SCREENING OF EGGPLANT GENOTYPES FOR RESISTANCE TO ANTHRACNOSE

BY

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SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

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DECLARATION

I, hereby declare that this thesis "Screening of eggplant genotypes for resistance to anthracnose" herein presented for a degree of Master of Science Crop Protection (Plant Pathology) is the result of my own investigations. References to other authors have been duly acknowledged.

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ABSTRACT

Anthracnose is one of the major diseases of eggplant and is controlled mainly by the use of chemicals. The use of chemicals, although beneficial, possesses threat to both human and the environment. The need for healthy food and healthy human environment has necessitated the use of resistant eggplant genotypes, following the increasing world demand and consumption. In view of these, a study was conducted between August, 2012 and August, 2013 to quantify the disease incidence and severity of eggplant anthracnose and also to screen for eggplant resistant genotypes. Questionnaires were administered to eggplant farmers for their perception on anthracnose and eggplant production. It was observed from the studies that Aworoworo and Obolo were the commonly grown eggplant varieties in the surveyed areas. However, both vegetative and fruit characteristics were found to be paramount in the selection of these varieties by farmers as they directly affect pest management practices and marketing of the produce. The study further showed that diseases and insect pests were the major problems that farmers often encounter in eggplant production. The highest eggplant anthracnose disease incidence and severity occurrence were recorded in Techiman and Offinso North Districts during the field survey. Significant morphological (vegetative and fruit characteristics) variations were observed among the eggplant genotypes in the field experimentation. *Solanum melongena* var. Zebrina had the highest total yield of 34.0 tons/ha followed by *S. aethiopicum* var. Dwumo 24.0tons/ha and then *Solanum melongena* var. Kalenda F1 21.8tons/ha. Among the two most cultivated genotypes, however, *S. aethiopicum* var. Obolo had 20.9tons/ha, compared with *S. aethiopicum* var. Aworoworo 10.7tons/ha. The result further showed a significant ($P<0.05$) positive correlation between disease incidence and severity ($r = 0.95$), number of branches and number of fruits ($r = 0.65$), fruit weight and total yield ($r = 0.51$) and stem girth and number of branches ($r = 0.60$). On the contrary, disease severity significantly affected fruit weight adversely ($r = -0.51$). Plant height was positively correlated with all the growth and yield parameters, except fruit weight and total yield. Anthracnose disease resistance was observed in the genotypes Antropo, Zebrina and Kalenda F1, both in the laboratory and field evaluations.

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CHAPTER ONE

1.0 INTRODUCTION

Eggplant is an important edible vegetable used worldwide. It is a solanaceous crop commonly grown in the sub-tropics and tropics. It has medicinal properties, good for diabetic patients and people suffering from liver complaints (Shukla and Naik, 1993; Akhter *et al*., 2012).

It is among the three most consumed vegetables in Ghana (Horna *et al*., 2007) and grown commercially for domestic consumption and also for export (Anonymous, 1997; Daunay *et al*., 2001). The fruits and leaves of eggplant are utilized as vegetables to contribute to the essential nutrients in human diet (Norman, 1992). Eggplant fruit is a good source of vitamins A and C, potassium, phosphorus, calcium and, dietary fibre (USDA, 2008). FAO (2003) reported that the fruit of an eggplant can be eaten raw or served to people baked, grilled, fried or boiled and can also be used in stews or as a garnish. Also, in some parts of Africa, the leaves and flowers of some varieties of eggplant are added to soups or sauces and served during meals. According to National Research Council (2006), eggplant has the ability to boost food security in Africa.

Eggplant is one of the most commonly grown vegetables in Ghana with ready market, not only in the urban areas, but also in the rural communities. It is a source of income and employment for most people in both cities and villages. The crop has been a source of foreign exchange for some countries including Ghana, though very low compared to other crops. Eggplant is traded internationally on a limited scale in the West African sub-region, and only a very small share of the total production in Ghana is exported to

Europe due to limited knowledge and research efforts involving eggplant in Ghana (Horna *et al*., 2007).

In Ghana, eggplant production is affected by many factors. These include poor husbandry techniques, shortage of improved seeds at the required time, limited extension service and insufficient use of fertilizers. Other factors are unreliable rainfall, inadequate irrigation facilities, lack of organized vegetable processing and marketing as well as low income (Sinnadurai, 1973). The fruit yield of eggplant is also dependent on a number of factors including flowering (anthesis), insect pests and diseases infection, soil fertility and the cost of fertilizer application (Huth and Pellmyer, 1977).

Eggplant is related to potato, pepper and tomato. It is, therefore, a host for many of the pests and diseases that attack these crops in Ghana (Kemble *et al*., 1998). Diseases of vegetables, including eggplant, are the main source of crop damage caused by plant pathogenic organisms. Eggplant is subjected to devastation from a number of diseases, particularly in the field. Major diseases include Anthracnose, Verticillium wilt, Fusarium wilt, Phytopthora fruit rot, Phompsis blight and Cucumber mosaic virus (McGrath, 2004; Acquaah, 2005).

Anthracnose is one of the most important and prevalent diseases of eggplant in the tropics, including Ghana. The pathogen causes damage to leaves, stems, flowers and fruits, thus affecting storage and marketability (Schwartz and Gent, 2007; Chaube and Pundhir, 2009; Mahendranathan *et al*., 2009). Anthracnose is caused by *Colletotrichum* species, a very important group of plant pathogens responsible for diseases on numerous plant species worldwide (Agrios, 2005; Roberts *et al*., 2009). Although the pathogen has a worldwide distribution, it is mainly found in the subtropical and

tropical regions and causes economically significant damage to plants, including cereals, legumes, vegetables, perennial crops, and fruit trees (Bailey and Jeger, 1992).

Diseases are common occurrence on plants, often having a significant economic impact on yield and yield quality, thus managing diseases is an essential component of crop production. Fungicides application is a common and effective technique to manage plant diseases. However, its use is controversial because of the rising cost involved and its polluting effect on the environment (Chaube and Pundhir, 2009). In contrast with most human medicines, most fungicides need to be applied before disease occurs or at the first appearance of symptoms to be effective (McGrath, 2004). Fungicides have been implicated in the suppression of beneficial fungi in many cropping systems. Also, several birth defects relating to pesticide usage have been reported (Garry, 1996; Ragsdale *et al*., 2008). The compatibility of natural enemies with fungicides usage is highly variable. Although fungicides may not directly or immediately be harmful to a specific natural enemy, they may have indirect or sub-lethal effects, such as delayed development, or decreased natural enemy survival (Cloyd, 2007).

According to Chaube and Pundhir (2009), host resistance is an important area of plant disease management due to increasing pressure for healthy food and healthy human environment. Anthracnose-resistant eggplant cultivars are not available in Ghana. The search for anthracnose-resistant cultivars is, therefore, necessary as resistant crop cultivar; if available, would be the most reliable, economical and effective disease management option. It was for these reasons that this study was conducted to quantify eggplant anthracnose and to search for anthracnose resistance in eggplant genotypes.

The specific objectives were to:

i. assess the incidence and severity of eggplant anthracnose disease in selected eggplant growing areas in Brong Ahafo and Ashanti Regions and

ii. evaluate eggplant genotypes for their reactions to *Colletotrichum* isolates.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Eggplant production in the world

Eggplant is an economically important vegetable crop widely grown in the tropics, sub-tropics and warm temperate regions (Sihachakr *et al*., 1994). The world total production was estimated at over 46 million metric tonnes in 2012 with China (27, 728, 135 metric tonnes) as the leading producer. Egypt was the leading producer of eggplant (1,166,430 metric tonnes) in Africa, followed by Algeria (105, 000 metric tonnes). The estimated total production of eggplant in Ghana, however, was 4,800 metric tonnes (FAOSAT, 2012).

2.2 Importance and health benefits of eggplant

Eggplant is one of the most important vegetable crops in Ghana and West Africa (Norman, 1992; Grubben and Denton, 2004). The crop is consumed on almost daily basis by rural and urban families. It is the main source of income for many rural households in Ghana (Danquah, 2000; Owusu-Ansah *et al*., 2001). Eggplant production is a means to ensuring rural development. The production of eggplant provides a continuing source of income for farmers throughout Africa. In rural districts of Senegal and Mozambique, women are usually seen hefting baskets of eggplant on their heads to sell in nearby villages and towns. Yet this vegetable has untapped commercial promise and could become an important localised rural economic development drive. There is also potential for exporting eggplant fruits to Europe and North America, thereby earning hard currency (National Research Council, 2006).

Eggplant has gone global and is now part of virtually every cuisine. The fruit is primarily used as a cooking vegetable for various dishes in different regions of the world. It is fried, grilled, roasted, boiled, baked and steamed. It can also be used in soups, stews, kebabs, and curries. It has taken firm hold as a meat substitute and popular vegetarian dishes now include eggplant parmesan, eggplant lasagne, eggplant curry, and eggplant chilli. The vegetable has much potential as raw material in pickle making and dehydration industries (Chen and Li, 1996; NRC, 2006; Department of Agriculture, Forestry and Fisheries, 2011). The leaves and flowers of some varieties of eggplant are edible and may be added to soups and sauces. The fruits of eggplant can be eaten raw, but more frequently cooked or fried (Tindal, 1992).

National Research Council (2006) reported eggplant as having the ability to boost food security in Africa. It is known for its ability to provide large amounts of food from a small space. Also, the fruits have a storage life up to three months and can be dried and stored for later use, when the growing season is over and nothing fresh is available (NRC, 2006; Stone *et al*., 2011).

Eggplant fruits provide protein, vitamins, and minerals but low in sodium, calories and fat. It contains a large quantity of water and good for balancing diets that are heavy in protein and starches. It is high in fibre and provides additional nutrients such as potassium, magnesium, folic acid, vitamin B_6 and A (National Research Council, 2006; DAFF, 2011). It is rich in reducing sugars, anthocyanin, phenols, glycoalkaloids, dry matter, and amide proteins (Bajaj *et al*., 1979).

Some medicinal properties have been attributed to the roots and fruits of eggplant. They are described as carminative and sedative, and are used to treat colic and blood pressure (Grubben and Denton, 2004). It is good aphrodisiac, cardiotonic, laxative, mutant and reliever of inflammation (Harish *et al*., 2011). Eggplant is good for diabetic patients and can be used to cure toothache. It has also been recommended as an excellent remedy for people suffering from liver complaints (Shukla and Naik, 1993; Chen and Li, 1996).

2.3 Factors affecting eggplant production in Ghana

Eggplant production is a profitable activity but involves some risks. Production constraints faced by farmers are multiple. Production is labour intensive and labour cost accounts for more than 60% of the total costs (Horna *et al*., 2007).

In Ghana, eggplant production is affected by many factors. These include poor husbandry techniques, inadequate availability of seeds at the required time, limited extension service and insufficient use of fertilizers. Also, unreliable rainfall, inadequate irrigation facilities, lack of organised vegetable processing and marketing as well as low income affect the business (Sinnadurai, 1973). Moreover, fruit yield of eggplant is dependent on a number of factors, including insects, diseases, soil fertility and fertilizer application (Huth and Pellmyer, 1977). Eggplant is related to potato, pepper and tomato. It is therefore a host for many of the pests and diseases that attack these crops in Ghana (Kemble *et al*., 1998; Mochiah *et al*., 2011).

Diseases of vegetables, including eggplant, are the main source of crop damage caused by plant pathogenic organisms. Major diseases include Anthracnose, Verticillium wilt,

Fusarium wilt, Phytopthora fruit rot, Phompsis blight and Cucumber mosaic virus (McGrath, 2004; Acquaah, 2005). Anthracnose is one of the most important and prevalent diseases of eggplant in the tropics, including Ghana. The pathogen causes damage to leaves, stems, flowers and fruits, thus affecting storage and marketability (Chaube and Pundhir, 2009; Mahendranathan *et al*., 2009).

2.4 Effect of anthracnose on eggplant

Eggplant is subject to attack by different pathogens which may cause diseases at some growth stage of the crop. Most of the eggplant cultivars are susceptible to a number of diseases. Biotic stresses caused by pathogens and insect pests that affect the productivity of eggplant are among the major yield and yield quality limiting constraints (Chen and Li, 1996).

Anthracnose is a very destructive disease in solanaceous crops such as eggplant, pepper and tomato (Hadden and Black, 1989; Pernezny *et al*., 2003; Agrios, 2005; Schwartz and Gent, 2007). Anthracnose in solanaceous crops manifests itself mainly by direct fruit infection, thus, causing severe losses in the field and during post-harvest period (Bosland and Votava, 2003; Agrios, 2005; Pedroso *et al*., 2011). In some developing countries, anthracnose disease has caused marketable yield reduction of 10 to 80% of crop production (Poonpolgul and Kumphai, 2007). Fruit infected after harvest often appears completely healthy at the time of harvest, with disease symptoms only manifesting themselves during storage. This is due to the ability of some species of *Colletotrichum* to cause latent or quiescent infections in which the fungus infects immature fruit in the field and then becomes dormant until the fruit ripens, at which time it resumes its growth, causing disease on the fruit (Prusky and Plumbey, 1992;

Prusky, 1996). The damaged fruits lose their value and are rapidly exposed to secondary rot by other pathogens (Messiaen, 1994).

2.5 Causal organism of eggplant anthracnose and its distribution

Anthracnose is caused by the fungus *Colletotrichum,* a very important plant pathogen responsible for diseases on numerous plant species worldwide (Agrios, 2005; Roberts *et al*., 2009). The pathogen is mainly found in the subtropical, tropical (Bailey and Jeger, 1992) and warm temperate regions. Fruit anthracnose of eggplant is caused by *Colletotrichum gloeosporoides* f. sp. *melongenae* Fournet in West Indies and *C. nigrum* Ellis & Halst and *C. capsici* (Syd.) Butler & Bisby in Cote d'Ivore (Messiaen, 1994; Daunay and Chadha, 2004). Other *Colletotrichum* species reported to have caused anthracnose in eggplant include *Gloeosporium melongenae* Sacc., *C. dematium* (Pers. ex Fr.) Grove and *C. lindemuthianum* (Sacc. & Magnus) Briosi & Cavara (Tindal, 1992; Mathur and Kongsdal, 2001; Obeng- Ofori *et al*., 2007).

2.6 Survival and spread of the causal organism of eggplant anthracnose

Colletotrichum gloeosporoides f. sp. *Melongenae* survives in the wild on fruits of *Solanum torvum* Sw., creating a large reservoir of inoculum for subsequent distribution unto cultivated eggplant fields (Messiaen, 1994). *Colletotrichum* species can also survive on infected crop residue and seeds in a form of mycelium, spores (conidia), acervuli and micro-sclerotia (Pernezny *et al*., 2003; Agrios, 2005; Plant Health Initiative, 2012). The pathogen can over-season on alternative hosts of other solanaceous crops (pepper, tomato and potato), plant debris and rotten fruits in the field. Naturally, the pathogen produces micro-sclerotia to allow dormancy in the soil under stressful conditions. These micro-sclerotia can survive in the soil for many years

even throughout a two-or a three-year rotation period, though significant reductions in inoculum are quite likely (Pring *et al*., 1995; Phoulivong, 2011).

According to Roberts *et al*. (2009), conidia from acervuli and micro-sclerotia are splashed by rain or irrigation water during warm and wet periods from diseased to healthy fruit and foliage. This diseased fruit acts as a source of inoculum, thus allowing the pathogen to spread from plant to plant within the field. *Colletotrichum* species is not soil-borne and, therefore, cannot survive in the soil for long periods in the absence of infected plant debris. The fungus may also be introduced into a crop through infected seeds (Melanie *et al*., 2004).

Colletotrichum infection initially involves a series of processes. These include the attachment of conidia to plant surfaces, germination of conidia, production of adhesive appressoria, penetration of plant epidermis, growth and colonization of plant tissue and production of acervuli and sporulation (Bailey and Jeger, 1992; Prusky *et al*., 2000). Than *et al*. (2008) reported that the appressoria that are formed on immature fruits may remain quiescent until the fruits mature or ripen.

2.7 Importance of *Colletotrichum* species

Colletotrichum is one of the most important genera of plant pathogenic fungi worldwide, causing economically significant diseases to a wide range of host plants. In addition to economically important crops such as pepper, tomato, beans, sugar cane, guava, and yam, some species of *Colletotrichum* infect a variety of wild and weedy plants. Increasing attention is being paid to the use of microorganisms in biological control of weeds, pathogens, and insects (Charudattan and Walker, 1982; Lisansky and Hall, 1983). The fungus, *C. gloeosporioides*, has been successfully used to control

several species of weeds (Templeton, 1992; Boyette *et al*., 2007). *Colletotrichum gloeosporioides* f. sp. *malvae* (Penz.) Penz. & Sacc. has been developed as a myco-herbicide to control round-leaved mallow (*Malva pusilla*) Sm. weed in Canada (Goodwin, 2001). This fungus has been used for the control of northern jointvetch (*Aeschynomene virginica* (L.) Briton, Sterns & Poggenb weeds in soybean and rice (Smith, 1986). Also, Trujillo (1986) reported *C. gloeosporioides* as a possible biological control agent for *Clidemia hirta* (L.) D. Don, an invading weed in Hawaiian forest.

2.8 Symptoms of anthracnose disease in eggplant

Anthracnose disease is characterised by very dark, sunken lesions, containing spores (Isaac, 1992). The disease appears as small circular spots that coalesce to form large elliptical spots on fruits and leaves. Under severe conditions, defoliation of affected plants occurs (Nayaka *et al*., 2009). Mahendranathan *et al*. (2009) observed that these spots first appear as small, water-soaked lesions on fruit and then become raised with corky surfaces. Later, lesions are accompanied with the eruption of pink, slimy spore masses on the surface. Lesions become expanded rapidly on fruits. Fully expanded lesions appear soft, sunken and range in colour from dark red to tan to black (Wharton and Dieguez-Uribeondo, 2004; Voorrips *et al*., 2004).

Colletotrichum is capable of affecting various plant parts such as root, twigs, leaves, blooms and fruits, causing a range of symptoms such as crow root rot, defoliation, bloom blight and fruit rot (Isaac, 1992; Agrios, 2005; Lubbe *et al*., 2006). The fungus can cause damping-off in seedlings, particularly if infected seeds are used. Also, it can establish itself in seedlings without symptoms until the plants begin to flower. Often,

secondary infections may develop mainly from wind or rain-blown spores produced from infected plant residues (Plant Health Initiative, 2012).

Colletotrichum species are the most important pathogens that cause latent infection in crops. Therefore, post-harvest disease of a fruit often exhibits the phenomenon of quiescence in which symptoms do not develop until the fruit ripens (Jeffries *et al*., 1990). Bailey and Jeger (1992) indicated that appressoria are known to form adhesive disks that adhere to plant surfaces and remain latent until physiological changes occur in fruits. In contrast, appressoria that are formed on immature fruits may remain quiescent until ontogenic changes occur in the fruits (Prusky and Plumbley, 1992).

2.9 Climatic conditions of eggplant and anthracnose disease development relationship

Eggplant is a warm season vegetable. It requires a warm to hot condition over a five-month growing period to produce high yields and quality fruits. Periods of cool weather during the growing period will retard plant growth and reduce yields. Affected plants seldom recover, even if favourable growing conditions return (Ullio, 2003). Eggplant can tolerate drought and excessive rainfall, but shows relatively slow growth under very high temperatures, thus resulting in stunting. When both temperature and relative humidity are high, the plant becomes more vegetative (Chen and Li, 1996) thus, favouring the development of most fungal diseases. The optimum growing temperature range is 21–30 °C, with a maximum of 35 °C and minimum of 18 °C (Ullio, 2003).

Environmental factors which affect the plant growth also play vital role in the life cycle and survival of the pathogen, establishment of infection, host-parasite relation,

symptom and development of diseases as well as spread and recurrence of diseases (Pandey, 2010). The development and spread of post-harvest fungal diseases of fruits are equally influenced by these factors (Gadgile *et al*., 2009). Anthracnose disease is favoured by moderate to high temperatures, high relative humidity and frequent incidence of rains (Pernezny *et al.,* 2003). The relationships between rainfall intensity, duration, crop density and the dispersal of inoculum possibly lead to different levels of disease severity (Dodd *et al*., 1992). Royle and Butler (1986) reported that the effect of temperature often interact with factors, such as leaf surface wetness, humidity, light and perhaps competitive micro-biota. The duration of the surface wetness on the host, however, appears to have a direct influence on germination, infection and growth of the pathogen.

Generally, infection occurs during warm, wet weather. Temperatures around 27 °C and high humidity of 80 % are optimum for anthracnose disease development. However, infection can occur at both higher and lower temperatures. Severe losses occur during rainy season because the spores are washed or splashed to other fruit resulting in more infections (Roberts *et al*., 2009). Anthracnose fruit rot of eggplant caused by *Colletotrichum melongenae* is favoured by temperatures between 13 and 35 °C with optimum growth at 27 °C and humidity at 93 % or higher (DAFF, 2011). High temperature and relative humidity or wet weather at the time of ripening favours the spread of the fungus infection and often lead to destructive epidemic (Agrios, 2005).

2.10 The role of host plant resistance in managing eggplant anthracnose

The value of host plant resistance in controlling plant diseases was recognised in the early 1900s. Breeding for resistant varieties became necessary and desirable because of the advantages of planting a resistant variety instead of a susceptible one. Also, the

realisation of the dangers of polluting the environment through chemical control of plant diseases gave an additional impetus and importance to the search for resistant varieties of crops, including eggplant (Agrios, 2005; Chaube and Pundhir, 2009). The use of resistant cultivars not only eliminates losses from diseases, but also reduces the need for and cost of other controls. Moreover, the usefulness and importance of host plant resistance are paramount in the production of food, fibre (Pataky and Carson, 2004; Agrios, 2005) and other raw materials necessary for industrial use.

Host resistance utilizes in-built mechanism to resist the activities of pathogens. The infection or damage caused by pathogens can be rendered ineffective through genetic manipulation. Also, host resistance can be induced by the use of certain biotic and abiotic factors. The discovery of Mendelian laws of inheritance and developments in plant breeding techniques have contributed to developing resistant varieties to certain pathogens. Some of the breeding techniques include selection, mutation and hybridization. Biotechnological tools are also used to develop resistant cultivars of various economically important crops (Chaube and Pundhir, 2009).

Cultivated *S. melongena* genotypes often have insufficient levels of resistance to biotic and abiotic stresses. The genetic resources of this species have been assessed for resistance to its most serious diseases and pests. The attempts at crossing eggplant with its wild relatives often result in limited success due to sexual incompatibilities (Sekara *et al*., 2007). Also, Than *et al*. (2008) reported that breeding to develop long-lasting resistant varieties have not been successful due to involvement of multiple *Colletotrichum* species in anthracnose infection.

According to Chen and Li (1996), breeding for disease resistance is one of the major objectives of eggplant improvement. However, there are a number of economically important diseases for which control is either absent or prohibitively costly. Exploitation of host plant resistance in breeding gives rise to resistant cultivars which will make production in disease prone areas economically feasible. In collaboration with plant pathologists, eggplant breeders have successfully developed increasingly higher disease resistant lines.

Attempts to develop eggplant resistant to diseases would not have been possible without the genetic resources to sustain the breeding efforts. The genus *Solanum* is a source of genetic variability. At the Indian Agricultural and Research Institute (IARI), New Delhi, genes for resistance to various eggplant diseases have been uncovered from both cultivated and wild relatives and in many cases, their underlying source of inheritance has also been studied (Messiaen, 1994; Daunay and Chadha, 2004). As a result, sources of resistance to major diseases (Bacterial wilt, Verticillium wilt, Phomopsis blight and Anthracnose) have been identified either from the cultivated *S. melongena* from other related *Solanum* species. Cultivars such as Zebrina, Aranquez, Aomura and Porcelaine have been reported to be resistant to anthracnose (Daunay and Chadha, 2004). The resistance in Zebrina and Aranquez has been observed to be inherited by a single dominant gene. Improvement in eggplant export in India was achieved with the release of Kalenda, a hybrid from L 17 and Aranquez. This hybrid is resistant to anthracnose and moderately resistant to bacterial wilt (Messiaen, 1994).

2.11 Management of eggplant anthracnose

The most effective and efficient way of controlling eggplant anthracnose caused by *Colletotrichum* species usually involves the use of one or a combination of several control methods. These control methods include cultural, chemical, biological (using antagonistic organisms) and the use of resistant eggplant cultivars (Wharton and Deiguez-Uribeondo, 2004; Agrios, 2005).

2.11.1 Cultural control of eggplant anthracnose

Cultural control involves activities or tactics aimed at disease avoidance through phytosanitation, manipulation of cropping patterns, or by enhancing resistance and avoiding pre-disposition (Agrios, 2005; Roberts *et al*., 2009). The ubiquitous nature of inoculum sources of *Colletotrichum* under suitable conditions reduces the effectiveness of most pre-harvest general phytosanitary practices. However, general farm hygiene has a place in integrated disease control, as removal of inoculum sources such as diseased leaves and fruit can increase the efficiency of chemical control (Bailey and Jeger, 1992). Eggplant seeds and transplants (seedlings) free from *Colletotrichum* should be used (Sutton, 1992; Kefialew and Ayalew, 2008). Proper plant spacing should be maintained to provide adequate movement of air around plants which helps reduce the severity of foliar diseases (Abang *et al*., 2009). Transplants should be kept clean by controlling weeds and solanaceous volunteer plants which could be the source of the inoculum.

Bailey and Jeger (1992) reported crop rotation as one of the best ways to promote healthy crops production, since it helps minimize diseases especially those caused by soil-borne pathogens. Mulching materials, if available, should be provided to reduce the

splashing of soil onto fruit and lower leaves during rains. Overhead irrigation should be minimized or avoided to reduce periods of wetness. The field should have good drainage and free from infected plant debris. Insects should be controlled to reduce fruit wounds as they provide entry points for *Colletotrichum* species (Agrios, 2005; Than *et al*., 2008; Roberts *et al*., 2009). Harvesting eggplant fruits as soon as they mature or start ripening reduces post-harvest infection (Jeyalakshmi and Seetharaman, 1998; Kefialew and Ayalew, 2008). In addition, proper sanitation measures should be taken after harvesting eggplant fruits to minimize the resumption of growth of the dormant infection of the pathogen (Abang *et al*., 2009).

2.11.2 Chemical control of eggplant anthracnose

Jeger and Plumbley (1998) observed that chemicals are widely used for controlling anthracnose in fruits of many crops, including eggplant. This could be due to the increase in value of the produce which usually offsets the chemical expenditure. Also, the availability and efficiency of chemical control is relatively greater, compared to other control methods. In general, anthracnose disease caused by *Colletotrichum* species is controlled by a wide range of fungicides (Waller *et al*., 1993). Broad-spectrum fumigants may be applied to the soil to control the pathogen (Bailey and Jeger, 1992). Some of these fungicides include mancozeb, propineb, carbendazim, dipheconasol, dicolad, strobilurins and benomyl (Voorrips *et al*., 2004).

Hartman and Wang (1992) indicated that even with the application of fungicides, pre- and post-harvest anthracnose fruit rot can still cause severe losses. Moreover, the problem of fungicide tolerance may arise quickly if farmers rely upon a single fungicide too heavily. Also, there could be negative effects on farmers' income and

health, particularly in developing countries such as Ghana (Voorrips *et al*., 2004; Wharton and Deiguez-Uribeondo, 2004; Agrios, 2005). Farmers may get into the habit of over-spraying their crops with fungicides and may lead to other forms of damage. Also, this increases the cost of chemical applications.

Proper timing and placement are of critical significance for a successful chemical control. The application of fungicides to plants when the first fruit are set may be recommended for effective control of anthracnose, particularly when environmental conditions are less than optimum for disease development or when a low level of inoculum is present. This will prevent or minimize the occurrence of infections (Asian Vegetable Research and Development Center, 2003). However, poorly timed fungicide applications may actually lead to an increase in the severity of disease due to the disturbance of natural biological control mechanisms and increased crop susceptibility. Although treatment with fungicides can significantly reduce the incidence and severity of disease, eradication cannot normally be achieved. Thus, if treatments are stopped and conditions favourable for disease re-occur, then the disease in the crop may subsequently increase. Applications prior to conducive conditions are, thus, required and rotation programmes between fungicides of different classes are highly recommended (Adaskaveg and Forster, 2000). Development of models to predict anthracnose risk due to environmental conditions can efficiently reduce the number of fungicide applications (Wharton and Diéguez-Uribeondo, 2004).

2.11.3 Biological control of eggplant anthracnose

Phoulivong (2011) indicated that biological control methods for anthracnose diseases caused by *Colletotrichum* species have not received much attention until recently. The

possibilities of biological control for post-harvest fruit diseases caused by *C. gloeosporioides* using *Pseudomonas fluorescens* (Flugge) Migula have been successful in reducing anthracnose development (Jeger and Plumbley, 1998; Nakasone and Paul, 1998). These positive results indicate that there is considerable potential for the development of a biological control agent for control of anthracnose disease. Korsten *et al*. (1997) reported that most biological control methods are still at the research stage while others have resulted in a number of new commercial products developed for post-harvest applications. Jeyalakshmi and Seetharaman (1998) observed that biological control of anthracnose disease with plant products in laboratories and field trials showed that crude extracts from rhizome, leaves and creeping branches of sweet flag (*Acorus calamus* L.), palmorosa (*Cymbopogon martini*) (Roxb.) Wats. oil, and neem (*Azadirachta indica*) A. Juss. oil could restrict growth of the pathogen. Biological control agents such as *Bacillus subtilis* (Ehrenberg) Cohn and *Candida oleophila* Montrocher have been tested for their efficacy against *Colletotrichum* species (Wharton and Diéguez-Uribeondo, 2004). Some species of *Trichoderma* have also shown a positive inhibitory effect against some groups of *Colletotrichum* species (Shovan *et al*., 2008). Inducing natural disease resistance (NDR) mechanism in eggplant against anthracnose disease, using a biological elicitor, has also been studied (Mahendranathan *et al*., 2009).

2.11.4 Control of eggplant anthracnose by using resistant cultivars

The use of resistant cultivars is perhaps the most desirable method of controlling diseases in crops (Wharton and Diéguez-Uribeondo, 2004; Than *et al*., 2008). This approach, according to Voorrips *et al*. (2004), has been less exploited in fruit and vegetable crops mainly due to the longer time required for breeding and selecting for resistance and the short term advantage of chemical control. Cultivar resistance in fruit

crops is also complicated by the ability of most *Colletotrichum* fruit pathogens to form quiescent infections (Agrios, 2005).

In spite of all these, host resistance is considered the most prudent means of disease control because of its effectiveness, ease of use, and lack of potential negative effects on the environment (Phoulivong, 2011). In most host-pathogen interactions, resistance involves the triggering of host defense responses that prevent or retard pathogen growth and may be conditioned by a single gene pair, a host resistance gene and a pathogen avirulence gene (Flor, 1971). Resistant cultivars such as Kalenda, Aranquez, Zebrina, Aomura and Porcelaine can be used, if available, to the farmer. However, these cultivars must be used judiciously to prevent breakdown by the pathogen (Messiaen, 1994; Daunay and Chadha, 2004).

CHAPTER THREE

3.0 MATERIALS AND METHODS

The study was divided into two; surveys and experimentations. The experimentations included pathogen isolation and identification, proof of pathogenicity and screening of eggplant genotypes for anthracnose resistance.

3.1 Surveys: Assessment of eggplant anthracnose and farmers' perception on some factors affecting production

The surveys involved assessment of the incidence and severity of eggplant anthracnose in four selected major eggplant growing Districts of Ashanti and Brong Ahafo Regions. Three communities were selected from each District. Within each community, 10 eggplant farms were identified and visited. The communities and the farms were identified with the help of the District Ministry of Food and Agriculture staff. The districts and respective communities selected are tabulated below (Table 3.1).

Table 3.1: The list of regions, districts and communities surveyed during the study

REGION	DISTRICT	COMMUNITIES
Brong Ahafo	Techiman North	Aworowa, Tuobodom, Offuman
Brong Ahafo	Nkoranza South	Nkwabeng, Akumsa Domase, Akuma
Ashanti	Ejura	Ejura, Oku, Droma Kuma
Ashanti	Ofinso North	Afrancho, Nkwankwa, Akumadan

In all, 120 farmers were interviewed on some factors that affect eggplant production such as crop husbandry techniques, sources of seeds, pesticide use and anthracnose disease problem (Appendix 1). Disease assessment sheets (Appendix 2) were used to record both the incidence and severity in each farm in each of the communities

indicated above. Thirty plants were randomly sampled and examined in each farm for disease incidence and severity. Disease severity was scored using a scale 0-10 (Table 3.2).

Table 3.2: Scale for scoring disease severity

Severity scale	Surface area of plant affected by disease (%)	Reaction category
0	0	Highly resistant
1	1-10	Resistant
2	11-20	
3	21-30	Moderately resistant
4	31-40	
5	41-50	Moderately susceptible
6	51-60	
7	61-70	Susceptible
8	71-80	Highly susceptible
9	81-90	
10	91-100	

Source: (Paul *et al*., 2008)

Samples of anthracnose-infected eggplant leaves and fruits were collected and stored in a refrigerator during the surveys prior to pathogen isolation at the Plant Pathology Laboratory of the Department of Crop and Soil Sciences, KNUST, Kumasi.

3.2 Preparation of Potato Dextrose Agar (PDA) and dispensing of medium

Twenty grammes of commercially prepared Potato Dextrose Agar (Oxoid CM0139) was dissolved in 1000 ml of distilled water in a beaker. The medium was amended with 500 mg of chloramphenicol. It was then gently transferred into four flat bottom flasks,

covered with aluminium foil and sterilised in an autoclave at 121 ^{o}C for 15 minutes under pressure of 15 psi. The flasks were removed and cooled after sterilisation to about 45 ^{o}C. The medium was carefully dispensed into sterile 9-cm diameter Petri dishes in laminar flow hood and allowed to cool to room temperature. Each dish contained 25 ml of the medium

3.3 Preparation of *Colletotrichum* species inocula

Conidial suspension of *Colletotrichum* species was prepared by flooding a 14-day old culture with 10 ml of sterile-distilled water and gently brushing the surface with a sterile brush into 50 ml-beakers. The conidial suspension of the pathogen was filtered through double layered cheesecloth into a different beaker and the resultant suspension was used as the inoculum. The conidial concentration was adjusted to $1x10^{5}$ ml^{-1} and used for the inoculation. The conidia were countered, using haemocytometer.

3.4 Pathogen isolation and identification

Samples of anthracnose-infected leaves and fruits were collected during the field surveys as indicated earlier. Small sections of these leaves and fruits were removed using a scalpel with a sharp blade. These small sections of the anthracnose-infected leaves and fruits were surface sterilized with 10 % sodium hypochlorite (1 % Chlorine), rinsed thoroughly with sterile-distilled water and blotted dry. They were then plated on the PDA medium and incubated at 28 °C for seven days. Isolated colonies of the pathogen were sub-cultured into fresh plates of the PDA medium until pure cultures were obtained. The pathogens were observed, using compound microscope, and identified, using identification manuals by Barnett and Hunter (1986) and Watanabe (2002).

3.5 Sterilisation of soil and raising of eggplant seedlings

Loamy soil was collected from the Department of Horticulture, KNUST, Kumasi. The soil was steam-sterilised at 100 ^{o}C for about four hours and allowed to cool over-night. After cooling, the soil was filled in pots of 16-cm diameter to depth of about 12-cm. A space of 3-cm was left on top of the soil. Each pot had three holes at the bottom to allow for drainage after watering.

Seeds of the cultivar Obolo collected during the field surveys were raised in nursery box in the plant house of the Department of Crop and Soil Sciences, KNUST, Kumasi. The seedlings were transplanted six weeks after sowing at one seedling per pot. In the field experiment, however, seedlings of all the genotypes were raised separately in seedbeds.

3.6 Proof of pathogenicity of the *Colletotrichum* species

Disease-free fruits and potted seedlings of the susceptible eggplant cultivar (Obolo) were used for the study. The fruits were collected into polythene bags during the field surveys. The fruits were surface-sterilised in 70 % ethanol, rinsed twice with sterile-distilled water and blotted dry. A wound of 5-mm diameter and 5-mm deep was created on the fruit, using heat-sterilised cork borer and needle. One microlitre of the spore suspension was deposited into the wound and allowed to air dry. The inoculated fruit was placed under glass jar and incubated for seven days. Adequate humidity was ensured as shown in Plate 4.4. Also, potted seedlings were inoculated two weeks after transplanting. Ten microlitres of the inoculum suspension of each *Colletotrichum* species was sprayed onto five potted plants. Inoculated plants were covered with polythene bags to maintain humidity for 48 hours. Inoculated plants were incubated for

seven days. Fruit and potted plant symptoms were examined seven days after inoculation. The pathogens were re-isolated to confirm Koch's postulates.

3.7 Field experimentation: Screening of eggplant genotypes for resistance to anthracnose

3.7.1 Location of the experiment

The trial was conducted at Aworowa in the Techiman North District in Brong Ahafo Region of Ghana during the major cropping season from March to August, 2013.

3.7.2 Planting materials and sources

In all, 20 genotypes of eggplant were used in the study. These genotypes were made up of four different *Solanum* species and their sources are listed in Table 3.3.

3.7.3 Transplanting and crop management

As indicated earlier, seedlings of all the genotypes used in the field experimentation were raised separately in seedbeds. The seedlings were transplanted six weeks after sowing in three rows at spacing of 1 m x 0.8 m. Weeds were controlled three times by hoeing. Compound fertilizer NPK 15-15-15 at the rate of 300 kg/ha (45 kg N, 45 kg P_2O_5, 45 kg K_2O) was applied two weeks after transplanting. Sulphate of ammonia was also applied at flowering at the rate of 200 kg/ha. Generally, a total of 26.7 g of NPK and sulphate of ammonia was supplied per plant. An insecticide, Chlorpyriphos 48 % EC was applied at weekly intervals at a rate of 75 ml per 15 l of water against insect pests such as grasshoppers, fruit beetles and fruit and stem borers.

3.7.4 Data collection

Data collected were disease incidence and severity. Disease severity was scored based on total leaf and fruit symptoms expression using a scale of 0-10 (Paul *et al*., 2008). Also, agronomic data such as plant height (cm), stem girth (cm), number of branches, number of fruits, fruit weight/fruit (g) and total yield (t/ha) per eggplant genotype were assessed as elaborated below.

3.7.5 Plant height

Three plants from each genotype were randomly selected and tagged. Their heights (cm) were taken using a rule throughout the growth period and the mean determined each time. Plant heights were taken at two, four, six, eight, 10 and 12 weeks after transplanting.

3.7.6 Stem girth

The stem girth (cm) was taken from the three tagged plants of each genotype. A rope was tied around the stem of each plant about 5-cm from the ground/soil and then the rope was placed on a tape measure to determine their girth. The mean of three measurements per genotype was determined. The stem girth was taken at six and 12 weeks after transplanting.

3.7.7 Number of branches

The number of branches on each of the three tagged plants were counted and the mean taken for all the genotypes. Both primary and secondary branches were countered. The number of branches was taken at six and 12 weeks after transplanting.

Table 3.3: The list of eggplant genotypes, species and their sources

Eggplant genotype	Scientific name	Source of genotype
Kalenda F1	*Solanum melongena*	Agri-care (Technisem)
African beauty F1	*S. melongena*	Agri-care (Technisem)
Zebrina	*S. melongena*	Selection from farmers
Long white	*S. melongena*	Selection from farmers
Manyire green	*S. aetheopicum*	CRI – SARI Tamale
Tengaru white	*S. aetheopicum*	CRI – SARI Tamale
TZ SMN 2 – 8	*S. aetheopicum*	CRI – SARI Tamale
TZ SMN 3 – 10	*S. aetheopicum*	CRI – SARI Tamale
Lushoto	*S. aetheopicum*	CRI – SARI Tamale
Kpando	*S. aetheopicum*	CRI – Kwadaso
CRI 05 – 002	*S. aetheopicum*	CRI – Kwadaso
Dwumo	*S. aetheopicum*	CRI – Kwadaso
Oforiwaa	*S. aetheopicum*	CRI – Kwadaso
F1 Djamba	*S. aetheopicum*	Agri-care (Technisem)
Kotobi	*S. aetheopicum*	Agri-care (Technisem)
Aworoworo	*S. aetheopicum*	Selection from farmers
Obolo	*S. aetheopicum*	Selection from farmers
Antropo	*S. microcarpon*	Selection from farmers
Boasua green	*S. anguivi*	Selection from farmers
Nsusua	*S. anguivi*	Selection from farmers

3.7.8 Fruit weight per fruit

Four average fruits of each genotype were collected from each plot after harvesting and their mean weight determined, using an electronic scale.

3.7.9 Number of fruits per genotype

Fruits of the three tagged plants on each plot were counted and the mean determined. Very small immature fruits were not counted.

3.7.10 Total yield per genotype

Mature fruits per genotype from net area of 2 x 2.4 m were harvested on weekly interval and weighed (kg) with top pan scale. They were later summed up and converted to tonnes per hectare.

3.8 Evaluation of eggplant fruits for reactions to *Colletotrichum dematium* in vitro

Four fruits of uniform size were collected from each genotype in the field experiment. The fruits were sterilised in 70 % ethanol, rinsed twice in sterile-distilled water and blotted dry. A wound of 5-mm diameter and 5-mm deep was created on the fruits using a heat-sterilised cork borer and needle. Conidial suspension of *C. dematium* was prepared by flooding a 14-day old culture with 10 ml of sterile distilled water and gently brushing the surface with a sterile brush into 50 ml beaker. The conidial suspension of the pathogen was filtered through double layered cheesecloth into a different beaker and the resultant suspension was used as the inoculum. The conidia concentration was adjusted to $1x10^5$ ml^{-1} and used for the inoculation. The conidia were countered using haemocytometer. One microlitre of the spore suspension was dispensed into the wound created on the fruits and allowed to air-dry. Inoculated fruits were placed in polythene bags and incubated for seven days. Adequate humidity was ensured by placing a beaker with water in the setup. Fruits were examined for symptoms and lesion diameter was measured, using a rope and ruler.

3.9 Experimental design and data analysis

The field experiment was laid in a randomized complete block design (RCBD) with four replications. A treatment plot size of 2 x 4 m was used. The total plot size used for

the experiment was 640 m^2.Completely randomised design (CRD) with four replications was used for the laboratory experiment.

All field (agronomic) and laboratory data were subjected to statistical analysis using GENSTAT statistical package Ninth Edition (www.genstat.co.uk). Analysis of variance for randomized complete block design and completely randomized design were used to determine the genotype effect. Means were separated using Lsd at 5 % level of probability.

CHAPTER FOUR

4.0 RESULTS

4.1 Surveys: Assessment of eggplant anthracnose and farmers' perception on some factors affecting production

The study showed that 80 % of the farmers interviewed were between 20 and 50 years of age while 20 % were above 51years (Table 4.1). Out of a total of 120 farmers interviewed, 99 were males and 21 females (Table 4.2). From Figure 4.1, only 27 % of the farmers had no level of formal education. Although majority of the farmers had some level of education, not all could read and understand directions on pesticide labels. The eggplant varieties that farmers cultivated are Aworoworo, Obolo (Obaatia), Amantin, Boasua, Ansurowia and Nsusua. It was observed that the most commonly grown varieties of eggplant were Aworoworo and Obolo/Obaatia (Table 4.3). Boasua, Ansurowia and Nsusua were grown usually for domestic use. These eggplant varieties were selected for one reason or another (Table 4.4).

Table 4.1: The age range of eggplant farmers interviewed and the percentage of farmers in each age range

Age range of farmers interviewed	Percentage (%)
20 – 30	12.5
31 – 40	31.7
41 – 50	35.8
51 – 60	17.5
Over 60	2.5
Total	100.0

Table 4.2: The gender group of the eggplant farmers interviewed and number of farmers

Sex	Number of farmers	Age range (years)
Male	99.0	25 – 64
Female	21.0	35 – 56

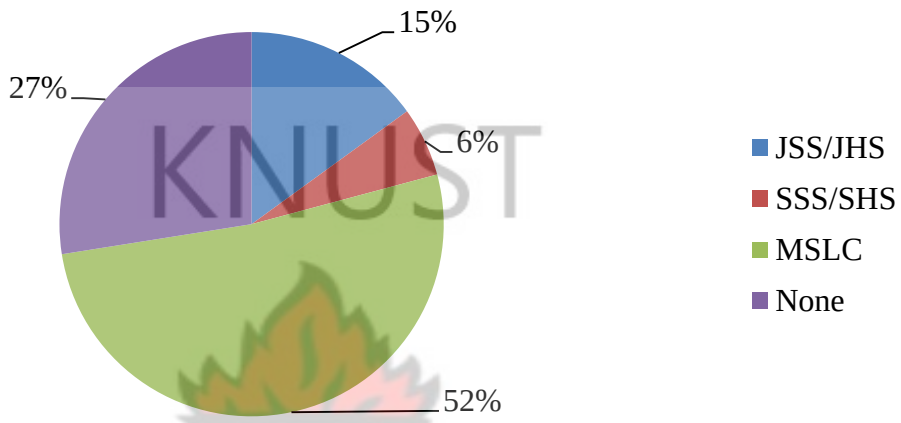


Figure 4.1: Educational status of eggplant farmers interviewed

Table 4.3: Eggplant varieties cultivated by farmers in the surveyed areas

Eggplant variety	Percentage (%)
Obolo/Obaatia	28.3
Aworoworo	41.7
Amantin	1.7
Aworoworo and Ansurowia	0.8
Boasua	5.0
Nsusua	4.2
Obolo and Aworoworo	15.0
Aworoworo and Amantin	3.3

Table 4.4: Farmers' reasons for choosing a particular eggplant variety

Reasons for choosing eggplant variety	Eggplant varieties/number of farmers					
	Obolo	**Aworoworo**	**Boasua**	**Amantin**	**Nsusua**	**Ansurowia**
Marketable	22	46	6	2	5	1
Sweet taste	0	34	5	0	5	0
Early maturing	34	0	0	0	0	0
Big fruit size	30	1	0	2	0	0
High yielding	34	10	4	0	5	0
Long fruiting period	0	41	6	2	5	1
Short plant height/easy spraying	34	0	0	0	0	0
Good fruit appearance	28	11	0	0	0	0
High consumer preference	9	38	5	2	4	1
High price	13	40	6	2	5	1

4.1.1 Sources of eggplant seeds for the farmers

Farmers obtained seeds of these varieties from friends, farmers' own seeds (selection from previous season), agro-dealers, and customers/buyers (Figure 4.2). The figure further shows that 35.8 % of the farmers depended on their own seeds.

4.1.2 Farm practices used by farmers

All the 120 farmers indicated that they do not treat the eggplant seeds with any chemical (either organic or synthetic) after obtaining the seeds. Also, all the farmers indicated that they do not cultivate on the same piece of land year after year. However, fallow period was either two or three years. Majority (64.2 %) of the farmers interviewed used fallow period of two years while 35.8 % used three years

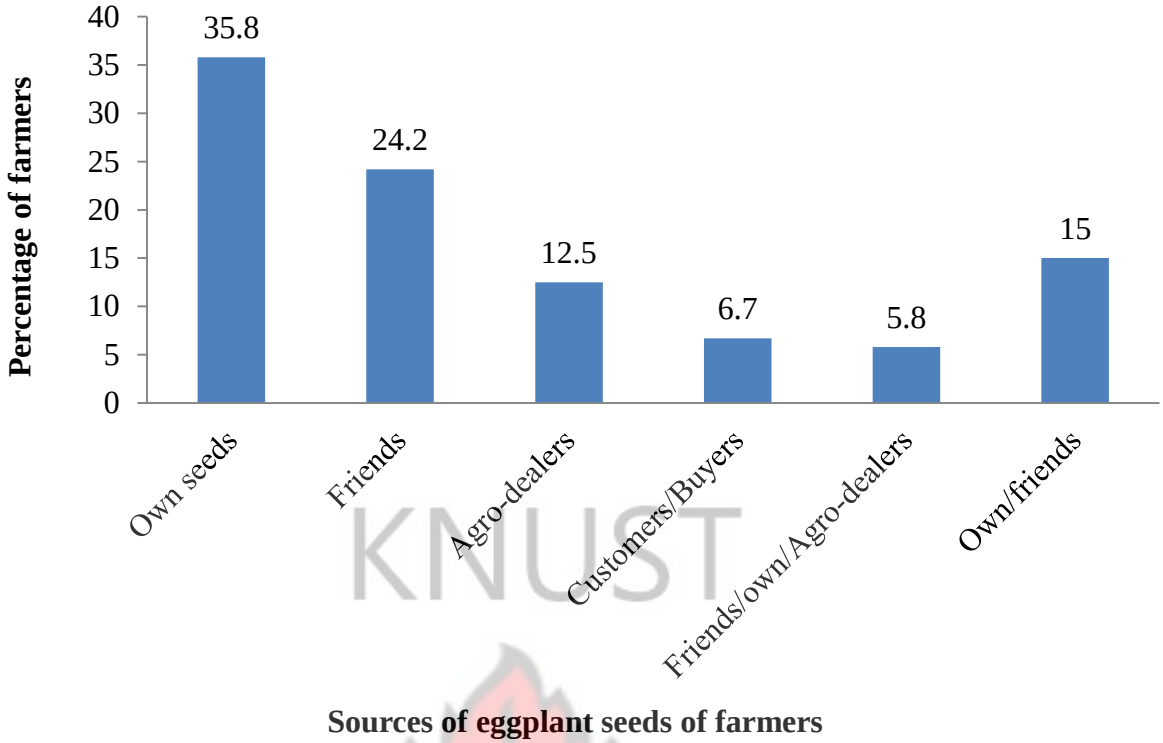


Figure 4.2: Sources of eggplant seeds for farmers interviewed in the studied areas

(Figure 4.3). Of all the farmers interviewed, 88.3 % practised sole cropping while 11.7 % practised intercropping (Figure 4.4). Generally, the farmers raised seedlings on nursery beds before transplanting. Seedlings were transplanted either on flat or ridges. None of the farmers interviewed used manure for production. Although some of the farmers indicated they have been cultivating under irrigation regimes, none of the farms visited was found cropping under irrigation.

4.1.3 Problems that farmers encounter in eggplant production

Farmers indicated that diseases, insect pests, marketing, capital, transportation and inadequate farm inputs (fertilizer and pesticide) were the problems encountered in the eggplant production (Table 4.5).

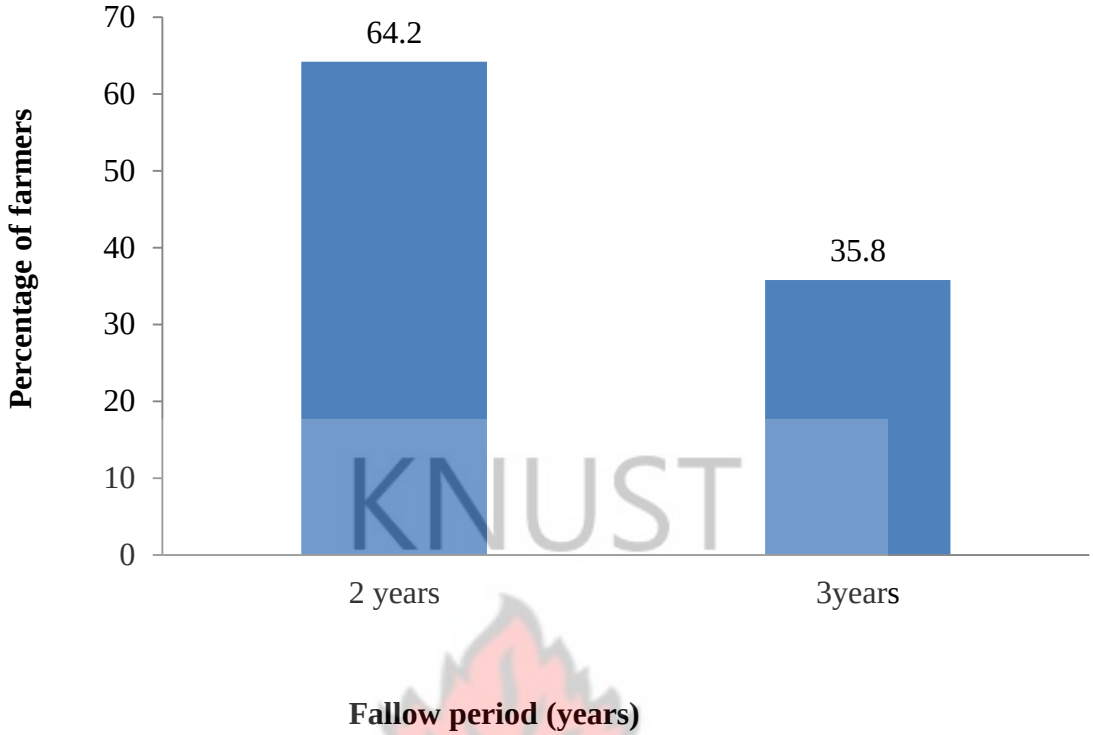


Figure 4.3: The number of years that farmers allowed land to fallow

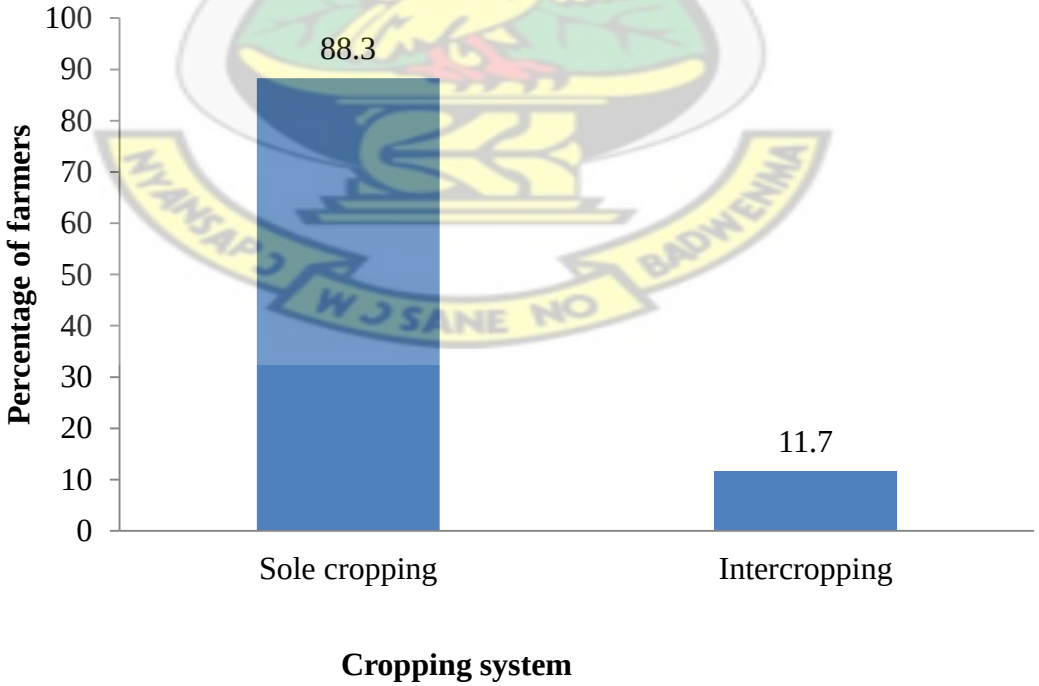


Figure 4.4: Cropping systems practiced by the eggplant farmers interviewed

Table 4.5: The problems that farmers encounter in eggplant production

Problems of eggplant production encountered by farmers	Number of farmers
Diseases	20
Insects	41
Diseases and insects	18
Insects and capital	3
Insects and marketing	8
Diseases, insects and capital	2
Diseases, insects and marketing	16
Insects, marketing and capital	2
Diseases, marketing and farm inputs	1
Diseases, marketing and capital	2
Diseases, insects and farm inputs	2
Diseases, capital and farm inputs	1
Diseases, insects, capital and farm inputs	3
Diseases, insects, marketing, transportation and farm inputs.	1

Some of the insect pests mentioned included grasshoppers, fruit and stem borers, fruit beetles and leaf rollers (Figure 4.5). Die-back, anthracnose fruit rot, damping-off, viral diseases (locally called macho) and wilts were among diseases that farmers often encountered in the field (Figure 4.6). About 17.5 % of the eggplant farmers interviewed mentioned anthracnose as a problem. The farmers, however, had different views concerning the frequency of anthracnose disease occurrence, even after they have been shown fruit and leaf symptoms (Table 4.6). Also, farmers had diverse views on the factors responsible for eggplant anthracnose (Table 4.7). Some believed that it was caused by drought, high temperature, pathogen and insect pest while others had no idea.

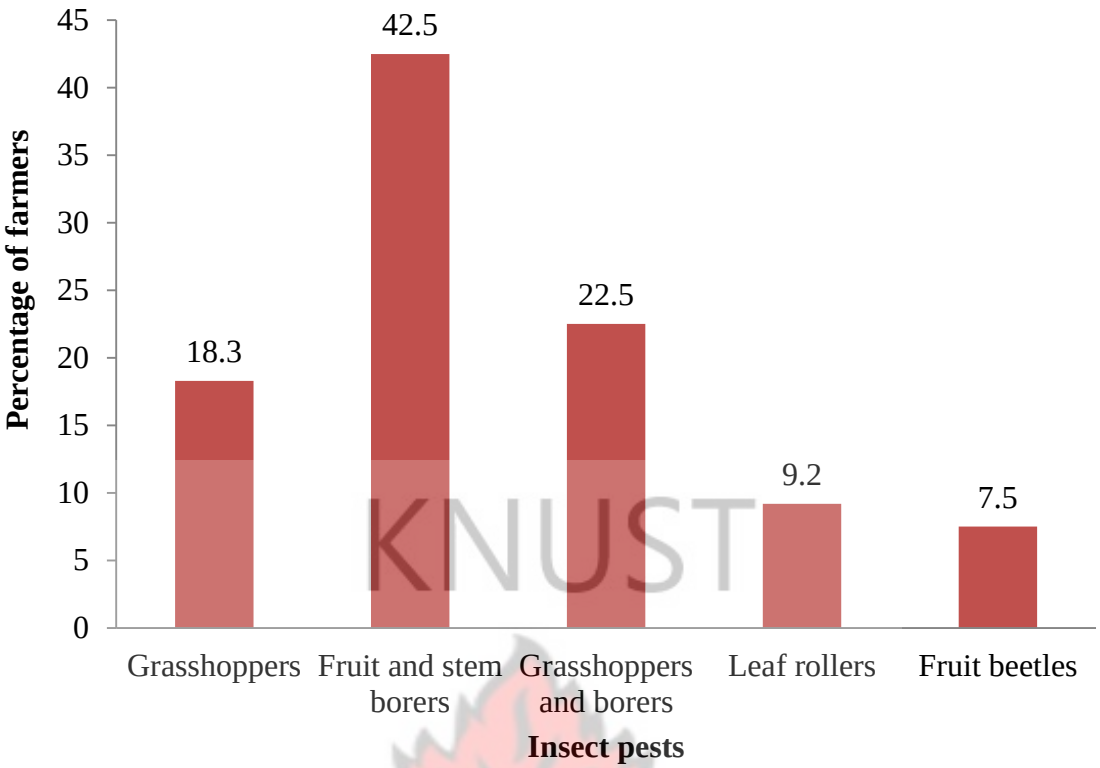


Figure 4.5: Insect pests that affect eggplant production in the surveyed areas

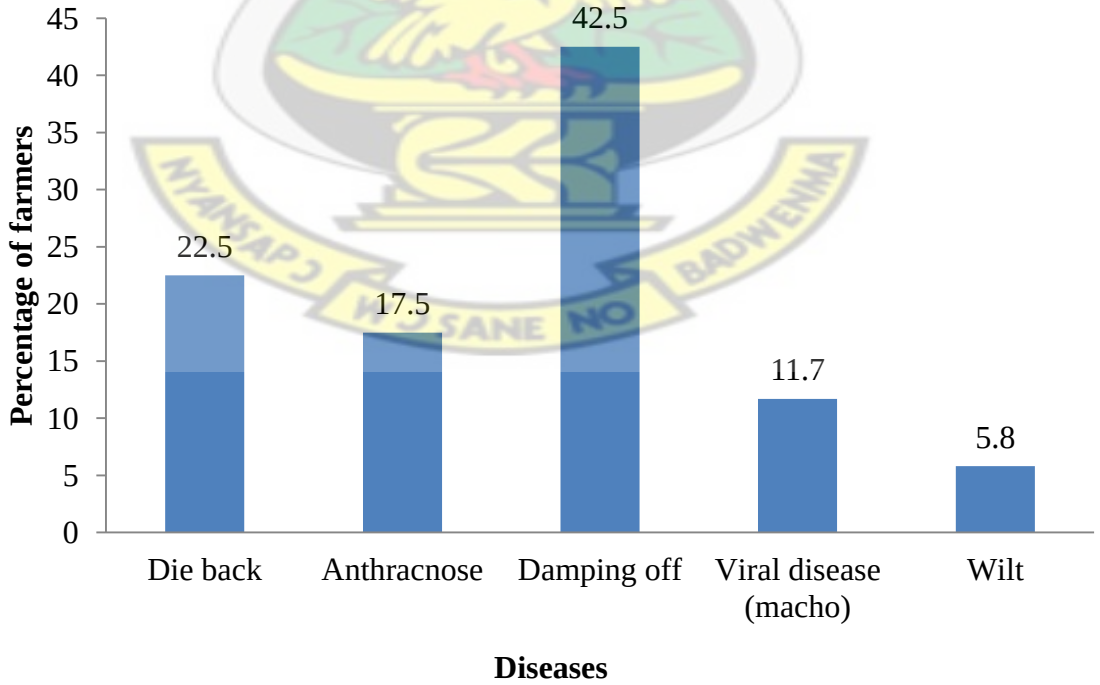


Figure 4.6: Diseases that affect eggplant production in the surveyed areas

Table 4.6: Farmers' view on the frequency of anthracnose disease occurrence in surveyed areas

Farmers' view on frequency of anthracnose occurrence	Number of farmers
Not common	41
Common	22
Very common	57

Table 4.7: Farmers' perception on factors that are responsible for eggplant anthracnose in the surveyed areas

Farmers' perception on causes of eggplant Anthracnose	Percentage of farmers (%)
Pathogen (s)	15.8
Weather (High temperature, drought and sun light)	27.5
Insects	20.0
Insects and pathogens	5.9
No idea	30.8

4.1.4 Assessment of eggplant disease incidence and severity during field survey

The mean incidence of eggplant anthracnose during the surveys in 30 farms in the Techiman North District was 47.3 % while disease severity was 6.0 (Table 4.8). The farm to farm incidence and severity ranged from 20-70 % and 3-10, respectively. Anthracnose disease incidence of eggplant in Nkoranza South District ranged from 0.0 to 63.3 % while severity was between 0 and 8 (Table 4.9). From Table 4.10, 45.0 % mean disease incidence and 6.0 disease severity were recorded in Offinso North District. Disease severity ranged from 4 to 10 while disease incidence was between 23.3 and 66.7 %. In general, the lowest (39.3 %) disease incidence was recorded in the Ejura District (Table 4.11). Disease severity however, was 5.5.

Table 4.8: Disease incidence and severity of eggplant anthracnose in Techiman North District

Community/Farm number	Disease incidence (%)	Disease severity (scale 0-10)
Aworowa		
1	63.3	7.0
2	46.7	5.0
3	70.0	7.0
4	40.0	7.0
5	56.7	7.0
6	36.7	5.0
7	53.3	6.0
8	33.3	4.0
9	43.3	4.0
10	60.0	6.0
Offuman		
1	26.7	4.0
2	60.0	8.0
3	36.7	6.0
4	50.0	5.0
5	33.3	5.0
6	60.0	7.0
7	33.3	5.0
8	20.0	3.0
9	43.3	6.0
10	63.3	6.0
Tuobodom		
1	53.3	9.0
2	43.3	6.0
3	30.0	4.0
4	60.0	7.0
5	50.0	7.0
6	66.7	6.0
7	56.7	6.0
8	43.3	7.0
9	23.3	4.0
10	63.3	10.0
Mean	47.3	6.0

Table 4.9: Disease incidence and severity of eggplant anthracnose in Nkoranza South District

Community/Farm number	Disease incidence (%)	Disease severity (scale 0-10)
Nkwabeng		
1	16.7	3.0
2	60.0	8.0
3	50.0	8.0
4	36.7	5.0
5	13.3	4.0
6	56.7	7.0
7	50.0	7.0
8	43.3	5.0
9	53.3	5.0
10	60.0	5.0
Akumsa Domase		
1	0.0	0.0
2	46.7	7.0
3	53.3	6.0
4	43.3	6.0
5	0.0	0.0
6	50.0	7.0
7	63.3	7.0
8	30.0	4.0
9	43.3	4.0
10	60.0	7.0
Akuma		
1	33.3	5.0
2	53.3	6.0
3	43.3	6.0
4	0.0	0.0
5	50.0	6.0
6	53.3	6.0
7	43.3	5.0
8	53.3	6.0
9	36.7	5.0
10	30.0	5.0
Mean	41.0	5.2

Table 4.10: Disease incidence and severity of eggplant anthracnose in Offinso North District

Community/Farm number	Disease incidence (%)	Disease severity (scale 0-10)
Akomadan		
1	56.7	10.0
2	36.7	6.0
3	43.3	6.0
4	56.7	9.0
5	33.3	5.0
6	46.7	7.0
7	30.0	5.0
8	36.7	4.0
9	66.7	7.0
10	23.3	4.0
Afrancho		
1	46.7	6.0
2	60.0	6.0
3	46.7	5.0
4	66.7	9.0
5	43.3	4.0
6	33.3	4.0
7	63.3	9.0
8	56.7	5.0
9	33.3	6.0
10	43.3	5.0
Nwankwa		
1	36.7	5.0
2	30.0	5.0
3	50.0	7.0
4	40.0	5.0
5	60.0	7.0
6	50.0	7.0
7	56.7	8.0
8	40.0	5.0
9	30.0	4.0
10	46.7	6.0
Mean	45.0	6.0

Table 4.11: Disease incidence and severity of eggplant anthracnose in Ejura District

Community/Farm number	Disease incidence (%)	Disease severity (scale 0-10)
Ejura		
1	33.3	5.0
2	50.0	8.0
3	43.3	6.0
4	33.3	5.0
5	50.0	8.0
6	43.3	8.0
7	0.0	0.0
8	56.7	8.0
9	36.7	6.0
10	46.7	5.0
Oku		
1	63.3	9.0
2	0.0	0.0
3	43.3	6.0
4	53.3	8.0
5	46.7	6.0
6	0.0	0.0
7	43.3	6.0
8	0.0	0.0
9	56.7	7.0
10	46.7	7.0
Droma Kuma		
1	46.7	6.0
2	40.0	6.0
3	56.7	7.0
4	33.3	4.0
5	50.0	6.0
6	40.0	5.0
7	33.3	5.0
8	46.7	5.0
9	23.3	4.0
0	63.3	9.0
Mean	39.3	5.5

4.1.5 Diseases and insect pests control by the eggplant farmers

Generally, insect pests were controlled with insecticides (locally termed poison). Some of these insecticides included Cymethoate, Lambda Super and Chlorpyriphos 48 % EC. Diseases were also controlled with fungicides such as Mancozeb, Ridomil plus, Funguran OH, Dithane M-45 and Kocide. Application of these pesticides were based on farmers' own experience.

4.2 Isolation and identification of the pathogens

Three different species of *Colletotrichum* were isolated and identified from the eggplant samples collected during the field surveys (Table 4.12) from different Districts. The pathogens, cultured on Potato Dextrose Agar medium, showed differences in the colour of mycelia growth (Plate 4.1 to 4.3). Differences in the shape and size of the conidia under the microscope were also observed. *Colletotrichum dematium* was the most common in all the districts visited.

Table 4.12: *Colletotrichum* species isolated from eggplants from the different Districts

***Colletotrichum* species**	**District**	**Colour of culture on PDA**
C. lindemuthianum	Techiman North	Whitish
C. dematium	Techiman North/Offinso North/ Nkoranza South	Whitish black
C. gloeosporioides	Ejura/Offinso North	Pinkish

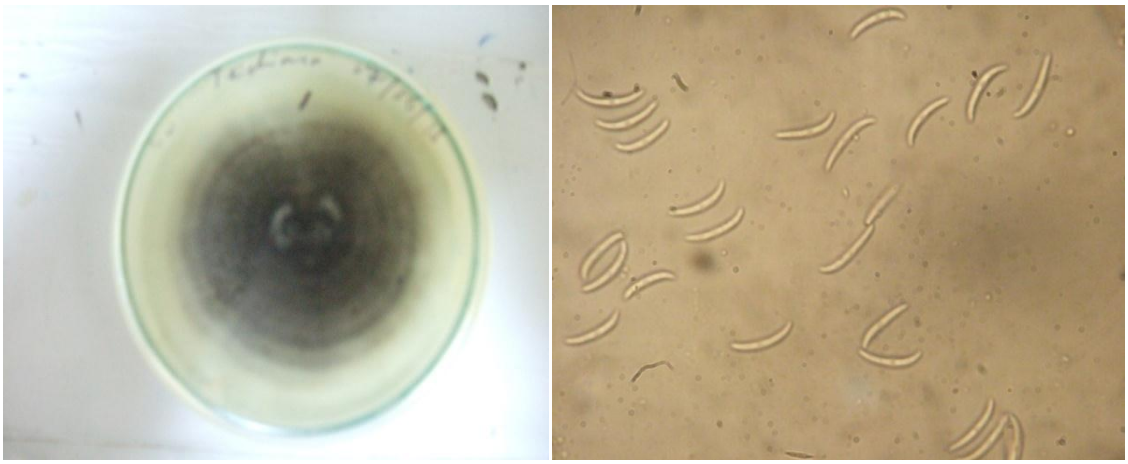


Plate 4.1: Mycelial growth and conidia of *Collectotrichum dematium*

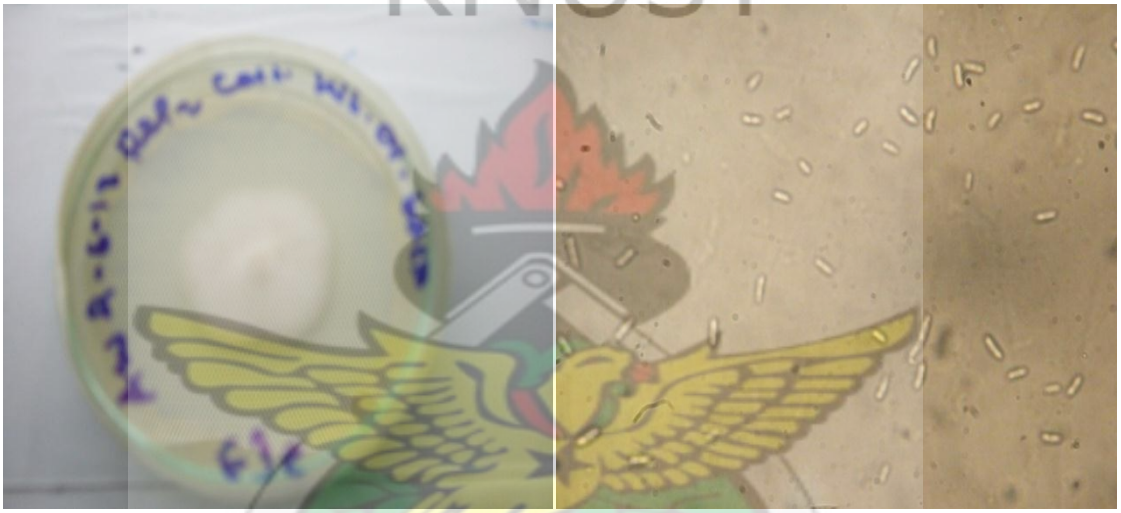


Plate 4.2: Mycelial growth and conidia of *Collectotrichum lindemuthianum*

Plate 4.3: Mycelial growth and conidia of *Collectotrichum gloeosporioides*

4.3 Proof of pathogenicity of the *Colletotrichum* species

It was observed from the pathogenicity tests that all the three *Colletotrichum* species were infective and caused symptoms on both fruits and seedlings. However, *Colletotrichum lindemuthianum* caused small lesion on fruits, compared with *C.dematium* and *C. gloeosporioides* seven days after inoculation. On the contrary, no differences in symptoms were observed on seedlings seven days after inoculation between the three *Colletotrichum* species used.

Plate 4.4: Set-up of proof of pathogenicity at day one of inoculation (Left) and seven days after inoculation (Right)

4.4 Field experimentation: Screening of eggplant genotypes for resistance to anthracnose

4.4.1 Vegetative characteristics of the eggplant genotypes

The vegetative characteristics (plant height, number of branches and stem girth) of the eggplant genotypes varied both between and within the four *Solanum* species used in the study. Significant differences ($P<0.05$) were observed among the genotypes from two to 12 weeks after transplanting (Table 4.13). Twelve weeks after transplanting, the difference between the height of Nsusua and that of all the other genotypes was highly significant ($P = 0.05$). The average plant height recorded in the study was 74-cm, thus genotypes with plant height less this value may be considered short.

Both the number of branches and stem girth per genotype increased from six to 12 weeks after transplanting (Table 4.14). Significant variations ($P<0.05$) were observed in the number of branches per genotype at six and 12 weeks after transplanting. The highest number of branches were observed in genotypes such as Zebrina, Nsusua, Manyire green and African beauty F1, compared to Antropo, Kotobi, F1 Djamba, Kalenda F1, TZ SMN 2-8, Aworoworo, Lushoto, and Long white six weeks after transplanting (Table 4.14). At 12 weeks after transplanting, the highest number of branches was recorded in Nsusua followed by Manyire green, Zebrina and Boasua green. Kotobi, F1 Djamba, Antropo and Kalenda F1, however, gave the least number of branches. The study also showed significant differences ($P<0.05$) in the stem girth of the genotypes at six and 12 weeks after transplanting (Table 4.14). The highest stem girth was recorded in Manyire green, Zebrina, and Kalenda F1, compared to Kotobi six and 12 weeks after transplanting.

Table 4.13: The mean plant height of eggplant genotypes at two, four, six, eight, 10 and 12 weeks after transplanting in the field

Eggplant genotypes	Mean plant height (cm) weeks transplanting in the field					
	2	4	6	8	10	12
***Solanum macrocarpon* var. Antropo**	9.7	13.9	22.3	39.0	57.3	59.9
***S. aethiopicum* var. Aworoworo**	10.2	17.8	34.5	65.0	81.3	86.2
***S. melongena* var. African beauty F1**	19.3	34.1	52.1	62.1	63.9	67.5
***S. anguivi* var. Boasua green**	17.9	35.6	59.9	76.2	85.4	89.5
***S. aethiopicum* var. CRI 05 – 002**	12.1	25.3	39.8	51.1	60.0	63.6
***S. aethiopicum* var. F1 Djamba**	14.0	27.4	41.9	45.0	51.9	56.8
***S. aethiopicum* var. Dwumo**	13.6	26.5	45.2	50.6	65.2	65.6
***S. melongena* var. Kalenda F1**	17.4	35.4	57.9	77.1	98.1	100.7
***S. aethiopicum* var. Kotobi**	14.2	20.2	29.8	40.4	47.7	51.8
***S. aethiopicum* var. Kpando**	13.3	23.0	52.8	68.4	80.0	80.9
***S. melongena* var. Long white**	16.2	29.0	48.8	55.3	56.5	60.2
***S. aethiopicum* var. Lushoto**	10.8	22.4	42.3	60.0	66.6	68.7
***S. aethiopicum* var. Manyire green**	16.0	33.8	57.1	73.2	77.8	81.2
***S. anguivi* var. Nsusua**	12.2	25.9	48.7	81.2	101.3	104.5
***S. aethiopicum* var. Obolo**	14.3	28.6	41.0	49.5	57.4	59.9
***S. aethiopicum* var. Oforiwaa**	16.5	28.7	48.4	62.7	77.6	81.3
***S. aethiopicum* var. Tengaru white**	14.9	33.9	59.6	73.9	76.9	78.3
***S. aethiopicum* var. TZ SMN 2-8**	10.0	22.9	46.1	66.5	82.8	82.2
***S. aethiopicum* var. TZ SMN 3-10**	9.7	24.6	46.0	61.3	67.8	70.7
***S. melongena* var. Zebrina**	19.8	40.5	52.8	64.8	69.8	70.8
Lsd (P = 0.05)	3.5	7.0	10.7	12.5	11.8	2.3
CV (%)	17.4	18.0	16.3	14.4	11.7	2.2

Table 4.14: The mean number of branches and stem girth per eggplant genotype at six and 12 weeks after transplanting in the field

Eggplant genotypes	Mean number of branches per genotypes weeks after transplanting		Mean stem girth (cm) per genotypes weeks after transplanting	
	6	12	6	12
***Solanum macrocarpon* var. Antropo**	3.9	10.7	2.8	5.0
***S. aethiopicum* var. Aworoworo**	5.7	17.5	2.7	5.0
***S. melongena* var. African beauty F1**	10.3	17.7	3.4	4.9
***S. anguivi* var. Boasua green**	12.5	23.2	3.1	4.9
***S. aethiopicum* var. CRI 05 – 002**	7.6	15.9	3.0	4.9
***S. aethiopicum* var. F1 Djamba**	6.1	10.7	3.1	4.0
***S. aethiopicum* var. Dwumo**	9.1	16.2	2.9	4.4
***S. melongena* var. Kalenda F1**	5.1	12.8	3.3	5.3
***S. aethiopicum* var. Kotobi**	5.0	9.1	2.7	3.9
***S. aethiopicum* var. Kpando**	7.3	15.6	3.3	5.2
***S. melongena* var. Long white**	6.8	16.2	3.1	4.4
***S. aethiopicum* var. Lushoto**	5.9	15.5	3.5	4.9
***S. aethiopicum* var. Manyire green**	10.6	27.5	3.7	5.8
***S. anguivi* var. Nsusua**	7.5	31.3	2.9	5.1
***S. aethiopicum* var. Obolo**	9.2	16.1	3.2	5.1
***S. aethiopicum* var. Oforiwaa**	7.4	18.0	3.1	5.0
***S. aethiopicum* var. Tengaru white**	8.9	19.6	3.3	5.2
***S. aethiopicum* var. TZ SMN 2-8**	5.3	14.6	3.0	4.6
***S. aethiopicum* var. TZ SMN 3-10**	7.4	17.6	3.4	5.0
***S. melongena* var. Zebrina**	13.0	26.9	4.0	5.3
Lsd (P = 0.05)	3.0	5.1	0.5	0.6
CV (%)	27.3	20.5	10.7	9.1

4.4.2 Fruit characteristics of the eggplant genotypes

Significant variations (P<0.05) were observed in the number of fruits per plant (Table 4.15). However, contrary to what was observed in fruit weight per genotype, Boasua green and Nsusua gave the highest number of fruits per plant, compared to Kalenda F1, Antropo, African beauty F1, Long white and Zebrina. From the study, it was observed that fruit weight per fruit was inversely proportional to the number of fruits per plant. Also, significant differences (P<0.05) were observed in the fruit weight per fruit (Table 4.15). The highest fruit weight was recorded in Kalenda F1, compared to all the genotypes. This was, however, followed by African beauty F1, Zebrina, Long white and Antropo. Genotypes such as Aworoworo, CRI 05-002, F1 Djamba, Dwumo, Kotobi, Kpando, Obolo and Oforiwaa, however, were not significantly different (P>0.05) from one another. The least fruit weight on the other hand, was observed in Boasua green and Nsusua.

There were also significant differences (P<0.05) in the total yield of the genotypes (Table 4.15). Similar differences were also observed in genotypes within the same species. *Solanum melongena* var. Zebrina had the highest total yield of 34.0 tons/ha followed by *S. aethiopicum* var. Dwumo with 24.0 ton/ha and *S. melongena* var. Kalenda F1 with 21.8 tons/ha. The least total yield was observed in TZ SMN 2-8 with 6.3 tons/ha. Considering the two most cultivated eggplant genotypes, Obolo was significantly higher (P<0.05) in yield than Aworoworo (Table 4.15).

Several variations were observed in the fruit shape, size, and colour of the eggplant genotypes used in the study (Plate 4.5-4.9). Genotypes such as African beauty F1 and Kalenda F1 had fruits with black colour while the other genotypes were either white, cream or green. The fruit of Zebrina, had white and pink stripes (Plate 4.5).

Table 4.15: The mean number of fruits, fruit weight and the total yield per eggplant genotype

Eggplant genotypes	Number of fruits per plant	Mean fruit weight (g) per fruit	Mean total yield (t/ha) per genotype
***Solanum macrocarpon* var. Antropo**	3.3	205.9	12.1
***S. aethiopicum* var. Aworoworo**	10.2	54.0	10.7
***S. melongena* var. African beauty F1**	6.2	392.0	16.2
***S. anguivi* var. Boasua green**	86.0	7.9	13.9
***S. aethiopicum* var. CRI 05 – 002**	9.1	56.9	16.3
***S. aethiopicum* var. F1 Djamba**	9.1	54.1	15.2
***S. aethiopicum* var. Dwumo**	13.6	53.4	24.0
***S. melongena* var. Kalenda F1**	2.5	430.4	21.8
***S. aethiopicum* var. Kotobi**	9.7	72.3	14.1
***S. aethiopicum* var. Kpando**	11.7	53.6	14.5
***S. melongena* var. Long white**	7.2	230.6	20.7
***S. aethiopicum* var. Lushoto**	14.4	25.1	9.5
***S. aethiopicum* var. Manyire green**	18.5	24.6	14.8
***S. anguivi* var. Nsusua**	136.7	2.1	10.4
***S. aethiopicum* var. Obolo**	10.9	71.3	20.9
***S. aethiopicum* var. Oforiwaa**	9.0	53.3	10.9
***S. aethiopicum* var. Tengaru white**	15.3	46.7	11.7
***S. aethiopicum* var. TZ SMN 2-8**	10.8	22.1	6.3
***S. aethiopicum* var. TZ SMN 3-10**	15.4	30.5	11.1
***S. melongena* var. Zebrina**	8.3	245.6	34.0
Lsd (P = 0.05)	1.7	21.0	0.6
CV (%)	5.7	13.9	6.1

African beauty F1 1 **Kalenda F1**

Long white **Zebrina**

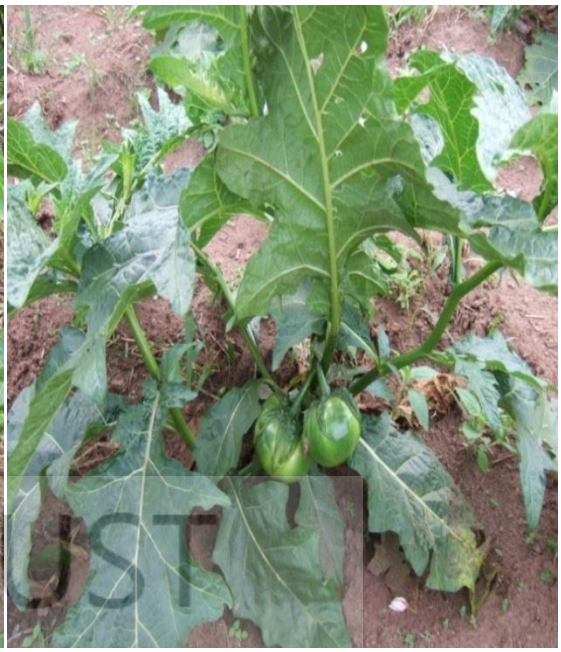
Plate 4.5: Eggplant genotypes with different vegetative and fruit characteristics

Kpando **Manyire green**

Kotobi **F1 Djamba**

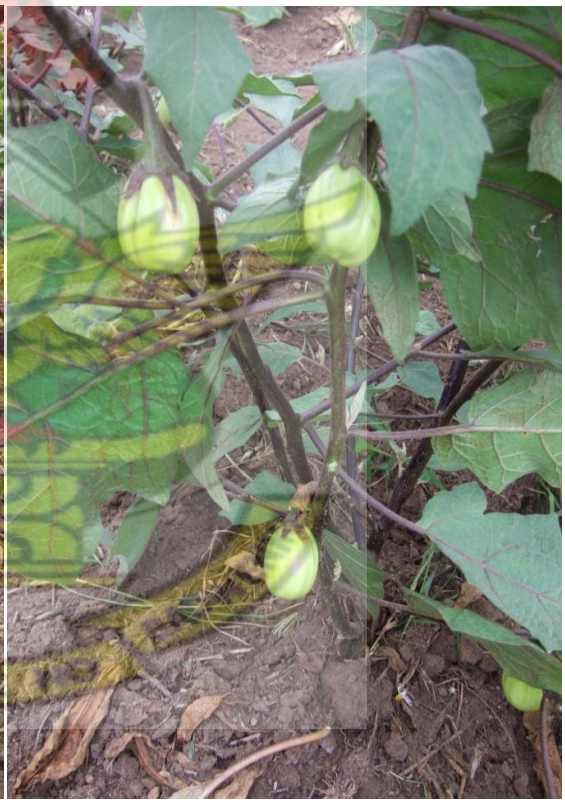
Plate 4.6: Eggplant genotypes with different vegetative and fruit characteristics

Obolo



Antropo

Lushoto



TZ SMN 3 – 10

Plate 4.7:Eggplant genotypes with different vegetative and fruit characteristics

Oforiwaa **Boasua green**

Tengaru white **Aworoworo**

Plate 4.8: Eggplant genotypes with different vegetative and fruit characteristics

CRI 05-002 **Dwumo**

Nsusua **TZ SMN 2 – 8**

Plate 4.9: Eggplant genotypes with different vegetative and fruit characteristics

4.4.3 Correlation matrix between disease incidence, severity, growth and yield parameters of eggplant

The results of the correlation matrix for disease incidence, disease severity, plant height, stem girth, number of branches, number of fruits, fruit weight and total yield (t/ha) are presented in Table 4.16. It was observed from the results that plant height positively correlated with all the growth and yield parameters with the exception of fruit weight and total yield (t/ha). Significant positive correlation r = 0.56 and r = 0.57 was observed between plant height and stem girth, plant height and number of branches and plant height and number of fruits, respectively. It was observed from the study that stem girth had significant positive correlation with number of branches (r = 0.60). Also, significant positive correlation (r = 0.65 and r = 0.51) was recorded between number of branches and number of fruits and fruit weight and total yield, respectively. The results further showed that disease incidence and severity were positively correlated (r = 0.95). However, disease severity significantly affected fruit weight adversely (r = -0.51).

4.4.4 Disease incidence and severity of the eggplant genotypes in field experimentation

The results from the field experiment showed variable degree of both leaf and fruit symptoms of eggplant anthracnose (Plate 4.10 and 4.11). With the exception of Antropo, there was a general increase in the disease incidence of eggplant anthracnose from four to 12 weeks after transplanting (Table 4.17). Disease incidence ranged from 0.0 % in Antropo, Kalenda F1 and Zebrina to 75.0 % in Nsusua four weeks after transplanting. The highest disease incidence eight weeks after transplanting was again recorded in Nsusua. Genotypes such as Nsusua, Manyire green, Dwumo and African beauty F1 had 100 % disease incidence 12 weeks after transplanting.

Table 4.16: Correlation between disease incidence, severity, growth and yield parameters of eggplant

	Disease incidence	Disease severity	Plant height	Stem girth	Number of branches	Number of fruits	Fruit weight	Total yield (t/ha)
Disease incidence	1.00							
Disease severity	0.95*	1.00						
Plant height	-0.06	-0.06	1.00					
Stem girth	-0.26	-0.25	0.56*	1.00				
Number of branches	0.20	0.20	0.56*	0.60*	1.00			
Number of fruits	0.22	0.23	0.57*	0.12	0.65*	1.00		
Fruit weight	-0.47	-0.51*	-0.02	0.11	-0.19	-0.36	1.00	
Total yield	-0.18	-0.19	-0.22	0.07	0.14	-0.23	0.51*	1.00

* Significant at 5 %

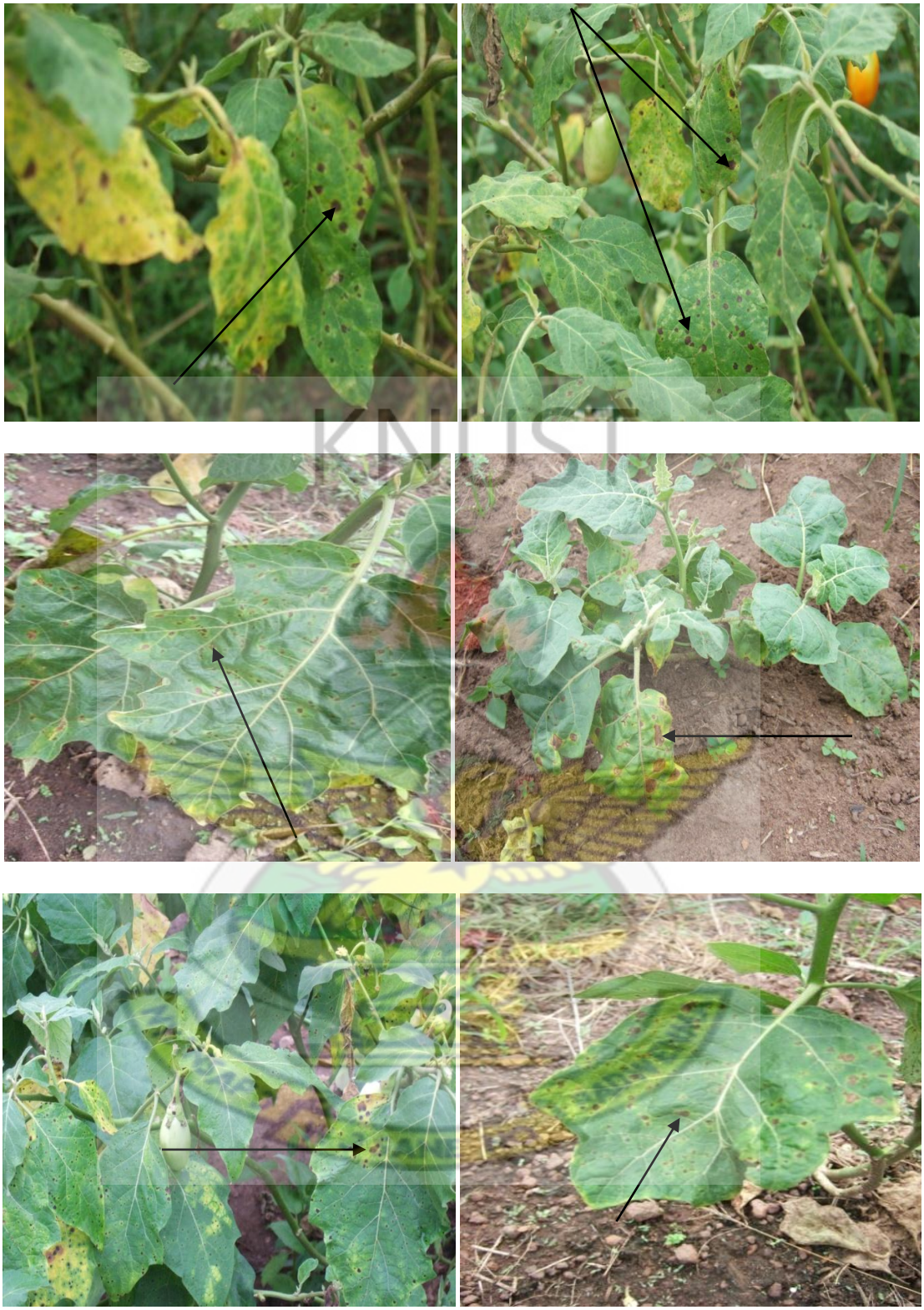


Plate 4.10: Leaf symptoms of anthracnose on some genotypes of eggplant

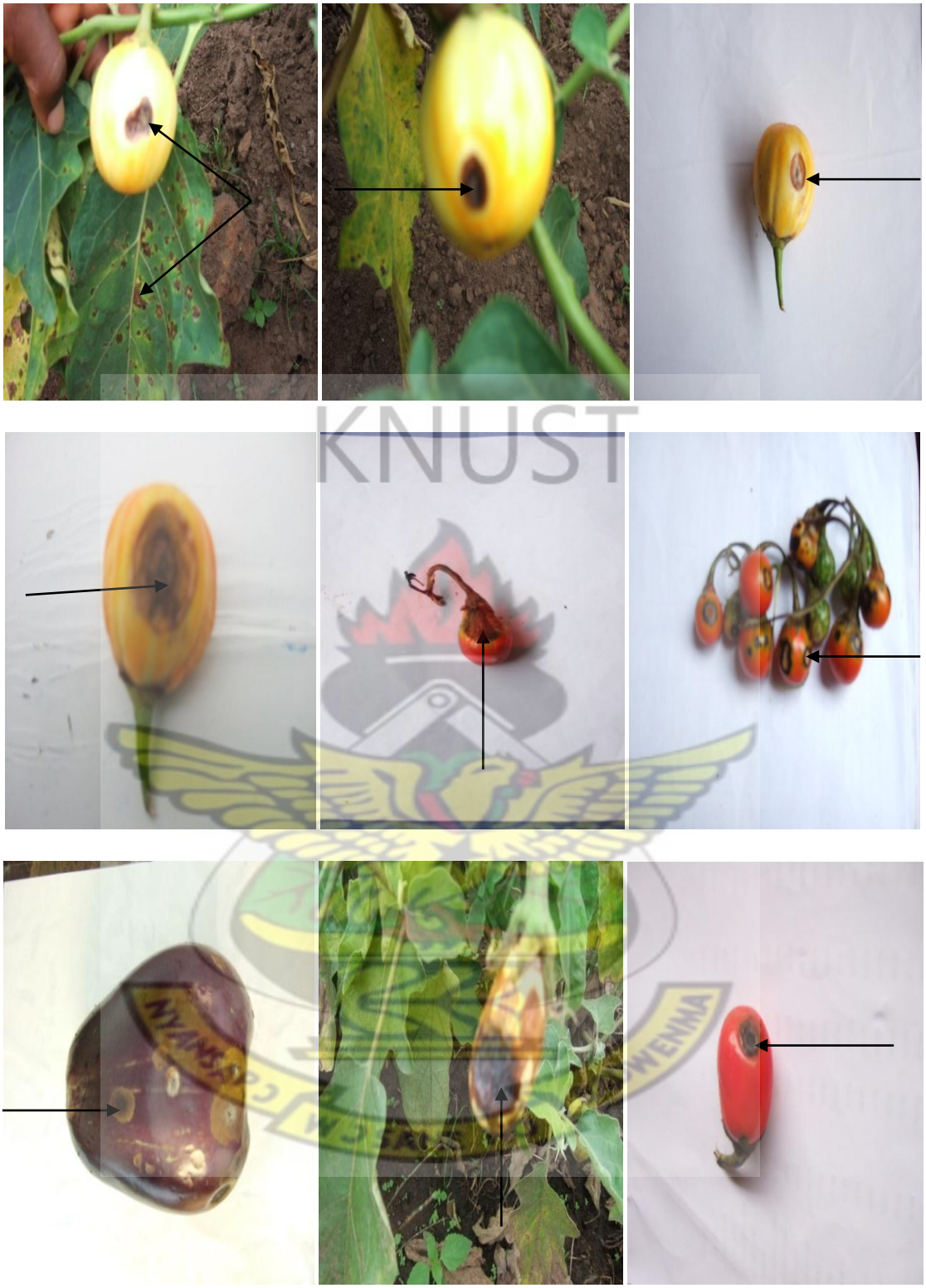


Plate 4.11: Fruit symptoms of anthracnose on some genotypes of eggplant

The least anthracnose disease incidence was recorded in Antropo, Kalenda F1 and Zebrina 12 weeks after transplanting (Table 4.17).

Similarly, there was an increase in the disease severity among the genotypes from four to 12 weeks after transplanting, with the exception of Antropo (Table 4.18). Disease severity score of 5.5 was recorded in Nsusua four weeks after transplanting. The highest disease severity was recorded in Nsusua, Long white and African beauty F1 with scores of 6.3, 6.0 and 5.5, respectively, eight weeks after transplanting. At 12 weeks after transplanting, Antropo was observed to be highly resistant while Kalenda F1 and Zebrina were found to be moderately resistant to anthracnose. Aworoworo and Kpando were found to be moderately susceptible while genotypes such as African beauty F1, F1 Djamba, Dwumo, TZ SMN 2-8, Kotobi, Long white, Boasua green, Oforiwaa and Manyire green were susceptible. Six genotypes (Nsusua, Obolo, Tengaru white, TZ SMN 3-10, Lushoto and CRI 05-002) were highly susceptible to the disease.

4.5 Evaluation of eggplant fruits for reaction to *Colletotrichum dematium*

Variations were also observed in lesion diameter (cm) seven days after fruit inoculation among the genotypes (Table 4.19). African beauty F1, Tengaru white, Dwumo, CRI 05-002 and Oforiwaa were significantly higher ($P<0.05$) in lesion diameter seven days after fruit inoculation, compared to Antropo and Kalenda F1 (Table 4.19). These five genotypes were also confirmed in the field experiment to be either susceptible or highly susceptible to anthracnose. The differences in lesion diameter were observed between and within the *Solanum* species. Considering the two most cultivated eggplant genotypes, however, *S. aethiopicum* var. Obolo again proved more susceptible than *S. aethiopicum* var. Aworoworo with lesion diameter of 3.9 and 2.4, respectively.

Table 4.17: The mean disease incidence at four, eight and 12 weeks after transplanting in the field

Genotypes	% Mean disease incidence weeks after transplanting		
	4	8	12
Solanum macrocarpon var. Antropo	0.0	0.0	0.0
S. aethiopicum var. Aworoworo	43.3	61.7	81.7
S. melongena var. African beauty F1	36.7	70.0	100.0
S. anguivi var. Boasua green	71.7	85.0	93.3
S. aethiopicum var. CRI 05 – 002	40.0	53.3	95.0
S. aethiopicum var. F1 Djamba	56.7	78.3	98.3
S. aethiopicum var. Dwumo	46.7	75.0	100.0
S. melongena var. Kalenda F1	0.0	15.0	45.0
S. aethiopicum var. Kotobi	53.3	76.7	98.3
S. aethiopicum var. Kpando	33.3	58.3	75.0
S. melongena var. Long white	36.7	61.7	95.0
S. aethiopicum var. Lushoto	43.3	61.7	93.3
S. aethiopicum var. Manyire green	55.0	86.7	100.0
S. anguivi var. Nsusua	75.0	86.7	100.0
S. aethiopicum var. Obolo	50.0	65.0	96.7
S. aethiopicum var. Oforiwaa	50.0	71.7	96.7
S. aethiopicum var. Tengaru white	45.0	56.7	91.7
S. aethiopicum var. TZ SMN 2-8	18.3	53.3	80.0
S. aethiopicum var. TZ SMN 3-10	33.3	58.3	96.7
S. melongena var. Zebrina	0.0	20.0	50.0

Table 4.18: The mean disease severity at four, eight and 12 weeks after transplanting in the field

Eggplant genotypes	Mean disease severity (scale 0 - 10) weeks after transplanting			Reaction
	4	8	12	
***Solanum macrocarpon* var. Antropo**	0.0	0.0	0.0	Highly resistant
***S. melongena* var. Kalenda F1**	0.0	2.0	3.8	Moderately resistant
***S. melongena* var. Zebrina**	0.0	2.8	4.8	Moderately resistant
***S. aethiopicum* var. Kpando**	2.3	2.8	5.8	Moderately susceptible
***S. aethiopicum* var. Aworoworo**	2.3	3.3	5.8	Moderately susceptible
***S. aethiopicum* var. F1 Djamba**	2.5	4.3	7.5	Susceptible
***S. aethiopicum* var. Dwumo**	2.3	4.0	7.5	Susceptible
***S. aethiopicum* var. Oforiwaa**	2.0	3.8	7.0	Susceptible
***S. aethiopicum* var. Kotobi**	3.0	4.5	7.8	Susceptible
***S. anguivi* var. Boasua green**	2.8	4.3	7.3	Susceptible
***S. melongena* var. Long white**	2.3	6.0	7.3	Susceptible
***S. aethiopicum* var. Manyire green**	2.5	4.3	7.0	Susceptible
***S. melongena* var. African beauty F1**	2.3	5.5	7.3	Susceptible
***S. aethiopicum* var. TZ SMN 2-8**	2.8	2.8	7.3	Susceptible
***S. aethiopicum* var. Lushoto**	4.0	5.0	8.3	Highly susceptible
***S. anguivi* var. Nsusua**	5.5	6.3	8.5	Highly susceptible
***S. aethiopicum* var. Obolo**	2.0	3.8	8.0	Highly susceptible
***S. aethiopicum* var. Tengaru white**	3.5	4.5	8.5	Highly susceptible
***S. aethiopicum* var. CRI 05 – 002**	2.5	3.8	8.0	Highly susceptible
***S. aethiopicum* var. TZ SMN 3-10**	4.3	5.0	8.3	Highly susceptible

0 = Highly resistant 1&2 = Resistant 3&4 = Moderately resistant
5&6 = Moderately susceptible 7 = Susceptible 8-10 = Highly susceptible

Table 4.19: Mean lesion diameter per genotype seven days after fruit inoculation

Eggplant genotypes	Mean lesion diameter (cm) seven days after fruit inoculation
***Solanum macrocarpon* var. Antropo**	0.0
***S. aethiopicum* var. Aworoworo**	2.4
***S. melongena* var. African beauty F1**	4.7
***S. anguivi* var. Boasua green**	1.9
***S. aethiopicum* var. CRI 05 – 002**	4.3
***S. aethiopicum* var. F1 Djamba**	3.0
***S. aethiopicum* var. Dwumo**	4.3
***S. melongena* var. Kalenda F1**	0.8
***S. aethiopicum* var. Kotobi**	2.9
***S. aethiopicum* var. Kpando**	2.5
***S. melongena* var. Long white**	3.5
***S. aethiopicum* var. Lushoto**	2.1
***S. aethiopicum* var. Manyire green**	3.2
***S. anguivi* var. Nsusua**	1.0
***S. aethiopicum* var. Obolo**	3.9
***S. aethiopicum* var. Oforiwaa**	4.2
***S. aethiopicum* var. Tengaru white**	4.7
***S. aethiopicum* var. TZ SMN 2-8**	2.8
***S. aethiopicum* var. TZ SMN 3-10**	2.1
***S. melongena* var. Zebrina**	1.1
Lsd (P=0.05)	0.8
CV (%)	17.4

CHAPTER FIVE

5.0 DISCUSSION

5.1 Surveys: Assessment of eggplant anthracnose and farmers' perception on some factors affecting production

The high percentage of farmers between 20 and 50 years of age observed in the study is an indication of a brighter future in the eggplant business. This is because greater number of the work force (youth) lies within this age range. The high number of males, 99, compared with females, 21, could be due to the challenges associated with eggplant production. Eggplant production is labour intensive and production constraints are numerous (Horna *et al*., 2007), thus, contributing to the low number of females in this business. Although, majority of the farmers seem to have some level of formal education, this had little or no effect on the way famers did farm activities.

The result further showed that the two most cultivated eggplant varieties were Aworoworo and Obolo due to high demand and easy access to seeds. According to Horna *et al*. (2007), these eggplant varieties are very common in Brong Ahafo and Ashanti Regions. In choosing a particular variety, however, several factors/reasons are taken into consideration. These factors include marketability, consumer preference, fruiting ability, earliness of maturity, taste, height, fruit appearance and size. Both vegetative and fruit characteristics were found to be paramount in the selection of a variety by farmers because these directly affect pest management practices and marketing of the produce. According to Bukenya-Ziraba and Bonsu (2004), consumer preference for a variety of eggplant is based on characteristics such as size, form, colour and taste.

Most of the farmers usually use their own seeds or seeds collected from friends, perhaps due to ease of access and the high cost associated with treated seeds from agro dealers. The source of seeds as indicated by the farmers could be one of the means through which anthracnose disease of eggplant spreads since the disease-causing organism could survive in seeds during off-season. Melanie *et al*. (2004) reported that the fungus (*Colletotrichum* sp.) may be introduced into a field through the use of infected seeds. The practice of farmers, allowing land to fallow for two or three years according to Pring *et al*. (1995), could help reduce the activity of the pathogen. Although farmers encountered several problems in eggplant production, insect pests and diseases were the most prevalent. The low level (17.5 %) of anthracnose as recorded compared to damping-off (42.5 %) was perhaps most the farmers knew little or nothing about eggplant anthracnose disease. Also, the frequent application of fungicides such as Mancozeb, Dithane, Funguran OH, Kocide and Ridomil plus at vegetative, flowering and fruiting stages than at nursery could be a contributing factor. According to Schwartz and Gent (2007), these fungicides are effective against anthracnose. The little or no knowledge of eggplant anthracnose could perhaps be responsible for the different views expressed by farmers on the frequency of occurrence and the cause of the disease.

The high anthracnose disease incidence and severity observed on eggplant in both Techiman and Offinso North Districts could be as a result of the increased cultivation of solanaceous crops such as eggplant, pepper and tomato in these areas. Also, the cultivation of Obolo which is susceptible to anthracnose was very high in these districts, compared to Ejura and Nkoranza South Districts. The cultivation of Obolo in Techiman has been reported (Horna *et al*., 2007). Farmers in Ejura mostly grow the

Aworoworo (moderately susceptible to anthracnose) variety, hence, the low disease incidence. The variation in disease incidence and severity between the districts observed during the field survey could be as a result of the different *Colletotrichum* spp. isolated.

5.2 Vegetative and fruit characteristics of the eggplant genotypes

The significant differences ($P<0.05$) observed in the plant height, number of branches, stem girth, number of fruits, fruit weight and total yield per genotype could be attributed to wide genetic variation in the genotypes. Wide morphological diversity has been observed among eggplant accessions/genotypes (Daunay *et al*., 1991; Naujeer, 2009). Variations in vegetative growth and fruit characteristics between genotypes have also been reported (AVRDC, 2003; Frary *et al*., 2007; Osei *et al*., 2011). Plant height was found to be positively correlated with the number of branches ($r = 0.56$) and stem girth ($r = 0.56$). This explains why genotypes such as Manyire green, Boasua, Kalenda F1 and others had significantly higher ($P<0.05$) plant height and stem girth.

The significantly higher ($P<0.05$) fruit weight observed in Kalenda F1 (430.4 g), African beauty F1 (392 g) and Zebrina (245.6 g), compared with Boasua green and Nsusua during the study, could be attributed to wide genetic variability among *Solanum* species. The wide morphological and genetic diversity in eggplant is attributed to domestication, mutation, human selection, natural intercrossing and hybridization (Frary *et al*., 2007). Fruit weights of between 2.1-430.4 g were recorded in the study. These fall within what Swarup (1995) reported that eggplants vary in their fruits weight between 0.5 g to 1500 g. Naujeer (2009) also recorded fruit weight of between 2 g and 440 g among eggplant accessions/genotypes. The average fruit weight of Kalenda F1,

African beauty F1 and Zebrina ranged from 350-450, 300-450 and 220-250 g, respectively (http://www.technisem.com./en/european-eggplants). The differences in fruit colour, size and shape observed in Plate 4.5-4.9 could be attributed to genetic variation in these genotypes. Kumar *et al*. (2008) reported that fruit colour, size and shape are the most distinctive characters that vary between the cultivated *Solanum* species. Fruit weight and number of fruits per plant were negatively correlated (r = -0.36). This explains why genotypes with the highest fruit weight usually had fewer numbers of fruits. On the contrary, genotypes with smaller fruit weight had more fruits. The number of fruits per plant during the study varied from 2.5 (~3) to 136.7 (~137). Between 16 and 145 fruits per plant have been observed in some genotypes of eggplant (Naujeer, 2009).

The significantly higher (P<0.05) number of fruits per plant observed in Boasua green, Nsusua and Manyire green, compared to Kalenda F1 and Antropo (Table 4.15), could probably be attributed to the higher number of branches coupled with smaller fruit weight and more than one fruit per inflorescence associated with these genotypes. AVRDC (2003) reported that more and wide branches are very good traits to increase the number of fruits per plant and hence total yield. According to Bukenya-Ziraba (2004), Boasua (*S. anguivi*) is of potential use as male parent in breeding programmes to improve *S. aethiopicum* to increase the number of fruits per inflorescence.

Total yield (t/ha) of eggplant was significantly higher (P<0.05) in Zebrina than all the other genotypes. This could be attributed to higher number of branches per plant and higher fruit weight. This was further confirmed (Table 4.16) by the significant positive correlation found between the number of branches and number of fruits (r = 0.65) and

fruit weight and total yield (r = 0.51). Naujeer (2009) also observed positive correlation between these parameters. The total yield of Obolo was significantly higher (P<0.05) than Aworoworo, thus, confirming earlier reports by farmers that Obolo is high yielding.

5.3 Disease incidence and severity of the eggplant genotypes in field experimentation

The results showed that both disease incidence and severity increased with time (Tables 4.17 and 4.18). The increase in disease incidence and severity observed in the study from four to 12 weeks after transplanting could be as a result of inoculum spread or dispersal influenced by the environment. Also, changes in plant physiology with time could perhaps be a contributing factor. Bowen (2004) reported that disease incidence and severity increase with inoculum spread. An increase in disease incidence of plants in a population is due to the spread of disease-causing inoculum. Some inoculum, however, spread no further than the leaves of the original infected plant, hence leading to greater disease levels through an increase in disease severity. Disease severity and incidence are usually positively related; as disease severity increases so does disease incidence. Dodd *et al*. (1992) indicated that the relationships between rainfall intensity, duration, crop density and the dispersal of inoculum possibly lead to different levels of disease severity. Bowen (2004) also reported that the age of a host plant can influence the rate of disease development. Plant growth provides more tissues that have the potential to become diseased. As plants grow, they go through several developmental stages that involve physiological changes, and these changes can influence disease development.

Variations in the anthracnose disease incidence and severity among the eggplant genotypes were as a result of genetic differences or inherent characteristics. Although there may be differences in the stages of disease progress at a point in time, these differences are more likely due to the time infection occurred, genetic variations between the plants in the population and perhaps due to differences in the micro environment (Bowen, 2004). The highly resistant eggplant genotype, according to the study, was *Solanum macrocarpon* var. Antropo (Table 4.18). Bukenya-Ziraba and Bonsu (2004) reported that *S. macrocarpon* is resistant to anthracnose caused by *Gloeosporium melongenae*. Kalenda F1 and Zebrina were also moderately resistant with incidence of 45 and 50 %, respectively. Resistance in cultivars such as Kalenda F1 and Zebrina has been reported (Messiaen 1994; Daunay and Chadha, 2004). Although these genotypes have the potential of controlling anthracnose, they are less cultivated in Ghana perhaps due to their morphological characteristics such as height, fruit size and colour, number of fruits per plant and consumer preference. On the contrary, genotypes such as Dwumo, CRI 05-002, F1 Djamba and Kotobi, although similar to Obolo (most cultivated by farmers), were either susceptible or highly susceptible. Eggplant has a wide genetic variability, but they offer partial resistance often at low levels to pests and diseases (Daunay *et al*., 1991; Kashyap *et al*., 2003). Genetic variability in morphological and molecular diversity can be effectively used to develop more productive transgenic local eggplant with improved agronomic trait such as better resistance to insect pests and diseases (Naujeer, 2009).

5.4 Evaluation of eggplant fruits for reactions to *Colletotrichum dematium*

Significant differences ($P<0.05$) in lesion diameter were observed between the eggplant genotypes when fruits were inoculated and incubated for seven days (Table, 4.19).

When fruits are harvested, they undergo physiological changes, until they are consumed. Variations in these physiological changes coupled with genetic variability of the genotypes, could affect the rate at which infection occurs and hence the size of the lesions. This supports earlier report (Jeffries *et al*., 1990; Bailey and Jeger, 1992) that *Colletotrichum* species continue to cause latent infection of harvested fruits and symptoms only develop until ontogenic changes had occurred. The result from this study was similar to what was observed in the field experimentation.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

Eggplant production is a very important business that has a bright future since a greater percentage of the youth has gone into this business. From the study, both vegetative and yield parameters were found to be paramount in the selection of eggplant variety by farmers. The most cultivated varieties, according to the farmers, were Aworoworo and Obolo. Also, the field experiment confirmed earlier reports by farmers that Obolo was high yielding, compared to Aworoworo. Since farmers obtained eggplant seeds mostly from friends and previous selections, this could be the means through which the anthracnose pathogen spreads. In addition, seeds were not treated with any chemical. Significant ($P<0.05$) differences were found among the genotypes on all the growth and yield parameter determined. Generally, fruit weight (g) and total yield (t/ha) were positively correlated, but number of fruits and fruit weight were negatively correlated.

Anthracnose disease resistance was observed in genotypes Antropo, Kalenda F1 and Zebrina. Varied level of susceptibility was observed in the other genotypes. The study further revealed significant differences between lesion diameter of the genotypes seven days after inoculation. The highest lesion diameter was observed in African beauty F1 and Tengaru white. Also, both field and laboratory experiments showed similar results of disease resistance and susceptibility among the genotypes. It is, therefore, recommended that since the resistant varieties identified are frequently less cultivated, their gene for resistance should be incorporated into the most cultivated varieties to promote farmers' work. This work should be carried out in other agro-ecological zones of Ghana.

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APPENDIX 1

Questionnaire

Farmers' perception about eggplant production and eggplant anthracnose in the field

Name of eggplant farmer…….Age…….....Sex.....Farm No……

Town/Village……..District…….Region……

1. What is your level of education…….……
2. What eggplant variety do you grow?.....…….…….
3. Why?.....

   .....

   ……
4. Where do you obtain the seeds?.....
5. Do you dress the seeds with chemical when you obtain it?.....
6. Do you cultivate on the same field yearly?.....
7. Do you intercrop with solanaceous crops (pepper and tomato)?…….
8. What problems do you encounter in the eggplant production?…….....

   .....

   .....
9. What are some of the insect pest encountered …….....

   ……
10. What are some of the diseases encountered in the eggplant production……

    .....
11. How often do you observe anthracnose in eggplant?.....
12. What do you think causes anthracnose in eggplant……..

13. How do you control the insect pests and diseases of eggplant?.....

14. What type of pesticide do you use?…….....

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Personal observations…….

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APPENDIX 2

Assessment sheet of disease incidence and severity of eggplant anthracnose

Name of the District…….

Name Community …….....

Farm Number	Disease Incidence (%)	Diseases Severity Score (Scale 0 – 10)										
		0	1	2	3	4	5	6	7	8	9	10
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

0 = Highly resistant 1&2 = Resistant 3&4 = Moderately resistant

5&6 = Moderately susceptible 7 = Susceptible 8-10 = Highly susceptible