	35	1.53	50	1.70	0	0	57	1.87
7	0	0	53	2.06	50	1.70	0	0	0	0	31	1.32	0	0
8	47	1.47	0	0	0	0	0	0	26	0.70	70	1.73	0	0
9	60	1.73	0	0	47	1.90	0	0	0	0	0	0	47	1.87
10	20	0.60	50	1.63	0	0	53	1.67	0	0	50	1.43	0	0
Mean	**38.2**	**1.22**	**22.0**	**0.74**	**25.2**	**0.81**	**14.5**	**0.50**	**18.9**	**0.68**	**28.5**	**0.98**	**33.9**	**1.23**
11	40	1.97	0	0	67	1.87	50	1.97	53	1.80	53	1.93	50	1.80
12	50	1.60	0	0	63	2.07	0	0	0	0	0	0	0	0
13	43	1.60	50	1.53	0	0	0	0	0	0	47	1.83	0	0
14	50	1.90	67	1.97	50	1.67	0	0	0	0	0	0	50	1.70
15	0	0	50	1.60	0	0	0	0	55	2.17	50	1.43	48	1.77
16	60	1.77	53	1.97	0	0	60	2.07	0	0	0	0	53	1.53
17	40	1.53	0	0	70	1.97	0	0	57	1.90	37	1.43	53	1.63
18	0	0	0	0	0	0	0	0	0	0	59	1.53	47	1.57
19	57	1.87	0	0	0	0	0	0	30	1.70	50	1.73	0	0
20	50	1.67	0	0	0	0	34	0.70	0	0	0	0	47	1.47
Mean	**39.0**	**1.39**	**21.9**	**0.71**	**24.9**	**0.76**	**14.4**	**0.47**	**19.5**	**0.76**	**29.6**	**0.99**	**34.8**	**1.15**
21	0	0	0	0	57	1.70	53	1.83	0	0	40	1.73	57	1.83
22	43	1.43	0	0	0	0	10	0.30	0	0	0	0	50	1.70
23	50	1.97	49	1.93	0	0	0	0	0	0	50	1.90	0	0
24	47	1.90	0	0	43	1.50	0	0	0	0	47	1.80	47	1.90
25	53	2.23	53	1.63	0	0	0	0	47	2.07	0	0	50	1.80
26	60	1.87	57	1.97	0	0	0	0	0	0	57	1.50	53	2.07
27	63	2.03	0	0	67	1.97	0	0	60	2.27	60	1.93	0	0
28	57	1.80	0	0	0	0	57	1.57	0	0	0	0	47	1.93
29	0	0	0	0	50	1.90	0	0	43	1.77	21	0.63	0	0
30	0	0	60	1.93	30	0.77	23	0.7	40	1.0	0	0	53	1.80
Mean	**37.3**	**1.32**	**22.0**	**0.75**	**24.7**	**0.78**	**14.3**	**0.44**	**19.0**	**0.71**	**27.5**	**0.95**	**35.7**	**1.30**
AV.%DI	38.1		21.9		24.9		14.4		19.1		28.5		34.8	
AV.DSI		1.31		0.73		0.78		0.47		0.72		0.97		1.23

Disease incidence = [Number of infected plants / total plant scored x100]

$$\text{Disease severity} = \frac{\sum \text{(Number of plants scored for each rating x the rating value)}}{\text{Total plants scored}}$$

(CSIR- Crops Research Institute Kumasi, Ghana)

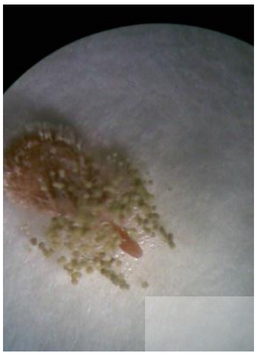
Appendix 5

Pathogens isolated from infected tomato seedlings and unknown diseased plants identified

Lable for Sample of diseased tomato seedling and unknown diseased plant	Infection	Isolated pathogen (s) / symptom identification
A	Leaf yellowing	*Alternaria* sp., *Bipolaris* sp
B	Wilting	*Fusarium oxysporum*, *Fusarium* spp.
C	Black spots and lesions on stems & leaves	*Curvularia pallescens*
D	Basal stem canker	*Fusarium oxysporum, Fusarium* spp., *Fusarium verticillioides, Trichoderma* spp.
E	Damping off	None
I	yellowing and curling of leaves	Viral disease
J	Whitish spots on leaf and leaf curling	Viral disease

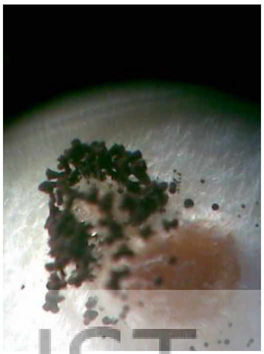
Appendix 6

Fungal growth on tomato seeds



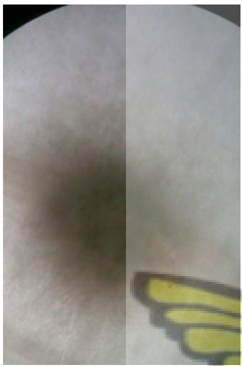
Aspergillus flavus

A. flavus

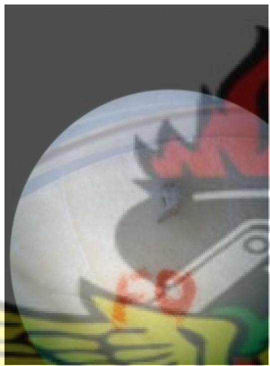


A.niger

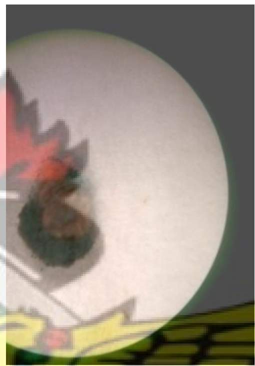
Aspergillus sp.



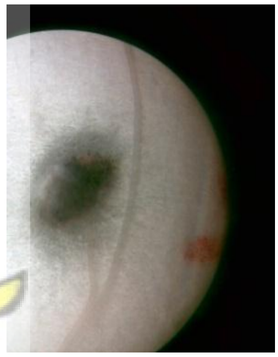
Alternaria sp.



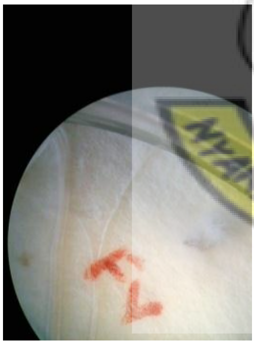
Fusarium oxysporum



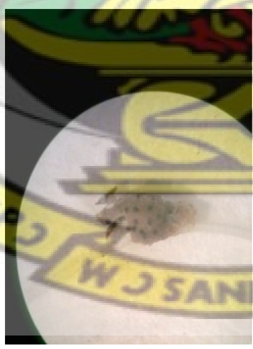
Penicillium sp.



Curvularia pallescens

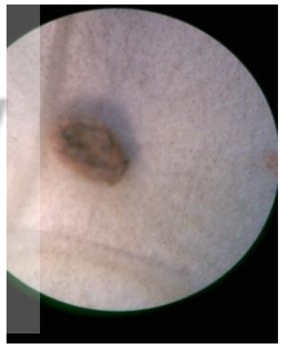


F.verticillioides



Phoma exigua

Rhizopus sp.



Rhizoctonia solani

Photos: Growth of fungal species on tomato seeds

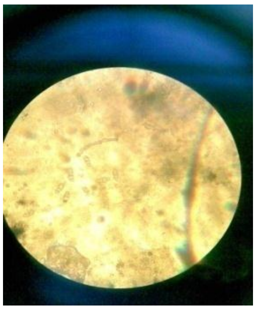
Appendix 7

Microscopic identification of some seed-borne fungi of tomato

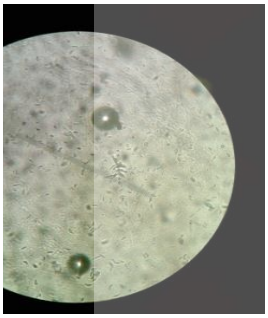
Alternaria solani

Alternaria sp.

Curvularia lunata



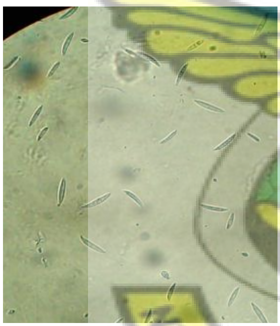
Curvularia pallescens



Colletotrichum sp.

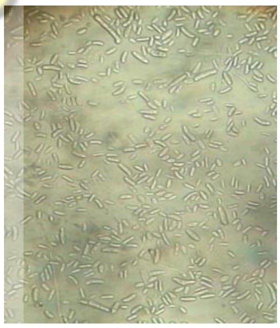
Fusarium equiseti

F. oxysporum

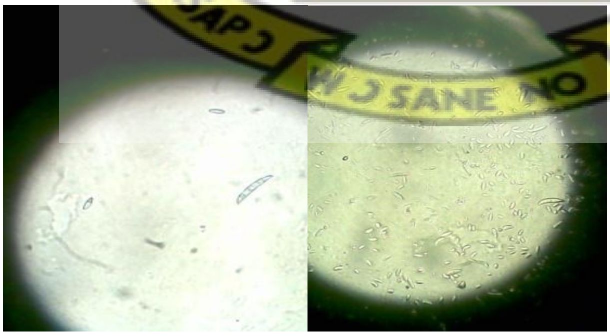


F.oxysporum

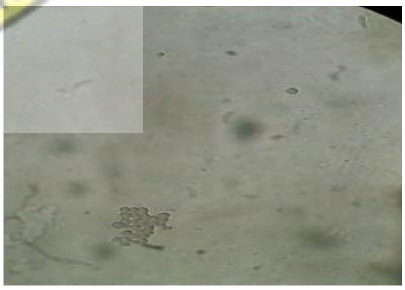
F.culmorum



F. poae



Fusarium verticillioides



Rhizopus sp.

Photos: Spores of some isolated fungal species on tomato seeds

Appendix 8

Sample of Questionnaire administered during the survey

Que No: …………….

PART 1.PERSONAL INFORMATION OF THE TOMATO FARMER

Farm No …………………………….

Name of tomato farmer: ……………………………………………......................

Locality/Village: ……………………………………………………………………

District / municipal……………………………………………………………….

1. Sex: M ( ) or F ( ) T (Tick) Age: …………………………………..

2. Educational level of the farmer: Basic ( ) / Secondary ( ) Tertiary ( ) Non- formal ( ) No education ( )

3. How many years have you been in tomato production and on this land? (.) and (..)

4. a. Number of times tomato is cultivated /year on this land? Once ( ) / Twice ( ) / Thrice ( )

b. What is the average acreage of your tomato production per season? …………

c. Month and local name for Seasons of tomato production in this locality? F ill in Table 1

No	Month	Local name for the season
1		
2		

5. a.What are the major constraints in tomato production in this locality? High rainfall ( ) / Drought ( ) / Labour ( ) / Inputs ( ) / Credit ( ) / Transportation ( ) / Pest and diseases ( ) / Storage ( ) / Marketing ( ) (Tick)

b. Which of these Problems highly affect your yield? High rainfall ( ) / Drought ( ) / Labour ( ) / Inputs ( ) / Credit ( ) / Transportation ( ) / Pest and diseases ( ) / Storage ( ) / Marketing () (Tick and rank 1-9)

PART 2 IDENTIFYING PEST AND DISEASE ON TOMATO FIELD

6. What type of insect that affect your tomato farm? Fill in Table 2

No	Local name (if any)	Scientific /Species name
I		
II		
III		

[Take photo on insects on tomato farm if any]

Researcher critical observation: Any Pathogenic diseases observed in the tomato farm (*symptoms identified not to cause by any insect)*? Fungi [Early blight ( ) / Late blight ( ) / Septoria leaf spot ( ) / Fusarium wilt ( ) / Verticillium wilt ( ) Powdery mildew ( ) Southern blight ( ) / Leaf mold ( ) / Colla rot ( ) / Anthracnose ( ) / Fruit Rot ( )] Nematode ( ) / Virus ( ) / Bacteria ( ) ***(Tick and rank 1-14)***

7. a. What major fungal diseases that affect your tomato production? (*symptoms identified not to cause by any insect, nematode and bacteria)*? [Early blight ( ) / Late blight ( ) / Septoria leaf spot ( ) / Fusarium wilt ( ) / Verticillium wilt ( ) Powdery mildew ( ) Southern blight ( ) / Leaf mold ( ) / Collar rot ( ) / Anthracnose ( ) / Fruit Rot ( ) ***(Tick and rank 1-11)***

[Take photo on infected plants, take plant / fruit and soil samples]

b. At what **stage of plant growth** does the infection occur on the tomato crop? Nursery/seedling stage / 3WAP on field / Active growing stage / Flowering stage / Fruiting stage / maturity or ripening stage

A…………………………………………

B……………………………………………

C…………………………………………

D……………………………………………..

[write the appropriate stage in order of ranking for que.9a]

c. Does the infection prevail in other tomato farms in this locality?

A Yes (   ) / No (   ) B Yes (   ) / No (   ) C Yes (   ) / No (   ) D Yes (   ) / No (   ) (Tick)

d. What is the extent of damage that the infection has on your tomato farm? ***[write in order of ranking for que.9a]***

A…………………………………………

B……………………………………………

C…………………………………………

D……………………………………………..

e. Does the infection affect your yield? A Yes (   ) / No (   ) B Yes (   ) / No (   ) C Yes (   ) / No (   ) D Yes (   ) / No (   ) (Tick)

f. i. Average number of crates of tomato harvested per acre upon severe disease infection and the absence of infection……………………………………………

ii. Cost of production per acre of tomato cultivation …………………………….

iii. Monetary value of the extent of crop/yield losses to the farmer in case of these infections A.GH¢…………B. GH¢…………C. GH¢………………D. GH¢…………

g. What measures do you take to **control** the infection(s)?

A………………………………………………………………………………………

B………………………………………………………………………………………

C………………………………………………………………………………………

D………………………………………………………………………………………

h. When is the control measure implemented?..

………………………………………………………………………………………..

i. Is the control measure effective? AYes ( ) / No ( ) B Yes ( ) / No C Yes ( ) / No D Yes ( ) / No

j. Do you accept the control measure as the right treatment to the infection? AYes ( ) / No ( ) B Yes ( ) / No C Yes ( ) / No D Yes ( ) / No

NB [A, B, C and D stand for the infections ranked highest in order forquestion 7a]

8 What crops do you rotate with tomato on tomato fields?

i……………………………………………………

ii.…………………………………………………

iii... ………………………………………………..

[Take photo of labels or containers of chemicals use]

9. a. What is the **source** of your tomato **seeds** for planting? Farmer saved seeds from previous production (   ) / Certified seeds imported (   ) / Locally processed seeds purchased from local market (   ) (Tick)

b. What make you prefer the source of tomato seeds stated above than the others?……………………………………………………………………………………

…………………………………………………………………………………………………

c. i. Any seed treatment before storage? Yes ( ) / No ( ), if yes provide the treatment

…………………………………………………………………………………………………

…………………………………………………………………………………………………

ii. Any Seed or bed treatment against infections before nursing? Yes ( ) / No ( )

If yes provide the treatment ……………………………………………………………….

…………………………………………………………………………………………………..

d. Nursery practices:

i .Location of nursery ……………………………………………………………………

ii .Source of water for watering …………………………………………………………

iii. Any observed disease symptoms on nursery ……………………………………..

…………………………………………………………………………………………………..

iv .Name of infection ……………………………………………………………………….

v. How is this tomato seedling infection controlled? ………………………………

[Take seed samples use for planting and photo on seedling infection]

10. Type of tomato variety(s) cultivated by the farmer? Fill in the Table 3a below

No	Local name (if any)	Varietal name
V1		
V2		
V3		

11. Which of these tomato varieties is able to withstand / resist the diseases identified?

…………………………………………………………………………………………………