Phaseolus vulgaris Cv. ROSECOCO-GLP-2 SEED CONTAMINATION AND INFECTION BY *Colletotrichum lindemuthianum* (SACC & MAGN) BRI & CAV., AND IMPLICATIONS ON DISEASE INCIDENCE AND SEVERITY

ISANDA GEORGE OMWENGA (BSc Honours, Nairobi.)

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DECLARATION:

This thesis is my original work and has not been presented for a degree of any other University.

Signed. _____ Date 22/6/95

ISANDA GEORGE OMWENGA

This thesis has been submitted for examination with our approval as University supervisors.

Signed. A.W. Mwang'ombe. Date 22/6/95

DR.(MRS) A. W. MWANG'OMBE.

Signed. _____ Date 23-6-95

for DR. R. K. MIBEY.

DEDICATION

To my Parents.

Stephen Omwenga Onsembe

and

Isabellah Moraa Omwenga

and

To my Wife

Jacqueline Kerubo Isanda

and

My son

Brian Obino Isanda.

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List of Abbreviations.

1. µm - Micrometer
2. mm - millimeter
3. M - meter.
4. PDA- potato dextrose agar.
5. cm - centimeter.
6. °C - degree centigrade.
7. % - per cent.
8. ml - millimeter.
9. NaOCl - Sodium hypochlorite.
10. c.v. -cultivar.
11. AUDPC- Area Under Disease Progress Curve
    - .AUDPC-AI- Area Under Disease Progress Curve Anthracnose incidence
    - .AUDPC-ASL-Area Under Disease Progress Curve Anthracnose severity on leaves
    - .AUDPC-ASP-Area Under Disease Progress Curve Anthracnose severity on pods

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Abstract

Surveys were conducted in several locations in Kisii, Kiambu and Meru districts, during which seeds of the common bean (*Phaseolus vulgaris*) L. cv. Rose Coco-GLP-2 were collected from the small-scale farmers. The visual observation test and rolled paper towel, agar plate and blotter tests as recommended by the International Association of Seed Testing were applied to 38 samples. About 53% of the samples assessed by visual observation were contaminated by *C. lindemuthianum* with an average infection of 0.34% (range 0.0 - 4.5%). The rolled paper towel test detected *C. lindemuthianum* in about 74% of the samples, with mean infection level of 1.2% (range 0.0-10.0%). Of the samples assessed by the agar plate test, 61% were contaminated with *C. lindemuthianum*, with an infection range of 0.0-4.25%. The blotter test recorded the disease from 32.0% of the samples, with a mean infection of 0.32% (range 0.0-1.50%).

Inoculations of beans with *C. lindemuthainum* 2 weeks after emergence gave significantly high levels of seed infection compared to seed infections attained when plants were inoculated at 4 and 6 weeks after emergence, pod filling stage and maturity. Seed infection was between 0.5%-24.1% and 0.9%-38.8% during the short and long rains respectively.

Planting of seeds with varying levels of *C. lindemuthianum* infection in the field produced significa.t levels of anthracnose incidence, severity on leaves and pods, measured as AUDPC-AI, AUDPC-ASL and AUDPC-ASP respectively at Kabete and Tigoni. There was significant and positive correlations between level of seed-

borne *C. lindemuthianum* infection and AUDPC-AI, AUDPC-ASL and AUDPC-ASP.

Yields/ha, number of pods/plant and 100-seed weight were significantly low in plots sown with farmers' seeds with varying levels of *C. lindemuthianum* infection compared to plots sown with pathogen free seeds and certified seeds. Negative and significant correlations were established between yields/ha, number of pods/plant and 100-seed weight and AUDPC-AI, AUDPC-ASL and AUDPC-ASP. The reduction in yields was mainly as a result of reduction in number of pods and 100-seed weight.

Field studies were carried out to determine the relationship between time of inoculation and anthracnose incidence and severity on bean plants, expressed as AUDPC. Significantly high AUDPC values were recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence, compared to AUDPC recorded in plots receiving other treatments. Correlations time of inoculation and AUDPC-AI, AUDPC-ASL and AUDPC-ASP were not significant.

Yields/ha, number of pods/plant and 100-seed weight were all significantly reduced in plots inoculated with *C. lindemuthianum* at 2, 4 and 6 weeks after emergence and pod filling stage during both the short and long rains seasons. There were negative and significant correlations between yields/ha, number of pods/plant and 100-seed weight and AUDPC-AI, AUDPC-ASL and AUDPC-ASP. No significant correlations between AUDPC-AI, AUDPC-ASL and AUDPC-ASP and number of seeds/pod was observed. The reduction in yields was mainly as a result of reduction in number of pods and 100-seed weight.

CHAPTER ONE

INTRODUCTION

Legumes are among the most important group of food crops in Kenya. The common bean (*Phaseolus vulgaris* L) known as dry beans (Mukunya and Keya, 1975) is the most important and occupy the largest acreage under legume production in Kenya. In Kenya beans occupy an area ranging between 300,000 and 500,000 hectares (Anon, 1975).

Great amounts of beans are produced from the Eastern and Central provinces. Beans are grown quite extensively in the Nyanza and Western provinces but much less in the Rift Valley and the Coast provinces. In Coast province, beans are mainly grown in Taita Hills while in Rift Valley, beans are mainly grown in Elgeyo/Marakwet districts (Mukunya and Keya,1975).

Beans in Kenya like in most other East Africa countries are grown in the small-holder sector mainly as mixtures consisting of different land races and intercropped with other crops such as Maize, Sorghum, Cowpeas, Pigeon peas, Potatoes, Cotton and Cassava (Acland,1971; Mukunya and Keya, 1975). Some of these land races include a great mixture of seed types while others have a high proportion of similar seed types but with different growth habits (Mukunya and Keya, 1975). Some of the local cultivars available in Kenya include Canadian Wonder grown as a late maturing cultivar and commonly grown in Central Province, Rosecoco, as a medium maturing cultivar, commonly grown in Western,Central and Eastern provinces, Mwezi moja, as an early maturing cultivar, grown in the drier lower altitudes, and finally Mexico 142, the outstanding small white

seeded canning bean (Mukunya and Keya, 1975).

Beans yields are generally low with a national average below 500 kg/ha (Mukunya and Keya, 1975; Mutitu and Musyimi, 1980). With improved varieties and good husbandry it is possible to get well over, 2,000 kg/ha (Mutitu and Musyimi, 1980).

Current varieties of beans are developed from types originally found in Central America.They require relatively high temperatures (above 10°C) with a well distributed rainfall during the entire growing season for effective growth. Beans need free draining and moist soil throughout growing period (Acland 1971; Mukunya and Keya, 1975).

1.1 Beans as source of protein in diets

Due to the fast growth in human population, the supply of adequate and right foodstuffs is becoming a big problem in the developing countries. One of the agricultural problems in the developing countries such as Kenya is the production of high quality protein in sufficient amounts to meet the human demands, at prices affordable by the majority of the population. This is based on the fact that animal protein sources are either very scarce or too expensive, hence beans together with other pulses provide the cheapest source of proteins to low-income earners in towns and the rural poor population (Buruchara, 1979).

Beans have a high protein content. They contain in composition 11% moisture, 1.6% fat, 57.8% carbohydrates, 4.9% fibre, 3.6% ash and 22% protein (Smartt 1976). They are rich in lysine and tryptophan amino acids and complement the amino-acid zein found in

maize, so that food of high biological value is achieved (Purseglove, 1987; Leakey, 1970). Beans are utilized in a variety of ways in Kenya. Most rural people boil them in water together with either maize, rice, vegetables, bananas, cassava or potatoes and thus yield a balanced diet in the absence of relatively expensive animal proteins (Kay, 1979). When cooked and fried, beans can be used with "ugali". Young pods (French beans) of certain varieties are used as green vegetables or canned as baked beans (Buruchara, 1979; Lang, *et al.*,1984) (Purseglove, 1987). In some cases green leaves may be used as pot herbs or vegetables (Buruchara,1979; Purseglove,1987).

1.2 Bean production constraints in Kenya

There are many factors responsible for the low yields of beans in Kenya with the national average below 500 kg/ha (Mukunya and Keya,1975; Mutitu and Musyimi,1980). The major problems in bean production include land scarcity due to competition with cash crops such as Tea, maize, coffee, potatoes and others, prices of fertilizers that are very high for the small scale farmer prevent their use for the beans since priority is given to cash crops (Mutitu and Musyimi, 1980). Uneven rainfall, poor cultural practices, destruction by pests and diseases and the availability of good quality planting seeds has been indicated as a major problem in Kenya (Schonherr and Mbugua, 1976).

Diseases are probably the major factor limiting bean production (Robins and Domingo, 1956; Dunbar, 1969; Acland, 1971). The bean plant is subject to attack by more than 100 pathogens

(Harter and Zaumeyer, 1944). The major fungal diseases, in Kenya include angular leafspot caused by *Phaeoisariopsis griseola* sacc, bean anthracnose caused by *Colletotrichum Iindemuthianum* (Sacc and Magn) Bri and Cav, bean rust caused by *Uromyces appendiculatus* (pers) Fr, Fusasium root rot and wilt, Ashy stem blight caused by *Macrophomina phaseoli* Ascochyta leafspot caused by *Ascochyta phaseolorum*. Other important diseases include common mosaic caused by bean common mosaic virus, halo blight caused by *Pseudomonas syringae* p.v. *phaseolicola* , common bacterial blight caused by *Xanthomonas campestris* p.v. *phaseoli* (Bock, 1970; Acland, 1971; Mukunya and Keya, 1975).

Bean anthracnose caused by *C. lindemuthianum* is a major disease of beans (Leakey and Simbwa-Bunnya, 1972). It is prevalent in all bean growing regions of the country. The pathogen is internally seed-borne. It survives as dormant mycelium within the seed coat and cotyledon (Neergaard, 1979; Arden and Macnab, 1986) and as spores between cotyledons and elsewhere (Arden and Macnab, 1986).

The anthracnose fungus is seed-borne. This was first demonstrated by Frank in 1883 (Neergaard, 1979; Heald, 1981). It also survives in crop residues from six months to about two years depending on the moisture conditions (Tu, 1983) but seed infection is considered to provide the initial inoculum foci for the secondary spread of the disease (Fernandez *et al.*, 1987). The anthracnose incidence in the field is directly proportional to the primary inoculum provided by contaminated seeds (Fernandez, *et al.*,

1987). Seedlings produced by infected seeds, in general have diseased cotyledons, primary leaves and hypocotyls, where the pathogen sporulate providing inoculum for secondary infection (Heald, 1981; Fernandez *et al.*, 1987). The degree of seed transmission of the anthracnose fungus increases with increasing severity of infection and density of conidia in infected seed (Tu, 1983). This variation in seed transmission is related to the degree of infection as well as seventy and site of infection in the seed (Neergaard, 1979; Tu, 1983; Fernandez *et al.*, 1987).

1.3 Sources of Bean Seeds in Kenya

Small scale farmers use their own seed from the preceding season for planting. The use of such seed should be discouraged due to the high percentage of seed infection by pathogens causing anthracnose, bacterial blights and common bean mosaic (Mukunya and Keya, 1975). This infected / contaminated seed provide the initial inoculum foci for the secondary spread of anthracnose when planted in the field (Fernandez *et al.*, 1987). Certified bean seed demand for planting in Kenya is cyclical due to serious fluctuations in consumer prices and uncertainty of production (Anon., 1985). Seed demand is high after crop failure or when crops have sold at a high prices, and similarly low when market prices for produce are down. Consequently farmers plant their own seed in one year and purchase from the commercial seed suppliers in another (Groosman *et al*,1991).

Certified bean seed production in Kenya started in 1975,when the Kenya Seed company (KSC) undertook the responsibility for the

multiplication of bean cultivar M-142 for seed production (Mukunya and Keya,1975). As of 1986, KSC produced about 400 tones of bean seed with the East African seed company producing 27.6 tones (Groosman *et al.*, 1991). Other companies which also produce certified seeds include Simpson and Whitelow company, Kenya Highland seed company and Mount Kenya Agro Industries. This seeds are used locally or exported. However yield increase from the use of certified seeds is not substantial, about 20% (Groosman *et al.*, 1991).

If the production of beans is to be increased in Kenya, a source of high quality, disease free seed must be established and maintained. This can be achieved by the development of sensitive seed health testing procedures. Also studies of disease epidemiology are necessary to provide a practical guide to the levels of seed infection likely to result in serious anthracnose outbreaks and to determine tolerance limits for seed infection.

Considering the importance of beans in Kenya and losses that may be incurred through infection of susceptible bean cultivars like cv. Rosecoco-GLP-2 by anthracnose fungus, *C. lindemuthianum* this study was undertaken with the following objectives:

(a) To determine the levels of seed-borne *Colletotrichum lindemuthianum* on cv. Rosecoco-GLP-2 seeds largely used by small scale farmers for planting in Kenya, using visual and incubation tests.

(b) To determine the relationship between seed contamination/infection by *C. lindemuthianum* and bean

anthracnose incidence and severity.

(c) To determine the relationship between time and levels of bean anthracnose infection of cv. Rosecoco-GLP-2 seed crop and the level of seed infection of the seed thereof.

(d) To determine tolerance limits of the anthracnose pathogen.

CHAPTER TWO

LITERATURE REVIEW

2.0 Nomenclature of Beans:

Phaseolus species are annual or perennial, twinning or bushy herbs with large trifoliate leaves, stipules and stipels, and typically papilioneous flowers in axillary or terminal racemes (Purseglove, 1987).

Phaseolus belongs to the tribe Phaseoleae of the papilionoidae, and is morphologically similar to *Vigna* (cowpea) and lablab (hyacinth bean) in the same tribe. The genus *Phaseolus* differs from *Vigna* in that its stipules do not have appendages below their point of attachment to the stem its pollen grains are smooth, not with an open reticulation of raised walls, and its species have coiled keels whereas most *Vigna* species do not (Purseglove, 1987).

Beans belong to the class Megnoliopsida (Dicotyledons), subclass Rosidae, order Fabales and family Fabaceae or Papilionaceae (Leguminosae) (Holmes, 1986).

2.1 Geographical Distribution of Bean anthracnose

Bean anthracnose is widely distributed throughout the limits of bean culture. It occurs both on field and garden bean varieties (Dugger, 1909; Fulton 1968; Neergaard, 1979). The disease was first reported in Germany in 1875 and Lindemath reported it to Frank in the same year (Harter and Zaumeyer, 1944; Fulton 1968). In 1880, the same disease was found on kidney beans at Bedford, England (Harter and Zaumeyer, 1944; Heald 1981). In 1884 anthracnose was

common in Italy, France, Germany, and North America and in parts of Italy, it was exceedingly devastating (Neergaard,1979; Harter and Zaumeyer, 1944)). Since then it has been reported from practically all countries of Europe, Japan, Taiwan, India, Transvaal, South America, many Islands of the East and West Indies, the Union of Soviet Socialist Republics (Harter and Zaumeyer, 1944) and from East Africa (Bock, 1970).

2.2 Importance of Bean anthracnose

Bean anthracnose is a major disease of beans (*Phaseolus vulgaris* L) in humid regions with cool to moderate temperatures (Fernandez *et al.*, 1987). Under favourable environmental conditions for disease development, losses of upto 100% could occur when diseased seeds are planted (Chaves, 1980). Plots planted with diseased seeds exhibit disease levels absent in plots planted with clean seeds (Mukunya and Keya, 1979). Boyd (1942) reported complete destruction of a whole plot of beans. Heavy losses occurred when a prolonged wet period provided ideal conditions for infection and spread of the disease (Boyd,1942). Diseased seeds in humid conditions result in low stands beyond mutual compensation because such seedlings from such seeds may be killed before emergency (Hubbeling, 1957). Infected snap beans develop symptoms in transit becoming of low market value (Smartt, 1976). Dry beans from severely affected fields will be of poor quality because of the sunken and spotted seed (Heald, 1981). Medina (1970) found active pathogen propagules even after the seed had lost viability.

2.3 Nomenclature of *Colletotrichum lindemuthianum*

Bean anthracnose is caused by the fungus *C. lindemuthianum* (Saccardo and Magnus) Briosi and Cavana (Roberts and Boothroyd, 1984). Since anthracnose fungus produce setae, in some specimens and not others, there has been much confusion about its identity (Harter and Zaumeyer, 1944). Saccardo described the anthracnose fungus in 1878 as *Gleosporium lindemuthianum* Sacc and Magnus but later noted the presence of setae in the acervulus and concluded that the fungus should belong to the form genus *Colletotrichum* and called it *Colletotrichum lindemuthianum*. In 1880 Berkeley (cited by Harter and Zaumeyer, 1944) had ascribed the cause of anthracnose to *Ascochyta*. In 1893, Halsted (cited by Harter and Zaumeyer, 1944) concluded that the anthracnose fungus and watermelon anthracnose were identical and called them *Colletotrichum lagenarium* (pass) Ell and Halst. The information was not conclusive and was not generally accepted (Harter and Zaumeyer 1944).

The fungus belongs to the form class Deuteromycetes (Ainsworth, 1971; Alexopoulos and Mims, 1979). The perfect stage of the fungus has been described as *Glomerella lindemithiana* (Barnes, 1968),but Kimati and Galli (1970) cited by Neergaard, 1979) described it as *Glomerella cingulata* f.sp *Phaseoli*. *Colletotrichum lindemuthianum* is placed in the form order melanconiales due to the production of acervuli as the fruiting bodies. Members of this form order causes a group of disease called Anthracnose. The

fungus belongs to the section hyalosporae (Alexopoulos and Mims, 1979).

2.4 Morphological characteristics of *Colletotrichum lindemuthianum*

Colletotrichum lindemuthianum has filamentous septate and branched mycelium (Barnes 1968; Alexopoulos and Mims 1979). The cells are multinucleate and joined to each other by perforations. The mycelium is hyaline becoming darkish at maturity (Walker, 1969).The colonies are slow glowing dark brown to black, with abundant brown aerial immersed mycelium with regular margins (Sutton, 1980). The fruiting bodies are called acervuli which are saucer shaped (Lina 1977; Alexopoulos and Mims, 1979). Conidiophores are produced side by side with filiform setae which are 2 to 4 septate (Lina, 1977; Neergaard, 1979; Alexopoulos and Mims, 1979). The setae produced on beans are sparse as compared to those produced on cowpeas which are profuse (Onesirosan and Barker, 1971). The setae are often pointed, stiff, brown hairs varying in length from 30μm to 100μm (Harter and Zaumeyer, 1944; Chaves, 1980). The conidia of *C. lindemuthianum* are hyaline and non-septate (Harter and Zaumeyer, 1944; Lina, 1977). They are borne on hyaline, unbranched, erect, continuous conidiophores, 40μm to 60μm in length and packed closely together in the acervulus (Harter and Zaumeyer, 1944; Barnes, 1968; Neergaard, 1979). The conidia are well rounded with a slight constricted middle (Alexopoulos and Mims, 1979; Walker, 1969). They measure 8-15μm in width and 13-22μm in length. They are cylindrical, Kidney or sigmoid in shape (Chaves, 1980; Sutton, 1980) and occur in pink masses in the

acervulus (Barnes, 1968; Neergaard, 1979; Sutton, 1980). Each conidium possesses vacuole like bodies at both ends or at the centre (Neergaard, 1979).

2.5 Host range of *Colletotrichum lindemuthianum*:

Anthracnose is primarily a disease of various varieties of common beans (*Phaseolus vulgaris* L.) (Harter and Zaumeyer, 1944; Heald, 1981) .In addition to infecting beans (*P. vulgaris*), the pathogen has also been observed to cause losses in Lima beans (*Phaseolus lunatus*), scarlet runner beans (*P. flovus*). Tepary beans (*P. acutifolius* Nar *latifolius*), Kudzu beans (*Dolichus biflorus*) and broad beans (*Vicia faba*) (Walker, 1969). The anthracnose fungus has also been isolated from cowpeas (*Vigna sinensis*) (Onesirosan and Barker, 1971). Kuch (1974) recorded anthracnose as a new disease attacking *Vigna sesqurpedalis*. It has also been recorded from *V. anguiculata*, and *V. vexillata* (Sutton, 1980). Venkata *et al.*, (1969) reported a new blight of onions in Southern India in 1966. The disease caused spots which were 2-4 X 0.5-1.2 cm with raised brown margins and a grey to light brown centre containing brown to black acervuli. The causal agent was identified as *C. lindemuthianum* (Venkata *et al.*, 1969).

2.6. Symptomatology of Bean Anthracnose:

Anthracnose symptoms may develop in all above ground parts of the bean depending on the time of infection and source of inoculum (Dugger, 1909; Westcott, 1971; Allen, 1983; Arden and Macnab, 1986).

2.6.1 Symptoms on seeds

The symptoms of anthracnose on the seed are not always easy to distinguish from those caused by certain microorganisms (Harter and Zaumeyer, 1944). The disease appears on the seed coat as yellowish, brownish or blackish spots, frequently quite evident on the white skinned varieties, but generally very obscure on the dark-skinned varieties (Heald, 1981). The spots may be small or extended over a large part of the seed-coat forming lesions which may or may not be sunken (Heald, 1981; Dugger, 1909; Harter and Zaumeyer, 1944; Westcott, 1971; Allen, 1983; Arden and Macnab, 1986). The lesions frequently extend through the seed-coat and involve the underlying cotyledons. In the young seedlings the black cotyledon lesions enlarge, become more depressed and develop sticky spore masses as in pod lesions (Heald, 1981). The common bacterial blight pathogen (*Xanthomonas campestris* p.v. *phaseoli*) and the halo blight organism (*Pseudomonas syringae* p.v. *phaseolicola*) causes rather similar cankers on the seed, which should not be confused with those caused by anthracnose fungus. These diseases can usually be distinguished by the type of lesions produced. In many cases the lesions caused by common blight organism may be distinguished by the yellow deposit of bacteria under the seed-coat (Harter and Zaumeyer, 1944).

2.6.2. Symptoms on hypocotyls:

Infection of the seedling hypocotyls usually results from the spore washing down from an infected cotyledon and causing a few or many lesions (Dugger, 1909; Harter and Zaumeyer, 1944; Westcott,

1971; Allen, 1983; Arden and Macnab, 1986). The lesions which often attain a considerable size begin as minute flesh-to-rust-coloured specks, which gradually enlarge lengthwise of the stem and to a lesser extent around it. The lesions finally become sunken and contain the fruiting bodies (acervuli) which produces large quantities of pink coloured spores (Dugger, 1909; Westcott, 1971; Allen, 1983; Arden and Macnab, 1986; Harter and Zaumeyer, 1944)). If the lesions are numerous and favourable conditions prevail for the development of the fungus, the stem may be so weakened that it is unable to support the top part of the plant (Harter and Zaumeyer, 1944).

2.6.3. Symptoms on leaves and petioles

Foliar symptoms are more conspicuous in the lower surface of leaves (Dugger, 1909; Westcott, 1971; Allen, 1983; Arden and Macnab, 1986). Infection may occur in both the petiole and the veins of the leaf. If the petiole is badly infected, the leaf droops and recovery to its normal position is not possible (Harter and Zaumeyer, 1944). Infections occur on the underside along the veins, causing a dark-red to purplish colour which later turns dark brown or almost black. Small lesions in which spores are generally present may be produced on the petiole and larger veins (Harter and Zaumeyer, 1944). Leaf tissue adjacent to the infected veins may wither and turn brown and later may become torn giving a ragged appearance. Early attacks on young leaves may cause them to become twisted or crinkled (Heald,1931).

2.6.4. Symptoms on the pods:

Anthracnose is best known and the symptoms most clearly defined on the pods. The first evidence is noted as small flesh to rust-coloured spots (Westcott, 1971; Arden and Macnab, 1986; Tu, 1988). The very young lesion may be longer in one direction than the other, but once fully developed are usually nearly circular. The lesions vary in size from 1 to 10 mm in diameter, averaging about 5 to 7.45 mm. The lesions develop into cankers which may extend through the endocarp and even to the seed particularly if infection takes place early in which case the pods fail to develop and become shrivelled and dried (Harter and Zaumeyer, 1944). Cankers resulting from infections that occur during the later growth of the pod seldom extend below the endocarp (Heald, 1981). As the pod matures the lesion is marked at the edge of a canker, by a slightly raised, brown, black ring with a cinnamon - rufus to chestnut coloured border. The centre of the spots is then somewhat light buff in colour (Harter and Zaumeyer, 1944; Heald, 1981). Flesh-coloured spore masses on the surface of a young canker turn to grey, brown or even black granulations or to small pimples (Harter and Zaumeyer, 1944). During wet weather the pinkish spore masses ooze from the acervuli (Dugger, 1909; Westcott, 1971; Allen, 1983; Arden and Macnab, 1986).

2.7. Control of bean anthracnose

Since the seed-borne inoculum is more important than any other source in epidemic development, the use of clean healthy seed is seen as a potentially powerful control measure in areas where

strict standards of seed health can be maintained (Allen, 1983; Farnandez *et al.*, 1987). However, by simple hand sorting of infected seeds, disease development in the field could be drastically reduced (Mukunya and Keya, 1979). The use of seed produced in the semi-arid areas, where climatic conditions are unsuitable for infection, has been the preferred disease control method especially in the U.S.A. but such seed is not always free of the pathogen (Kulik, 1984; Walker, 1969). Such a strategy of producing pathogen free seeds in the tropical regions, is usually difficult due to shortage of water in arid areas which leaves only the humid zones as the chief production areas where diseases could spread from a few infected plants (Kay, 1979; Yerkes and Ortiz, 1956). Crop rotation on a two-year basis has been recommended for the control of anthracnose (Zoebl, 1983). Roughing of diseased plants lead to a reduction in pod infection, but such a treatment when applied to plots planted with diseased seeds, might lead to the elimination of the whole stand (Mukunya and Keya, 1979). Water treatment of seeds at 50°C to 60°C lowers the seed contamination levels but reduces seed viability (Zaumeyer and Thomas, 1957).

Use of resistant varieties has been emphasized as the best control strategy but this suffers from the ability of the pathogen to produce resistance breaking races (Mukunya and Keya, 1975; Yerkes Jr. 1958). Fungicides such as Thiram, Ferbam, and Ceresan have been used to arrest the disease (Chaves, 1980). Mancozeb (Dithane M.45) and metraim (porryram combi) are commonly used for bean anthracnose control in Kenya (Esele, 1982). As much as

fungicide control of anthracnose is possible, their use has been found to be too costly in dry bean production at the small scale level in Kenya and can be hazardous to the untrained user (Mukunya and Keya, 1979).

Therefore the application of seed testing procedures is desirable, inorder to establish the health condition of the seed to be planted. Although ''zero tolerance'' is the objective of a seed testing program, in practice, this is impossible to achieve, as it will require the testing of the entire stock. Studies on anthracnose epidemiology are necessary to provide a practical guide to the levels of seed infection likely to result in serious disease outbreaks and to determine tolerance limits, for seed infection (Kulik, 1984).

2.8. Time of infection and disease development at various plant growth stages and resultant yield.

The degree of infection of seed may be related to the time of infection as defined by the growth stage of the host (Neergaard, 1979). Bronnimann (1968), related a range of growth stages of wheat, defined according to Feeke's scale, to infection by *Septoria nodorum*, which causes glume blotch of wheat. He established a clear relationship between the growth stage of the host at the time of infection with the rate of seed infection in terms of percent infected ears, as well as in terms of thousand grain weight, number of grains per ear and average of ears,. The same trend was observed by Cooke and Jones (1970) and Jones and Odebunmi (1971), who noted that when inoculum of *S. nodorum* was applied to spring wheat c.v.

Opel at growth stage 10, the mean yield per head was reduced by 70%.

The weather conditions in the period of flowering and seed development are decisive for infection. The exact time of infection within this period again determines the extent of infection in individual seeds and number of seed infected (Neergaard, 1979).

The degree of seed infection in cotton by *Colletotrichum gossypii (Glomerella gossypii)*, which causes pink poll rot, at the time the boll opened was directly related to the amount of rainfall (Arndt, 1956). The same correlation was established for seed infection of lucerne, at the time of harvest, by *Phoma medicaginis* which causes spring stem break (Mead and Cormack, 1961). Also bacterial blights and anthracnoses of bean, soybean and pea are strongly influenced by rainfall and high air humidity in both their development on the seed crop and establishment in the seed (Neergaard, 1979).

The time of infection in relation to the stage of the developing seed is decisive not only with regard to the extent of seed infection, the point of entry, infection and the parts of seed being involved, but may also determine the composition of the seed-borne fungus flora (Neergaard, 1979). Kilpatrick (1952) examined the seed-borne fungi of ten cultivars and strains of soybean in Mississippi, representing five maturation groups, harvested at intervals of one week. He reported that *Cercospora kikuchi*, which causes purple blotch, was isolated more frequently from late maturing cultivars than from the early maturing ones. The reverse

was encountered in the case of *Phomopsis sojae*, which causes pod and stem blight. From green immature seeds of soybean only very few fungi were isolated, while 75-100 percent of mature seeds with low water content were infected. The extent of seed infection by and seed transmission of *Phoma betae* in sugar beet is also highly dependent on the amount as well as the time of precipitation, i.e. whether rainfall prevail in the early or in the late part of crop development (Neergaard, 1979).

Young and Ross (1978) inoculated soybean with *Septoria glycines* at various growth stages, to determine the development and effect of brown spot on yield, on cv. Essex. They observed that during the year 1976, brown spot caused 17.1% yield loss in the Essex. However, yield and seed size were negatively correlated with percent leaf area diseased. The yield loss was due to reduction in seed size. When two susceptible hybrids of maize were inoculated with maize dwarf mosaic virus strain A (MDMV-A) in the three-, five-, seven-, nine- and 11- leaf stages during the two growing seasons, the highest disease incidence (58%) and the greatest yield reduction (23%) were obtained in plants inoculated at the five leaf stage. There was no significant difference in disease incidence or in yield reduction between plants inoculated in the three leaf stage and those inoculated in the seven leaf stage, when data from the two hybrids were combined (Rosenkranz and Scott, 1978).

The microclimate has considerable influence on seed infection and seed yield. Plants in the outskirts of the field are much less affected than plants inside the crop because of differences in

humidity. The plants on the outskirts are sooner dried after night dew or rain than those inside the crop, where ventilation is poor (Neergaard, 1979)

2.9. Detection of seed-borne plant fungal pathogens.

Direct examination, incubation and agar plating procedures are the most commonly used methods of detecting fungal pathogens in seeds (Neergaard,1979; Richardson,1983). These techniques are standardized methods for the detection of fungal pathogens and basically involve direct examination, incubation methods (including grow-on tests), agar plating, and to a much less extent, serological and chemical methods. Generally, these methods are relatively easy and do not require sophisticated and expensive equipments (Irwin, 1987).

Recent advances in the detection of seed-transmitted fungal plant pathogens have come largely through improving existing methods, in particular agar plating and incubation tests, to increase the efficiency of detection of pathogenic fungi on individual seeds (Irwin, 1987). Byford and Gambogi (1985) found the most efficient methods for the detection of *Phoma betae* Frank on beet (*Beta vulgaris* L) seed involved plating on potato dextrose agar + 10% benomyl and incubating continuously under near ultra violet light (NUV). Continuous incubation under NUV is known to facilitate sporulation of pycnidial fungi. The deep- freezing blotter method (incubation for two days at 25°C in the dark, followed by day at -20°C then five days at 25°C) was compared to the standard blotter test (Neergaard, 1979) and agar plating for

the detection of *Gerlachia oryzae* (Hashioka and Yokogi) Gams in rice *(Oryza sativa* L.) seed (Mia *et al.*, 1985). Both the standard and deep-freezing blotter methods were superior to plating on PDA. However for most fungal pathogens it has been generally found that agar plating methods are more reliable than direct examination or incubation methods (Richardson, 1983). With biotropic fungal pathogens, direct examination procedures are commonly used. Rao, *et al.* (1984) described a modification of the direct examination procedure to detect seed-borne inoculum of *Peronoscleropora sorghi* Western and Uppal in maize. The organism occurs either as vegetative mycelium or in the form of oospores in the pericarp, endosperm and embryo of maize seeds. Mycelium and oospores were detected after macerating the seeds in 5% NaOH with 0.015% trypan blue for 24 hours and separating the seed components by agitating the seeds in a water stream. Of 17 seeds samples tested, mycelium was recorded in all samples while oospores were detected only in eight. The maceration procedure could be speeded up by heating the seeds in 2.5% NaOH at 80°C for four hours. For this pathogen the authors considered a quantitative estimation of oospores was not essential, since a single viable oospore can bring about a successful infection on a susceptible host. Because of this, a zero tolerance is needed, thus obviating the need for quantification.

Gordon and Webster (1984) compared the efficiency of agar plating, grow-on plants tests in the glasshouse and quantifying the concentration of ergosterol as methods for the detection and quantification of *Drechslera graminea* (Rabinh ex Schlecht)

Shoemaker infestation of barley (*Hordeum vulgare* L.) seed. All methods allowed the detection of levels of infestation as low as 1% and the grow-on method was the most accurate tested. However, this procedure took seven weeks, whereas results from both agar plating and measurement of ergosterol were completed within seven days. Problems still to be overcome with the ergosterol procedure include the removal of other fungal components of the seed microflora which also produce ergosterol. Most of these organisms are saprophytic, but *Ustilago nuda* (Jens) Roster also infects barley seed and is capable of producing ergosterol.

CHAPTER THREE

MATERIALS AND METHODS

3.0. Bean samples.

Surveys were conducted in Kisii, Meru, and Kiambu districts during the months of July-September,1991. During the surveys samples of bean (*P. vulgaris* L cv. Rosecoco-GLP-2) seeds were collected from the farmers. In each district 12 sampling areas were randomly selected and from each sampling area, 16 farmers were randomly chosen. From each farmer, in a sampling area 0.5-1 kg seed sub-samples were collected and later the sub-samples were mixed together to form a representative sample of approximately 8-16 kg. Also seeds were bought from the markets in the sampling areas and mixed together with the farmers seeds. In addition to the above samples, one commercial bean seed sample (certified seeds) were obtained from Kenya Seed Company. Pathogen-free bean seeds of cv. Rosecoco-GLP-2 obtained from the Grain Legume Project at the National Horticultural Research Station, Thika served as the control. The seeds were brought to the laboratory at Kabete campus, University of Nairobi for assessment of the seed-borne inoculum of *Colletotrichum lindemuthianum*

3.1. Isolation of *Colletotrichum lindemuthianum* from infected materials.

Infected pods were obtained from a bean growing field at Kabete campus of the University of Nairobi. The samples were washed with tap water and then surface sterilized by soaking in a solution of Sodium hypochlorite (NaOCl) for ten minutes, containing 1% w/v

available chlorine and then rinsed in five changes of sterile distilled water. The infected plant parts were then dried by gently pressing them between two sterile filter papers and plated on PDA and PDA enriched with bean pod extract. Plates were incubated at 20^0 C and observations on growth of *C. lindemuthianum* were made after 5 days.

3.2. Preparation of *Colletotrichum lindemuthianum* culture media.

Since *C. lindemuthianum* has been found to sporulate poorly in most artificial media (Muther *et al*, 1950; Ramanowski *et al* 1962), special media composed of bean pod extracts and PDA were prepared.

Two hundred grams of green pods of c.v Rose coco- GLP-2 were ground in a warring blender to a homogenous broth. The homogenate was filtered through cheese cloth. The filtrate from 200gms of green pods was diluted to 2400 ml and incorporated in PDA. The media was used for culturing the fungus for inoculation of plants in the field.

3.3. Slide Cultures:

The Slide technique described by Riddel (1950) was used for observation of fungal morphological characteristic without disruption, all of which were important features for fungal identification.

Two sheets of filter papers, a bent glass rod, microscope slide (on the rod) and a cover slip were placed into a petri dish in that order and sterilized.

Meanwhile, sterilized PDA enriched with bean pod extract was poured into a sterile 9 cm petri dish to form a layer of about 2 mm

deep. When the agar had solidified, 1-cm^2 blocks were cut using a sterile scalpel blade. One agar block was placed on the sterile microscope slide. Using a transfer needle, the centre edge of the block was inoculated with mycelium/spores of the fungus and then the cover slip was centrally placed on the agar block. The petri dishes were incubated at room temperature (20-24° C). To maintain humidity and keep the paper moist, 2-3% aqueous solution of glycerine was added periodically to the petri dish.

After 7 days of incubation, the cover slip was lifted carefully and the agar block was discarded. The cover slip and the microscope slide were mounted in a drop of lactophenol in cotton blue. Examination was done under a light compound microscope. Photographs were taken to aid in identification of the fungus from the seeds.

3.4. Pathogenicity tests for bean seed isolates of *Colletotrichum lindemuthianum*.

Pathogenicity tests were conducted, for all isolates obtained from the various tests above, using healthy bean seedlings grown on 10 cm pots. The pots were filled with a steam sterilized soil mixture composed of soil, manure, sand and ballast in the ratio 2:1:1:1.

The inoculum was prepared by harvesting the spores from PDA enriched with bean pod extract plates and making a homogeneous spore suspension in sterile distilled water. The suspension was calibrated using haemocytometer and adjusted to 1 X 10^6 conidia/ml concentration. The inoculum was applied onto 14 day old plants

using a quick-fit atomizer, and the inoculated plants were covered with moistened polythene plastic bags for 48 hours, in the glasshouse. After 48 hours, the polythene plastic bags were removed and observations for the characteristic anthracnose symptoms were made after 7 days. An equal number of control plants were treated like the experimental ones, but sprayed with sterile distilled water.

3.5. Assessment of cv. Rosecoco-GLP-2 seeds for infection and contamination by *Colletotrichum lindemuthianum*.

3.5.1. Farmer's Seeds.

Samples collected from farmers, from each of the three districts were subjected to various procedures to determine the level of inoculum in each seed sample.

3.5.1.1. Examination of the Dry seeds:

3.5.1.1.1. Visual observation using a binocular microscope:

Sub-samples of four hundred seeds per seed sample were taken and examined in four replications of one hundred seeds, using a binocular microscope. Observations were made to identify bean anthracnose symptoms on the seeds i.e. acervular or yellow or brown discolourations on the seed coat. The number of seeds showing possible anthracnose symptoms were recorded.

3.5.1.1.2. Examination of seed washings:

Anthracnose spores intermingled with or adhering to the seeds were identified by vigorously shaking 400 seeds from each seed sample.

One hundred seeds were placed in a conical flask and 100 ml of sterile distilled water containing one to two drops detergent added. The flask and its contents was shaken on a mechanical shaker for one hour. The process was repeated at least once. The suspension obtained was centrifuged using a bench centrifuge at 3000 rpm for 15 minutes and the supernatant discarded. The pellet obtained was resuspended in 10 ml of sterile distilled water and examined under the light microscope. *C. lindemuthianum* spores were counted using an haemocytometer and recorded. Upto one different observations on haemocytometer were made for each batch of seeds shaken. Thereafter the concentration of *C. lindemuthianum* spores per ml were calculated for each sample.

3.5.1.2. Incubation Tests:

The incubation tests used in the determination of seed-borne inoculum of *C. lindemuthianum* were the rolled paper towel test, the agar Plate test and the blotter test.

In each test 400 seeds per sample were used.

3.5.1.2.1. Rolled paper towel test.

The seeds were surface sterilized by soaking in a solution of sodium hypochlorite for 10 minutes, containing 1% W/W available chlorine followed by draining off the surplus liquid. Fifty seeds were placed on two well moistened blotters (48 x 48 cm size) and then covered with another well moistened blotter of the same size, folded twice lengthwise, and covered with a sheet of polythene to maintain the moisture during incubation. Incubation was done at room temperature (20-24° C) in darkness for seven days (Anon.,

1985b).

After seven days, the seed coats of the incubated seeds were removed. With the aid of a stereoscopic microscope at x25 magnification, observations were made for the presence of dark spots with clearly defined margins on the cotyledons. The number of seeds showing such spots was recorded as percentage incidence of anthracnose.

3.5.1.2.2. Agar plate test:

The seeds were surface sterilized as described for the rolled paper towel test and plated on potato dextrose agar (PDA) at the rate of 5 seeds per petri dish and incubated at room temperature (20-24° C) under 12 hours alternating cycles near ultraviolet (NUV) and darkness for 7-10 days. Bacterial growth was checked by adding 200 ppm of streptomycin sulphate to the molten media cooled to 45° C just before dispensing into individual plates (Neergaard, 1973; 1979). To retard gemination of seeds, 50 ppm of 2, 4-dichlorophenoxyacetic acid (2,4-D) was added to the media before autoclaving (Hagborg *et al.*, 1950).

3.5.1.2.3. Blotter test.

The moist champers used were glass petri dishes measuring 9 cm in diameter. White absorbent filter papers (Whatman paper No.1) were used as blotters. They were soaked in distilled water, drip dried wrapped in aluminum foil and then autoclaved at 121° C for 15 minutes. Three blotters were placed in each sterilized glass petri plate aspectically in the lamina flow (Neergaard,1973; 1979; Aliza *et al.*,1979; Dhingra and Sinclar, 1986)

Ten seeds surface sterilized as described for the rolled paper towel test, were plated in petri dishes of 9 cm diameter containing three well moistened blotters, with 50 ppm of 2, 4-dichlorophenoxyacetic acid to retard germination of seeds added (Hagborg *et al.*,1950). The petri dishes were incubated at room temperature(20-24°C) under 12 hours of alternating cycles of near ultraviolet light (NUV) and darkness for seven days.

3.5.2. Seeds from artificially inoculated bean plants.

The harvested seeds from artificially inoculated bean plants were evaluated for the presence of seed-borne *C. lindemuthianum*. The procedure used was the rolled paper towel test described above. 1600 seeds divided into 4 replications of 400 seeds were assessed from each field treatment.

3.6. FIELD EXPERIMENTS:

3.6.1. Planting of farmer's seeds with varying levels of seed-borne *Colletotrichum lindemuthianum* infection.

The major objective in this experiment was to determine the degree of correlation between seed-borne *C. lindemuthianum* and bean anthracnose incidence and severity in the field using farmers' seed. This could provide the necessary data to be able to set up tolerance levels of seed-borne inoculum of *C. lindemuthianum* for c.v Rosecoco-GLP-2 seed under Kenyan conditions.

3.6.1.1. Location of experimental fields.

The experiment was conducted at two locations i.e. Kabete campus, Field station farm, Faculty of Agriculture, University of Nairobi, and at the Agricultural Development Corporation (ADC)

Updown Farm at Tigoni, Limuru, during the long rains from April 1992- August 1992.

Kabete station is about 1800 metres above sea level and lies within the latitudes 1 14' 20''s and 1 15' 15'' and the longitude 36 44'E and 36 45' 20''E (Wamburi, 1973). On the average kabete receives about 1046 mm of rainfall per annum with mean temperatures of 23.4 °C and 12.6°C (maximum and minimum respectively). The soils are deep, friable, clay resistant to soil erosion (Keya and Mukunya, 1979) with acid humic top soil (humic nitrosols) developed from Limuru trachyte (Michieka, 1979).

3.6.1.2. Planting Seeds.

The farmers seeds were used for planting. Cv. Rosecoco-GLP-2 samples showing the following percentages of seed infection as determined using the rolled paper towel test were planted viz; 0.00%, 0.25%, 0.50%, 0.75% 1.00%, 2.00%, 3.00%, 3.75%, 5.50% and 10.00% at the two locations . In addition to the farmers seeds, one commercial certified bean seed sample from Kenya seed company was included. Pathogen free seed from the National Horticulture Research Station, Thika served as the control.

3.6.1.3. Experimental design and field layout.

The trial consisted of three replications in each location in a randomized complete block design. Each plot size was 2 x 2 metres and contained 5 rows of cv. Rosecoco-GLP-2 beans with 50cm interrow and 10cm intrarow spacings. A distance of one metre was left between the plots and the space planted with certified bean seeds.

3.6.1.4. Cultural Practices.

3.6.1.4.1. Fertilizer application.

Fertilizer applications was 60 kg/ha of DAP and 30 kg/ha of CAN during planting. A second application of CAN two weeks after plant emergency was made at the rate of 30kg/ha as applied by Mukunya and Keya (1979).

3.6.1.4.2. Insect pest and weed control

Bean fly and Aphid damage was controlled by use of the insecticide Rogo ® L 30 which contain 40% W/V (400 ml/l) N-monomethyl amide of 0, 0 Dimethyldithiophosphorly-acetic acid (dimethoate). The insecticide was applied at the rate of 25 ml/20 litres (0.5g a.i./l). Plots were kept weed-free by hand weeding every time the weeds were noted.

3.6.1.5.2. Data collection:

3.6.1.5.2.1. Anthracnose incidence.

Individual plants were assessed for anthracnose infection in the field on a weekly basis. The whole plot was examined and the number of plants infected per plot noted, and expressed as percent anthracnose incidence per plot.

3.6.1.5.2.2. Anthracnose severity.

3.6.1.5.2.2.1. Anthracnose severity on the leaves.

Anthracnose severity on the leaves was recorded on a weekly basis on twenty randomly labelled plants per plot. The same plants were assessed for anthracnose severity for the entire growth period. The anthracnose severity on leaves was assessed using a modified C.I.A.T. scale (Schoonhoven and Corraks, 1987) and was

based on the percent leaf area infected. The anthracnose grades are presented diagrammatically in plate 1 and described in table 1.

3.6.1.5.2.2.2. Anthracnose severity on the pods.

Anthracnose severity data on the pods was taken after their development using a scale of 1-9 which was based on the size, number and state of the lesions on the pod and was based on a scale of 1-9 as described in table 2 and shown in plate 2.

3.6.1.5.4.3. Area under disease progress curve (AUDPC).

To correlate the effect of anthracnose incidence and severity on yield and yield components, the area under disease progress curves (AUDPC) for anthracnose incidence, anthracnose severity on leaves and anthracnose severity on pods were calculated using the formula of Shaner and Finney (1977). The formula used is:

$$AUDPC = \sum_{1}^{n} \left(\left(Y_{i+1} + Y_i \right)/2 \right) \left(X_{i+1} - X_i \right)$$

Where

Y_i = is the proportion of diseased plants (in percentage) or the proportion of diseased leaf area or the pod index on the time (weeks) on i^{th} observation.

X_i = is the time in weeks on the i^{th} observation.

n = is the total number of observations.

3.6.1.6. Yield data.

The plants were left to dry completely in the field before harvest. During harvesting plants at the border 0.2 m in the harvesting row were discarded. Thus a net plot of 1.6m and 1.2m was harvested. The total yield per plot for each treatment was converted to yield per hectare. In addition to the yield per

Table 1. Anthracnose severity scale used in assessing anthracnose infection on leaves.

Percent leaf area infected	Description
0	-No anthracnose symptoms observed on leaf
1	-Few lesions on the leaf confined mainly to the veins and covering approximately 1% of the leaf area.
5	-Lesions occurring on the underside of the leaf covering approximately 5% of the leaf area.
10	-Numerous lesions on the underside of the leaf, occupying approximately 10% of the leaf area with lesions on both veins and lamina.
25	-Lesions on both the underside and upper side of the leaf and covering approximately 25% of the leaf area.
50	-Coalescing lesions on both sides of the leaf and covering approximately 50% of the leaf area.
75	-Lesions on the leaf covering 75% of the leaf area.
100	-Dead leaf, folded into small crinkled shape

0 %

1%

5 %

10 %

KEY

□ = UNINFECTED PART.

■ = INFECTED PART

Plate Percent anthracnose severity scale used in evaluating bean leaves for anthracnose severity.

25 %

50 %

75%

100 %

Table 2. Anthracnose severity scale used in assessing anthracnose severity on pods (C.I.A.T).

Grade	Description
1	-No visible anthracnose symptoms on pods
2	-1-2 small lesions (less than 2mm in diameter) present on the pod.
3	-Presence of 1 large heavily sporulating lesion less than 2mm in diameter on the pod
4	-Presence of 2-3 large sporulating lesions of more than 2mm in diameter on the pod covering less than 4% of the pod surface area.
5	-Presence of numerous (less than 10) heavily sporulating lesions of more than 2mm with 1-2 lesions coalescing , covering approximately-7% of pod surface area.
6	-Presence of few coalescing lesions covering approximately 20% of the pod surface area.
7	-Presence of many coalescing and sporulating sunken lesions covering approximately 20% of the pod surface area.
8	-Presence of many coalescing and sporulating sunken lesions covering approximately 30% of the pod surface area.
9	-Numerous large sporulating coalescing sunken cankers which may result in pod malformation, low seed number and death of the pod and covering more than 50% of the pod surface area.

Plate 2. Anthracnose severity grades used for assessing anthracnose severity on pods.

hectare the following yield components were taken:

(i) Number of pods per plant

(ii) Number of seeds per pod

(iii) 100-seed weight

(iv) Percent yield losses.

Percent yield losses in each location were determined by using the average yield observed in the control plots for that location x 100%.

Percent deviation in yield due to treatment was calculated using the formula below.

$$\text{Percent loss in yield due to treatment.} = \frac{\text{Yield in control - Yield in treatment}}{\text{Yield in control}} \times 100\%$$

3.6.1.7. Data analysis.

Anthracnose incidence and severity on leaves and severity on pods taken over a period of time was computed using Gomez and Gomez (1984) procedure of analysis of multiobservation data format of pooled analysis of variance for measurements over time from a complete block design after square root transformation. The interaction sum of squares obtained was tested for significance at P=0.05 level. If the interaction sum of squares was significant, a regression analysis to estimate the functional relationship between the response (Y) and time of observation (X) was applied separately for each treatment. The linear, quadratic and cubic factors were

computed for each treatment, using the SAS procedures for linear, quadratic and cubic contrasts which were used for curve fitting (Anon, 1982).

AUDPC for anthracnose incidence, severity on leaves and pods and yield data from the 12 treatments were compared statistically by analysis of variance for each location , using Duncan's New Multiple Range Test (Steel and Torrie, 1981).

Yields obtained from the various treatments were compared statistically using Duncan's New Multiple Range analysis. The infection level at which the yield was not significantly different from the yield obtained from the pathogen free seeds (control) was taken as the tolerance level for the anthracnose pathogen in Kenya.

3.6.2. Artificial inoculation of cv. Rosecoco-GLP-2 plants at various growth stages.

The main objective of this experiment was to establish the critical time of anthracnose infection on bean plants that would not result in any detectable anthracnose infection on harvested seed. Once established, the concept could be used in disease control program for bean seed production in Kenya.

3.6.2.1. Field location, layout and design.

The experiment was carried at the University of Nairobi, Field Station farm on a piece of land which had not been planted with beans for the last 3 years or so. The planting was done in two seasons i.e. short rains (November,1991-February, 1992) and Long rains (April,1992-August, 1992).

The trial consisted of four replications in a randomized

complete block design. The plots used were 4 x 2m and contained 5 rows of cv. Rosecoco-GLP-2 beans with 50cm interrow and 10cm intrarow spacings. There was a 4m distance between plots and to reduce interplot interference, four rows of maize were planted in this space (Fernandez *et al.*, 1987). To avoid anthracnose fungus inoculum on infected bean debris, a rotation was carried by plating beans in the second season on plots which were previously sown with maize in the first season.

3.6.2.2. Seed planting in the field

Pathogen free seeds from the National Horticultural Research Station, Thika, were used in the experiment.

Seeds of cv. Rosecoco-GLP-2 were planted at a rate of 15 seeds/m row. After emergence the seedling population was adjusted to give to 10 plants per metre with 50 cm interrow and 10 cm intrarow spacing. Thus each plot contained 200 plants corresponding to a plant population of 250,000 plants per hectare.

3.6.2.3. Cultural practices.

3.6.2.3.1. Fertilizer application.

Was done as in 3.6.1.4.1

3.6.2.3.2. Insect pest and weed control

Was done as in 3.6.1.4.2.

3.6.2.4. Inoculum preparation:

A culture isolated as described earlier was used to inoculate plates containing PDA enriched with bean pod extract, for inoculum production and the plates incubated at 20 ° C for 15 days. 15 day old culture plates were flooded with sterile distilled water, and

using a sterile microscope slide, spores were gently scraping off the surface of the colony. The spore suspension was filtered through a sterile cheese cloth. The conidial suspension was adjusted to 10^7 spores per ml, a concentration that produces maximal infection (Tu, 1981).

3.6.2.5. Plant inoculation

The plants were inoculated at the following developmental growth stages:

(a) Control - inoculated with sterile distilled water.

(b) Seedling stage (2 weeks after planting) (1st trifoliate leaf).

(c) 4 weeks after planting

(d) 6 weeks (flowering time)

(e) Pod filling stage i.e. when plants had 50% pods.

(f) At maturity i.e. pods were fresh but had mature beans.

Plants were inoculated using a modified double inoculation technique of van der Vossen and co-workers (1976). Conidial suspension of *C. lindemuthianum* adjusted to 10^7 spores/ml, was applied on both sides of the leaves present on the plant using a half litre Baygon atomizer (Bayer East Africa Limited), held at a distance of 10-15 cm. Inoculation was done in the evening. A double inoculation at 48 hours interval was applied after the first inoculation in each treatments. Control plants were inoculated with sterile distilled water at two weeks after planting.

3.6.2.7. Data collection:

3.6.2.7.1. Anthracnose assessment

Anthracnose incidence, severity on leaves and severity on pods

data was taken as in 3.6.1.5.3.

In taking data observations were first done on plots inoculated with sterile distilled water, followed by those plots which had not been inoculated, and then with the most recently inoculated plots.

3.6.2.7.2. Yield data.

Yield data was taken as in 3.6.1.6.

3.6.2.9. Analysis of data:

Anthracnose incidence, severity on leaves and severity on pods data taken over a period of time was computed as in 3.6.1.7

AUDPC for anthracnose incidence, severity on leaves and pods and yield data from the 6 treatments were compared statistically by analysis of variance for each location , using Duncan's New Multiple Range Test (Steel and Torrie, 1981)

CHAPTER FOUR

RESULTS

4.1.0 Morphological Characteristics of *Colletotrichum lindemuthianum*.

Observation of the morphological characteristics of *C. lindemuthianum* after the preparation of the Riddel slide, showed hyaline, non-septate conidia borne on hyaline, unbranched, erect, continuous conidiophores 35μm to 55μm in length with the average length of 45μm. The conidia were well rounded with a slight constriction in the middle measuring 7-8μm in width with an average width of 12.5μm and 10-26μm in length with an average length of 18μm (Plate 3).

4.1.1. Pathogenicity Tests.

All the inoculated seedlings produced the characteristic anthracnose symptoms after 7 days. The symptoms began as minute specks which enlarged lengthwise on the hypocotyls. The symptoms were conspicuous on the lower side of the leaves. The infection occurred along the veins as brick-red to rust-brown lesions which later turned black. The tissue adjacent to the infected veins wilted and turned brown, dropping off to give a rugged appearance of the leaves. The seedlings collapsed and drooped when the heavily infected hypocotyls became weakened due to heavy infection. No symptoms developed on seedlings inoculated with sterile distilled water.

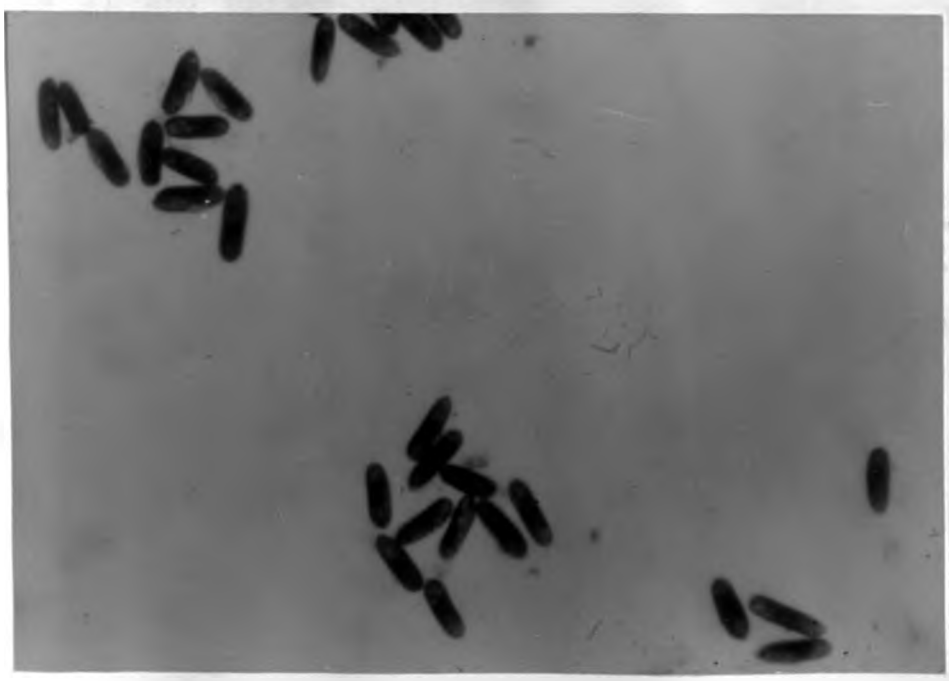

Plate 3. Conidia of *Colletotrichum lindemuthianum* X200.

4.2.0. Assessment of cv. Rosecoco-GLP-2 seeds for infection and contamination by *Colletotrichum lindemuthianum*.

4.2.1. Farmers' seeds.

4.2.1.1. Examination of dry seeds:

4.2.1.1.1. Visual observation Using a binocular microscope.

Visual inspection of 400 seeds per sample from the 38 samples revealed seeds with yellow to brown symptoms of various sizes and shapes (plate 4). Acervuli were observed on seeds having deep seated anthracnose lesions. Anthracnose incidence was found to be as high as 4.50% in seeds obtained from Metembe in Kisii district (Table 3) and this infection level was significantly (P = 0.05) higher than that recorded in seed samples from the other areas in Kisii district. When the three districts are considered, only 20 seed samples had seeds with anthracnose symptoms (Table 3).

4.2.1.1.2. Examination of bean seed washings:

Among the 38 samples, only washing of bean seeds of 12 samples had conidia of *C. lindemuthianum* (Table 3). Washings of cv. Rose Coco-GLP-2 seeds from Nyamware area in Kisii district had 333 conidia/ml which was significantly (P = 0.05) higher than that recorded in all the other seed samples obtained from different areas of the three districts.

4.2.1.2. Incubation tests.

Table 4 gives a summary of the results obtained using the three tests viz. rolled paper towel, agar plate and the blotter tests. In rolled paper towel test identification of the

Table 3: Percent (%) of seed in each sample of cv. Rose Coco-GLP-2 seeds showing possible anthracnose symptoms observed using a binocular microscope and conidial concentration in seed washings.

Sampling area	% seed with anthracnose symptoms	Conidial concentration ml^{-1}
Kisii district	$\bar{x}$ = 1.06 (0 - 6)	$\bar{x}$ = 97 (0-360)
Metembe	4.50	267
Nyamware	1.75	333
Taracha	0.5	200
Birongo	1.75	200
Suneka	1.0	118
Igare	0.5	0
Keroka	0.0	0
Nyachogochogo	0.25	0
Boochi	1.25	142
Bosingi	0	0
Kenyenya	0.75	0
Ibacho	0.5	0
SE	0.22	18.48
LSD 5% level	2.85	2.9
c.v. (%)	159	130
Kiambu district	$\bar{x}$= 0.33 (0-3)	$\bar{x}$= 52 (0-236)
Githunguri	0.0	0
Rironi	0.75	145
Karuri	0.25	0
Mainga	0.5	0
Ikinu	0.25	133
Nyaga	0.0	0
Gitaru	0.5	0
Nderi	0.75	208
Githunguchu	0.75	0
Kiambaa	0.0	141
Gathanga	0.0	0
Ndumberi	0.25	0
S.E.	0.035	11.94
LSD 5% level	2.85	2.9
c.v. (%)	360	172

Table 3 (Contd)

Meru district	$\bar{x}$ = 0.08 (0-1)	$\bar{x}$ = 22 (0-183)
Nkubu	0.0	0
Atanje	0.0	167
Githongo	0.0	0
Thuita	0.25	100
Igoki	0.25	0
Kiraro	0.0	0
Uringu	0.0	0
Ruiri	0.0	0
Chuka	0.0	0
Kithoka	0.25	0
Giaki	0.25	0
Nyambuguchi	0.0	0
S.E.	0.083	8.13
L.S.D 5% level	2.85	2.90
C.V. (%)	218	177
Pathogen free seed	0	0
Certified seed	0	0
Overall for the three districts	$\bar{x}$= 0.47 (0-6)	$\bar{x}$ = 51 (0-360)
SE	0.087	8.13
LSD 5% level	2.79	2.8
C.V. %	238	178

Table 4: Percent incidence of *Colletotrichum lindemuthianum* in cv. Rose Coco-GLP-2 seeds as determined by the rolled paper towel, agar plate and blotter tests.

Sampling area	Rolled paper towel	Agar plate	Blotter
<u>Kisii district</u>	$\bar{x}$ = 1.35 (0-8)	$\bar{x}$ = 1.1 (0.6)	$\bar{x}$ = 0.4 (0-2)
Metembe	5.0	4.25	1.5
Nyamware	2.13	1	0.25
Taracha	1.5	1.5	1.25
Birongo	2.75	1.75	0.5
Suneka	1	1.25	0.25
Igare	0.13	0.25	0
Keroka	0	0	0
Nyachogochogo	0.25	0.25	0
Boochi	1.88	0.75	0.25
Bosingi	0.25	0	0
Kenyenya	1	2.25	0.75
Ibacho	0.25	0	0
S.E.	0.163	0.19	0.082
LSD 5% level	2.81	2.85	2.85
CV (%)	149	147	180
<u>Kiambu district</u>	$\bar{x}$=0.41(0-3)	$\bar{x}$=0.4(0-3)	$\bar{x}$=0.17(0-1)
Githunguri	0.5	0.5	0.5
Rironi	1	1.5	0.75
Karuri	0	0	0
Mainga	0.13	0.75	0
Ikinu	0.38	0.5	0
Nyaga	0.25	0.25	0
Gitaru	0.38	0	0
Nderi	0.75	0.25	0
Githunguchu	0.63	0.5	.25
Kiambaa	0.5	0.25	0.25
Gathanga	0.13	0	0
Ndumberi	0.25	0.5	0.25
S.E.	0.058	0.078	0.047
L.S.D 5% level	2.81	2.85	2.85
C.V. (%)	175	170	247

Table 4 (Contd).

Meru district	x=0.14(0-2)	x = 0.1 (0-1)	x =0 (0)
Nkubu	0	0	0
Atanje	0.5	0	0
Githongo	0.25	0.25	0
Thuita	0.38	0.25	0
Igoki	0	0.25	0
Kiraro	0	0.25	0
Uringu	0.25	0	0
Ruiri	0	0.25	0
Chuka	0.13	0	0
Kithoka	0	0	0
Giaki	0	0	0
Nyambuguchi	0.13	0	0
		0	
S.E	0.033		0
		0.039	
LSD 5% level	2.81		0
		2.85	
CV (%)	300		0
		320	
Pathogen free seed	0		0
		0	
	0		0
Certified seed		0	
Overall for the three districts	$\bar{x}$ = 0.6 (0-8)	$\bar{x}$ = 0.51 (0-6)	$\bar{x}$ = 0.18(0-2)
S.E.	10.063		0.033
		10.074	
LSD 5% level	2.78		2.79
		2.79	
C.V. (%)	215		266
		265	

Plate 4. Anthracnose lesions (al) on seeds of cv. Rosecoco-GLP-2 collected from Metembe area in Kisii district.

note al= anthracnose lesions

anthracnose fungus was based on the anthracnose symptoms on cotyledons (plate 5). The anthracnose fungus was recorded in 77% seed samples when rolled paper towel test was used. In the agar plate and blotter tests, only 63% and 33% bean samples recorded the anthracnose pathogen respectively.

Seeds from Metembe area in Kisii district had 5% incidence of anthracnose infection which was significantly (P = 0.05) higher than those recorded in all seed samples, from the three districts, when rolled paper towel test was used (Table 4). Observations on incidence of anthracnose fungus using the agar plate test was based on colony characteristics (plate 6). The highest incidence of anthracnose fungus recorded when using agar plate test was 4.25%. This incidence was recorded in seeds collected from Metembe area in Kisii district and the incidence of seed infection was significantly (P = 0.05) higher when compared to those recorded in all seed samples from the three districts. Using the blotter test, the highest incidence (1.50%) of anthracnose infection was recorded on seeds obtained from Metembe area in Kisii district. This infection level of anthracnose was significantly (P = 0.05) higher than that recorded in all seed samples obtained from the three districts except the seed sample from Taracha (Table 4).

4.4.2.6. Seeds from artificially inoculated plants.

The anova for seed infection for both seasons is shown in appendix 1.

Plots inoculated with *C. lindemuthianum* at 2 weeks after

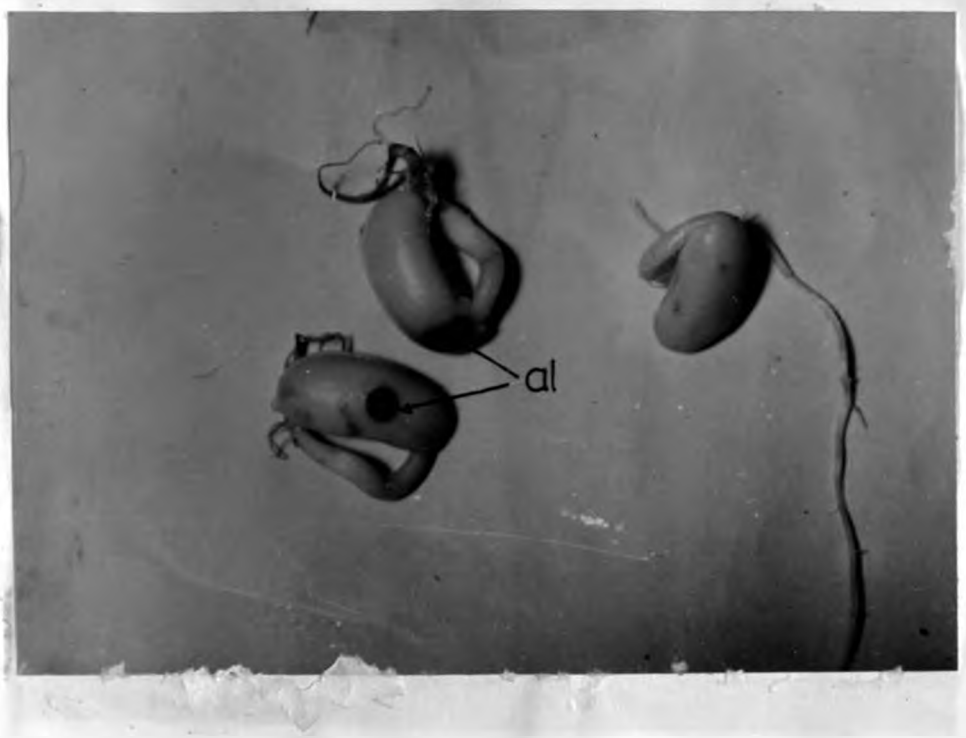

Plate 5. Anthracnose lesions (al) on cotyledons of seeds from Taracha area in Kisii district after incubation using rolled paper towel test.

note al= anthracnose lesion

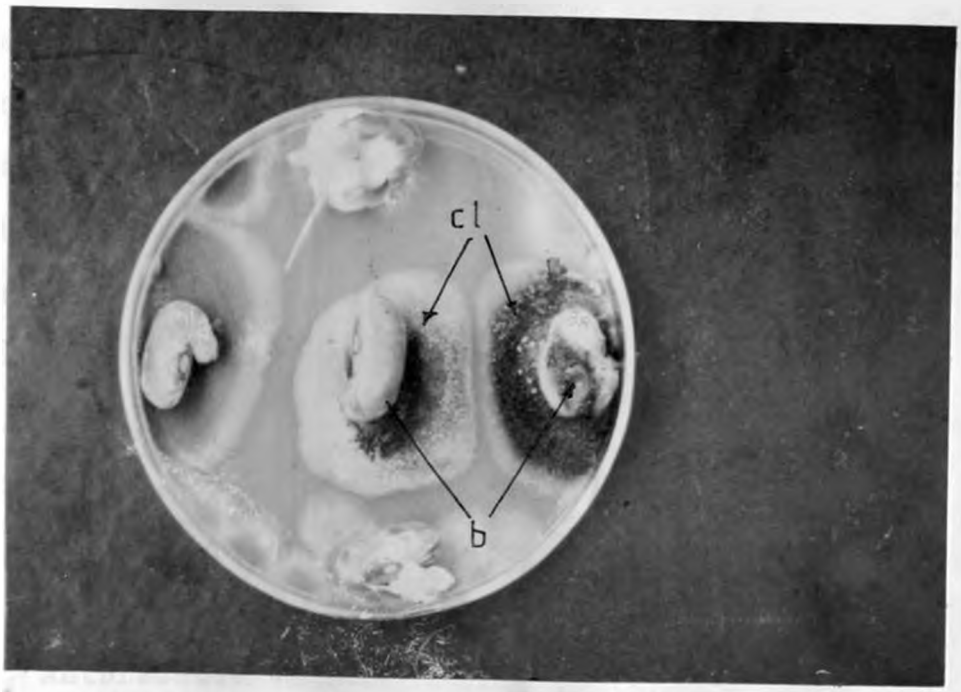

Plate 6. *Colletotrichum lindemuthianum* (cl) growing from infected seeds (b) after plating seeds of cv. Rosecoco-GLP-2 on PDA.

emergence recorded seed-borne *C. lindemuthianum* infection levels of 24.1% and 34.8% during the short and long rains respectively. These seed-borne *C. lindemuthianum* infection levels were significantly (P=0.05) higher than seed-borne *C. lindemuthianum* infection levels recorded in plots sprayed with sterile distilled water and inoculated with *C. lindemuthianum* at 4 and 6 weeks after emergence, pod filling stage and maturity during both the short rains and long rains seasons (Table 5).

Seed-borne *C. lindemuthianum* infection levels in the harvested seeds from plots inoculated with *C. lindemuthianum* at 4 and 6 weeks after emergence were not significantly different (P=0.05) from each other during the short rains. However they were significantly different (P=0.05) from each other during the long rains (Table 5).

4.3.0. FIELD EXPERIMENTS.

4.3.1. Anthracnose assessment during the growth of cv. Rosecoco-GLP-2 crop.

4.3.1. Farmers' seeds with varying levels of seed-borne *Colletotrichum lindemuthianum* infection.

4.3.2.1. Anthracnose incidence.

Anthracnose incidence varied greatly among treatments. Cv. Rose coco-GLP-2 seed samples with higher levels of seed-borne *C. lindemuthianum* gave rise to a higher number of seedlings with anthracnose infection. The climatic conditions which prevailed during the cropping seasons at Kabete and Tigoni are

Table 5. Percent Incidence of *Colletotrichum lindemuthianum* on harvested seeds of cv. Rose coco-GLP-2 during the short rains (November 1991-February 1992) and long rains (April-August 1992) at Kabete (1600 seeds tested in each treatment).

Time of inoculation	Percent seed-borne *C. lindemuthianum* infection		
	Short rains	Long rains	Time of inoculation means
1. Control	0.0[a]	0.0[a]	0.0
2. 2 weeks	24.1	34.8	29.4
3. 4 weeks	12.9[bc]	25.0[b]	19.0
4. 6 weeks	10.7[b]	19.9	15.3
5. pod filling stage.	15.0[c]	28.3[b]	21.6
6. maturity.	0.5[a]	0.9[a]	0.7
Seasons means	10.5	18.2	

Means followed by the same letter are not significantly different from each other at 95% level of significance.

shown in appendix 2a and 2b.

The Anova for anthracnose incidence for Kabete and Tigoni is shown in appendix 3. The level of seed-borne *C. lindemuthianum* infection (using rolled paper towel test), time of observation and interaction between level of seed-borne *C. lindemuthianum* infection and time of observation were all significant (P = 0.05).

Regression analysis to estimate the relationship between anthracnose incidence (Y) and time of observation (X) for each treatment is shown in appendix 4a and 4b and represented graphically in figs 1a and 1b and 2a and 2b for the Kabete and Tigoni trials respectively. Regression analysis showed that only the linear factor of anthracnose incidence recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 0.50% and 2.00% were significant (P = 0.05) at Kabete. Also the quadratic and cubic factors of anthracnose incidence recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 0.25% and 2.00% were the only ones found to be significant (P = 0.05) at Kabete. At Tigoni, the regression computed for anthracnose incidence recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%, 0.75%, 1.00%, 2.00%, 3.00%, 3.75%, 5.50%, and 10.00% had a significant (P = 0.05) linear factor while, anthracnose incidence recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 3.75% had a significant (P = 0.05) quadratic factor while anthracnose

Regression equations: for the graphs below are:

PFS = 0.707

CS = 0.707

FS = $1.005 - 0.379X + 0.113X^2 - 0.006X^3$

0.25% = $1.357 - 0.530X + 0.246X^2 - 0.017X^3$

0.50% = $0.076 + 0.803X - 0.088X^2 + 0.004X^3$

0.75% = $0.522 + 0.368X + 0.005X^2 - 0.001X^3$

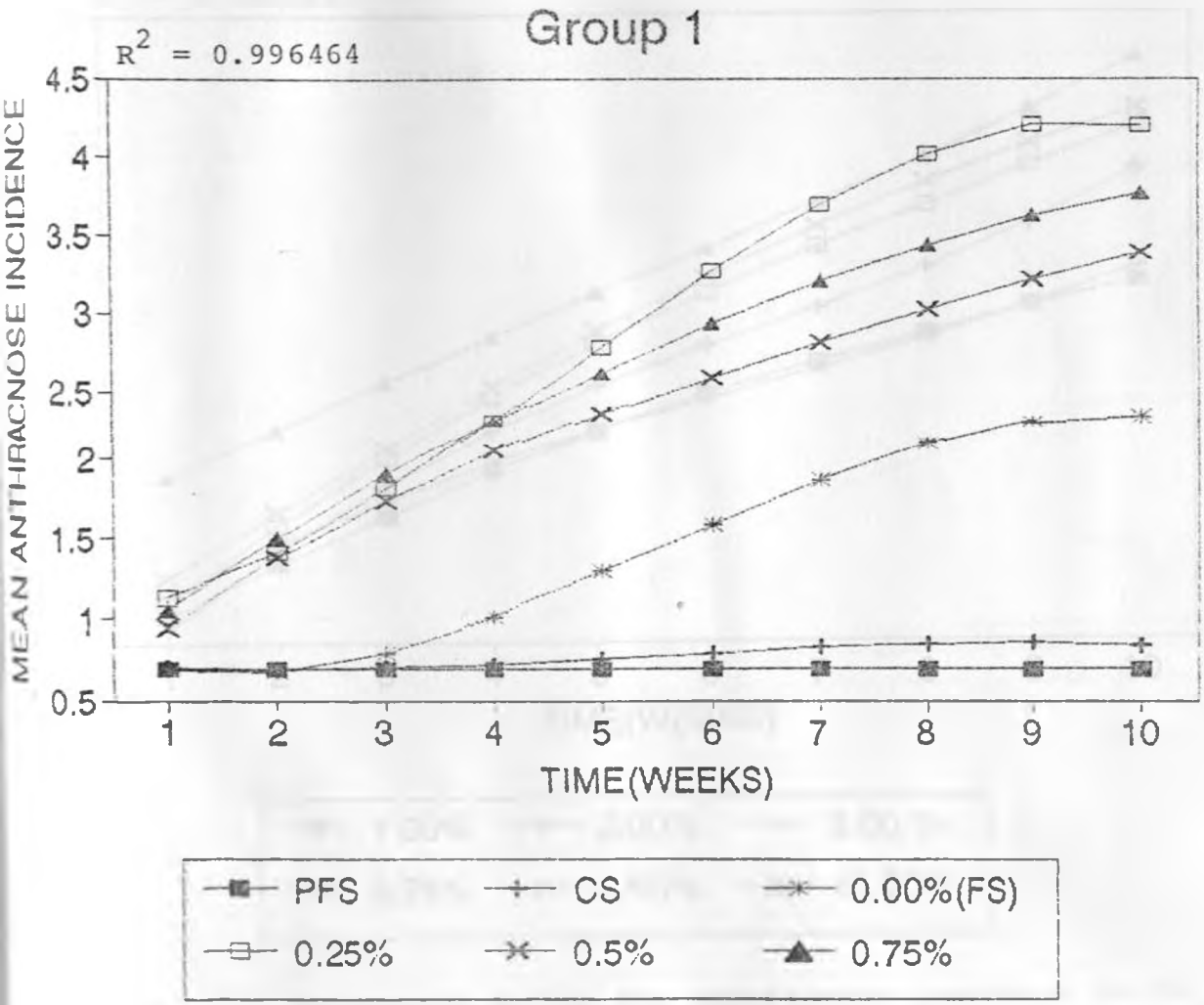

Fig 1a. Regression curves for anthracnose incidence on CV. Rosecoco-GLP-2 plants during the long rains at Kabete (Group 1).

The Regression equations for the graphs below are:

1.00% = $0.821 + 0.366X - 0.002X^2 - 0.001X^3$

2.00% = $-0.202 + 1.274X - 0.181X^2 + 0.010X^3$

3.00% = $1.169 + 0.440X - 0.050X^2 + 0.003X^3$

3.75% = $1.064 + 0.391X - 0.003X^2$

5.50% = $0.853 + 0.572X - 0.007X^2 - 0.001X^3$

10.00% = $1.928 + 0.343X + 0.001X^2$

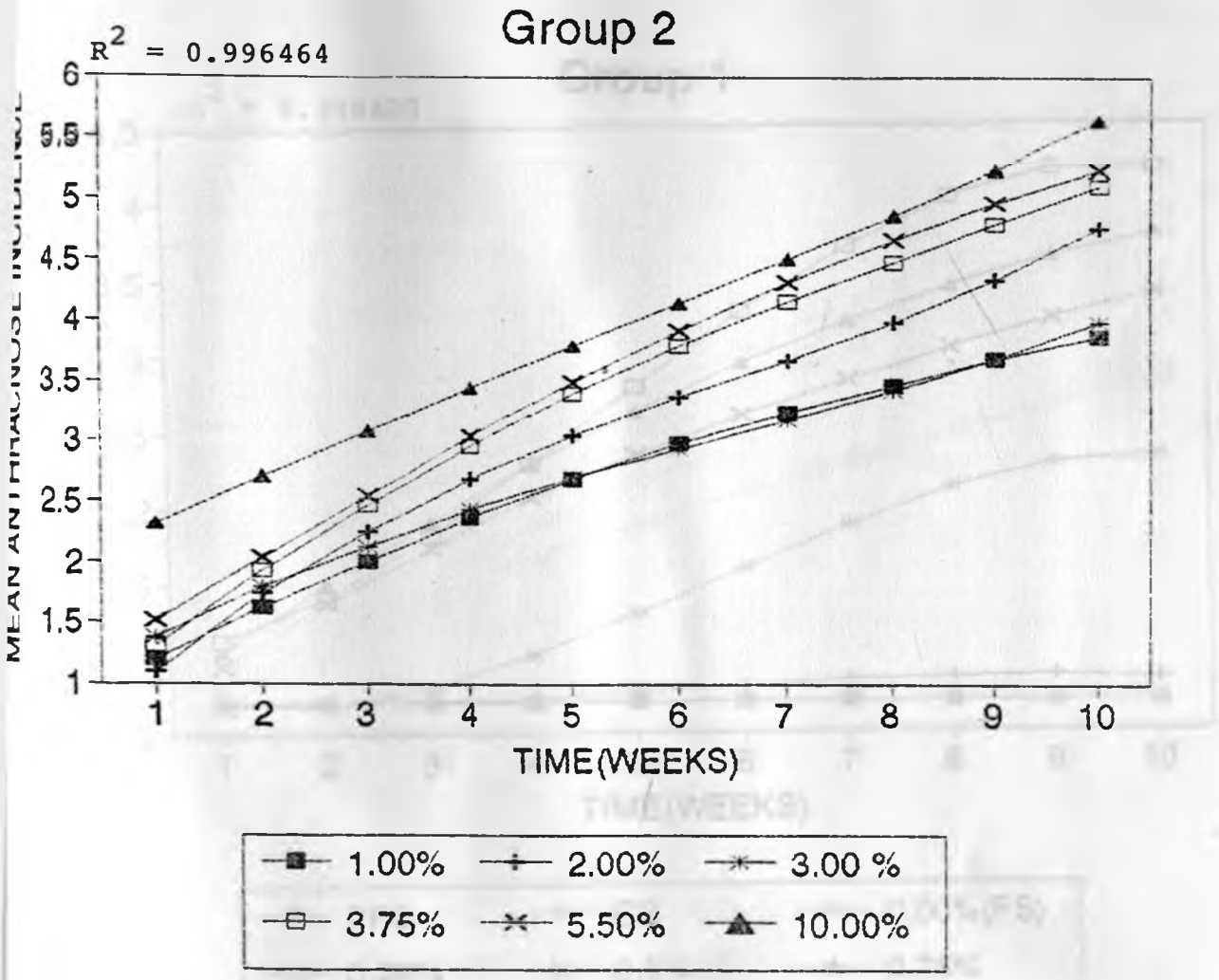

Fig. 1b. Regression curves for anthracnose incidence on Cv. Rosecoco-GLP-2 plants during the long rains at Kabete (Group 2).

Regression equations for the graphs are:

PFS = 0.707

CS = $0.707 - 0.112X + 0.035X^2 - 0.002X^3$

FS = $0.743 - 0.162X + 0.086X^2 - 0.005X^3$

0.25% = $0.639 + 0.595X - 0.043X^2 + 0.002X^3$

0.50% = $0.927 + 0.165X + 0.034X^2 - 0.002X^3$

0.75% = $0.659 + 0.589X - 0.030X^2 + 0.001X^3$

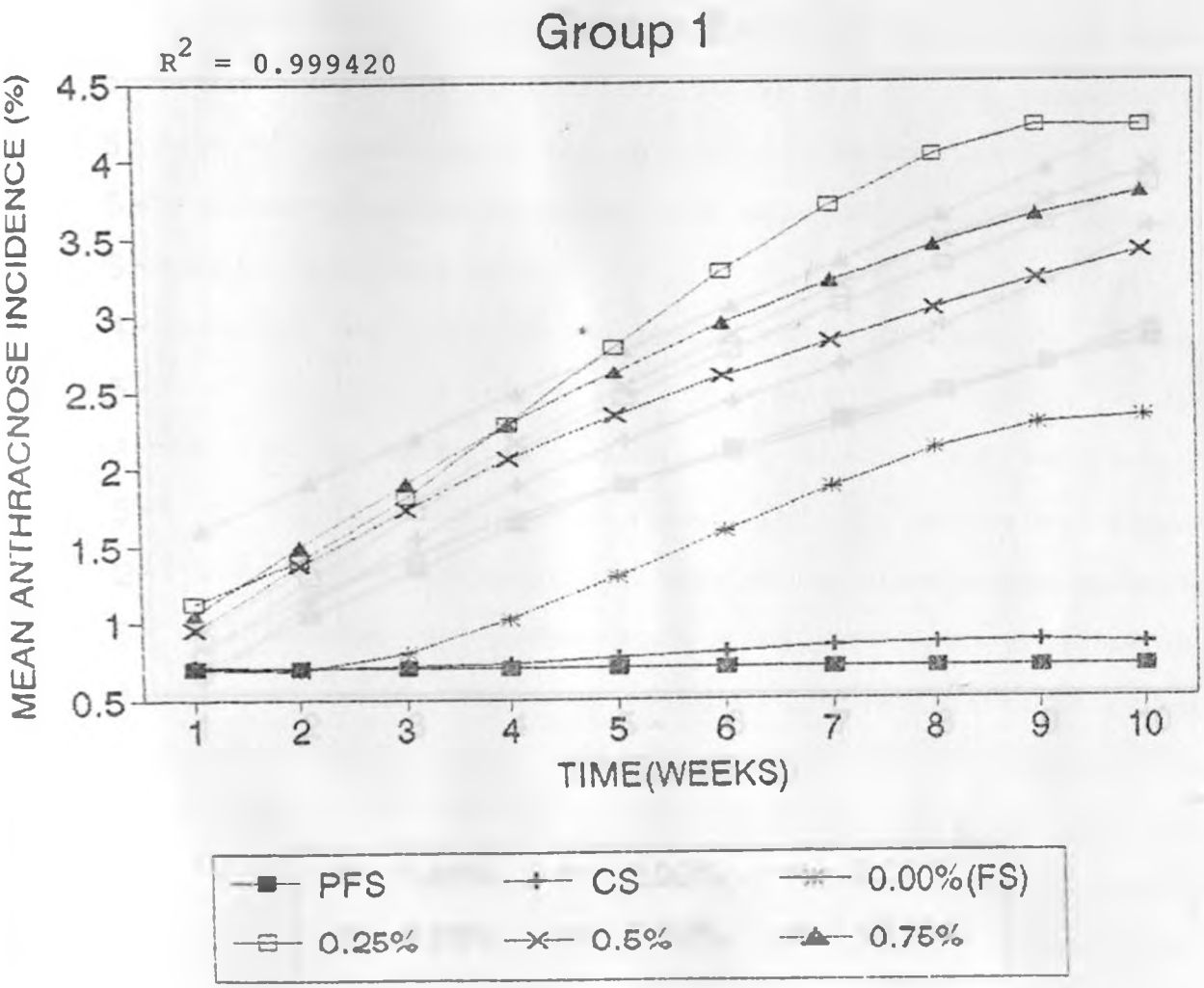

Fig 2a. Regression curves for anthracnose incidence on CV. Rosecoco-CLP-2 plants during the long rains at Tigoni (Group 1).

Regression equations for the graphs are:-

1.00% = $0.618 + 0.625X - 0.044X^2 + 0.002X^3$

2.00% = $0.791 + 0.489X + 0.003X^2 - 0.001X^3$

3.00% = $0.618 + 0.628X - 0.044X^2 - 0.002X^3$

3.75% = $0.180 + 1.067X - 0.086X^2 + 0.003X^3$

5.50% = $1.087 + 0.535X - 0.007X^2$

10.00% = $1.872 + 0.522X - 0.032X^2 + 0.002X^3$

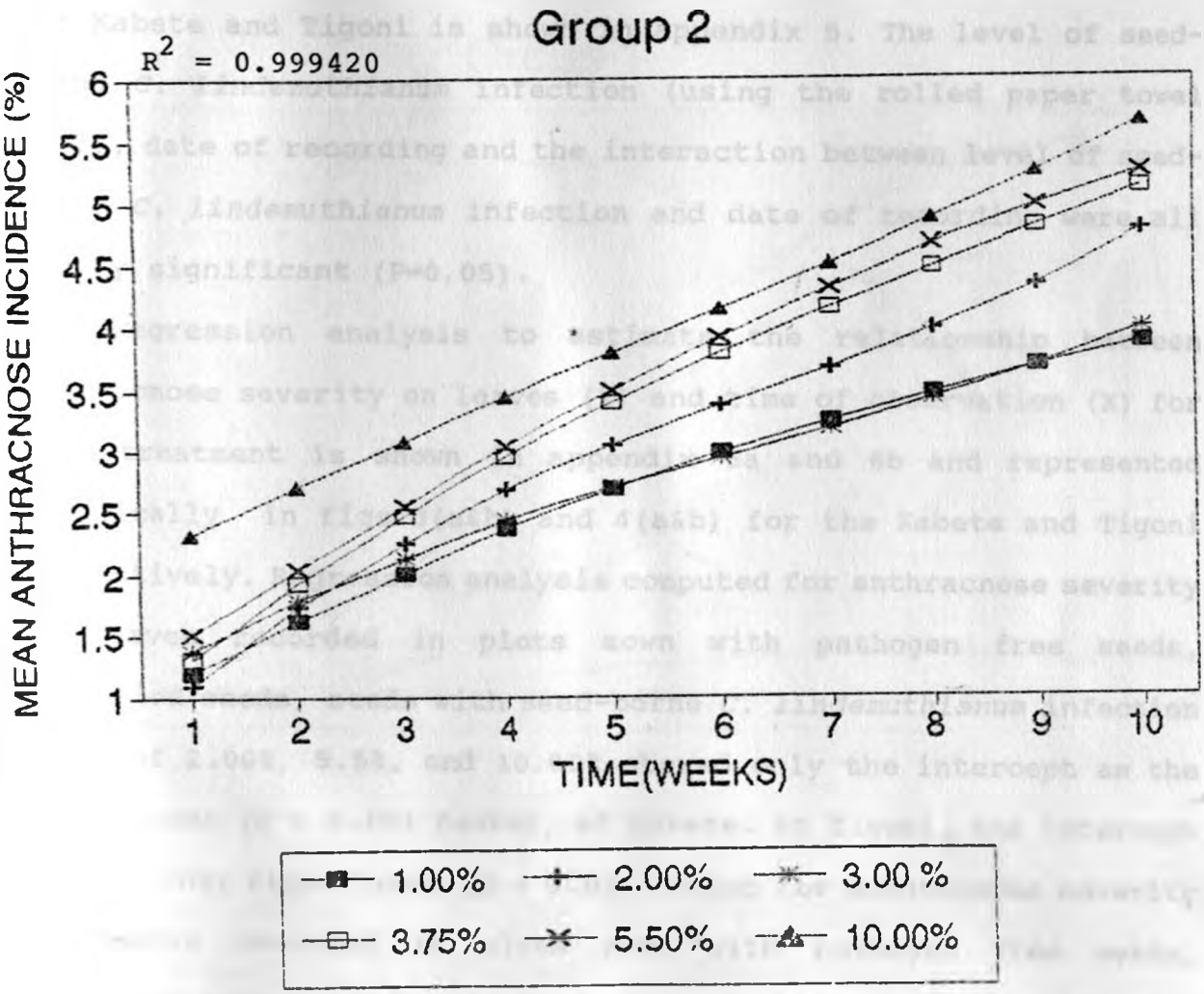

Fig. 2b. Regression curves for anthracnose incidence on CV. Rosecoco-GLP-2 plants during the long rains at Tigoni (Group 2).

incidence recorded in plots sown with the farmer's seed-sample with no seed-borne *C. lindemuthianum* infection showed a significant (P = 0.05) quadratic and cubic factors.

4.3.2.2. Anthracnose severity.

4.3.2.2.1. Anthracnose severity on the leaves.

The analysis of variance for anthracnose severity on leaves for Kabete and Tigoni is shown in appendix 5. The level of seed-borne *C. lindemuthianum* infection (using the rolled paper towel test), date of recording and the interaction between level of seed-borne *C. lindemuthianum* infection and date of recording were all highly significant (P=0.05).

Regression analysis to estimate the relationship between anthracnose severity on leaves (Y) and time of observation (X) for each treatment is shown in appendix 6a and 6b and represented graphically in figs 3(a&b) and 4(a&b) for the Kabete and Tigoni respectively. Regression analysis computed for anthracnose severity on leaves recorded in plots sown with pathogen free seeds, certified seeds, seeds with seed-borne *C. lindemuthianum* infection level of 2.00%, 5.5%, and 10.00% showed only the intercept as the significant (P = 0.05) factor, at Kabete. At Tigoni, the intercept was the only significant (P = 0.05) factor for anthracnose severity on leaves recorded in plots sown with pathogen free seeds, certified seeds, seeds with seed-borne *C. lindemuthianum* infection levels of 0.75%, 2.00% and 3.00%. The linear factor computed for anthracnose severity on leaves recorded in plots sown with seed-borne

Regression equation for the graphs below are:

PFS = 0.707

CS = 0.707

FS = $0.877 - 0.170X + 0.047X^2 - 0.002X^2$

0.25% = $0.182 + 0.603X + 0.061X^2 + 0.003X^3$

0.50% = $0.864 - 0.198X - 0.060X^2 + 0.003X^3$

0.75% = $0.913 - 0.289X + 0.096X^2 - 0.005X^3$

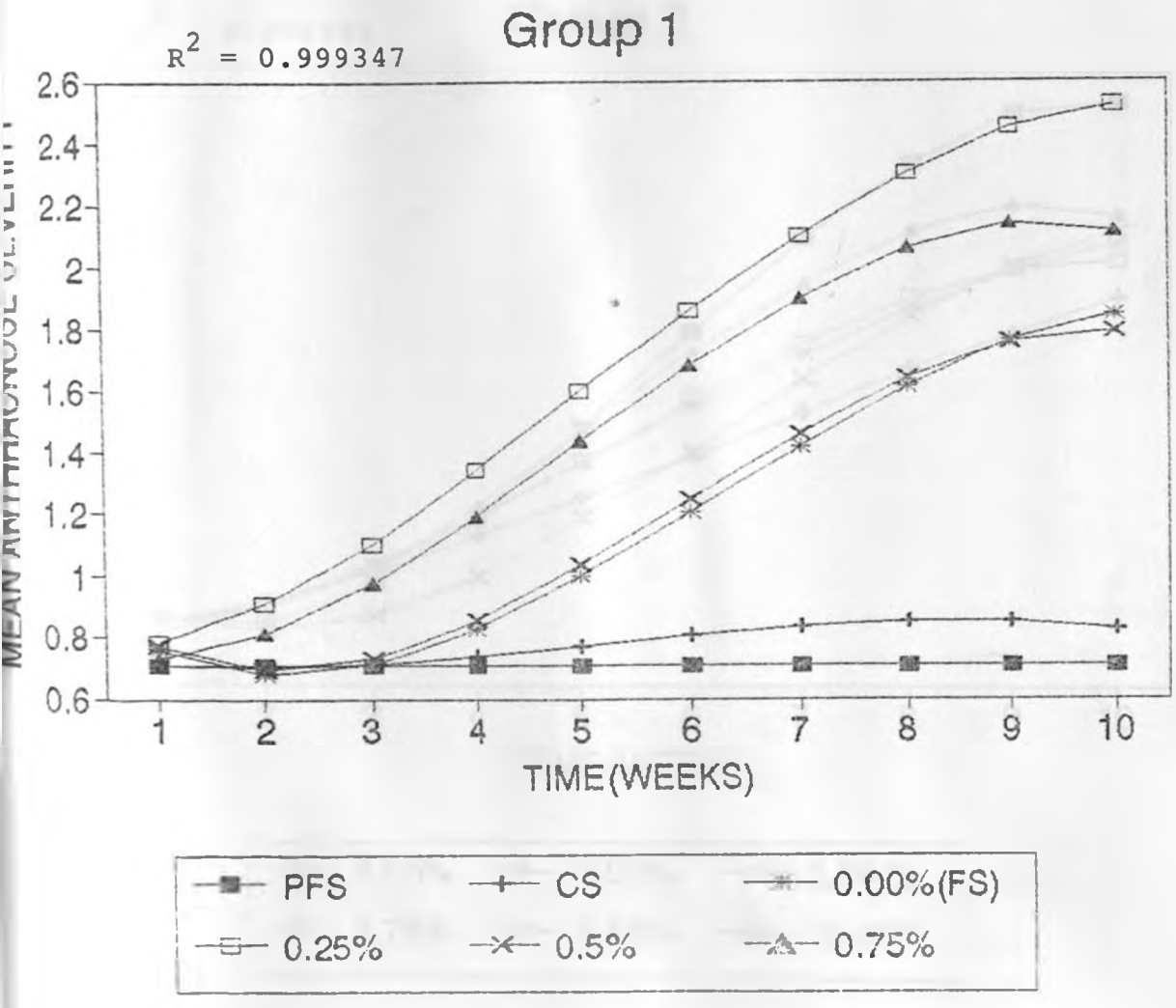

Fig. 3a. Regression curves for anthracnose severity on leaves on CV. Rosecoco-GLP-2 plants during the long rains at Kabete (Group 1).

Regression equation for the graphs below are:

1.00% = $0.786 - 0.232X + 0.137X^2 - 0.009X^3$

2.00% = $0.697 - 0.001X + 0.017X^2 - 0.001X^3$

3.00% = $0.717 - 0.051X + 0.039X^2 - 0.002X^3$

3.75% = $0.764 - 0.094X + 0.049X^2 - 0.002X^3$

5.50% = $0.662 + 0.012X + 0.013X^2 - 0.001X^3$

10.00% = $0.622 + 0.063X + 0.028X^2 - 0.002X^3$

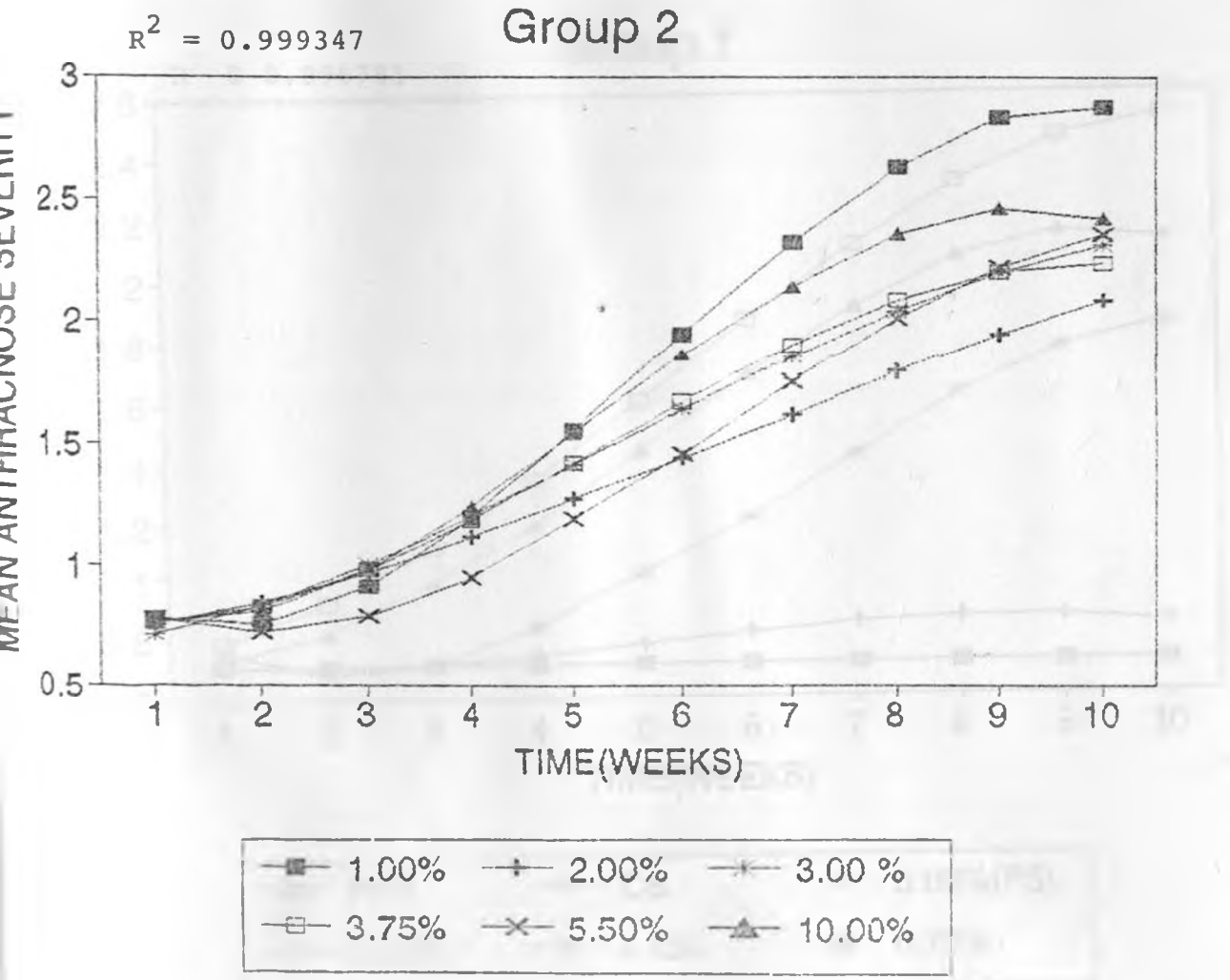

Fig. 3b. Regression curves for anthracnose severity on leaves on CV. Rosecoco-GLP-2 plants during the long rains at Kabete (Group 2).

Regression equations for the graphs below are:

PFs = 0.707

CS = $0.778 - 10.100 \times 0.033X^2 - 0.002 x^3$

Fs = $1.052 - 0.399 x + 0.112X^2 - 0.007 X^3$

0.25% = $1.284 - 0.605X + 0.164X^2 - 0.010 X^3$

0.50% = $1.110 - 0.404X + 0.113X^2 - 0.006 X^3$

0.75% = $0.596 + 0.119X + 0.042X^2 - 0.004X^3$

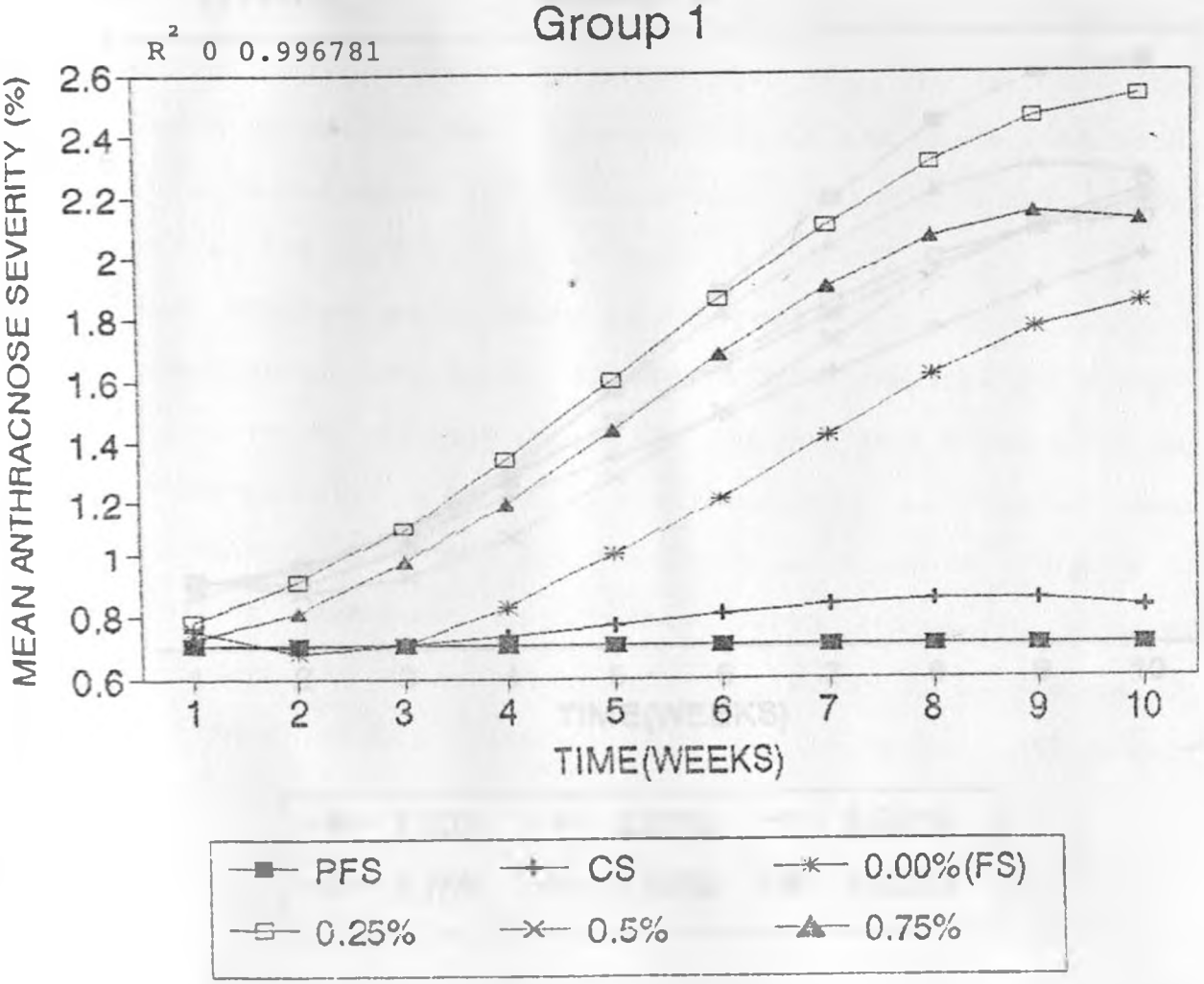

Fig. 4a. Regression curves for anthracnose severity on leaves on cv. Rosecoco-GLP-2 plants during the long rains at Tigoni (group 1).

Regression equations for the graphs below are:

$1.00\% = 1.256 - 0.507X + 0.132X^2 - 0.007X^3$

$2.00\% = 0.691 + 0.079X + 0.024X^2 - 0.002X^3$

$3.00\% = 0.580 - 0.116X + 0.032X^2 - 0.002X^3$

$3.75\% = 0.827 - 0.097X + 0.080X^2 - 0.006X^3$

$5.50\% = 1.334 - 0.624X + 0.174X^2 - 0.010X^3$

$10.00\% = 1.138 - 0.482X + 0.173X^2 - 0.011X^3$

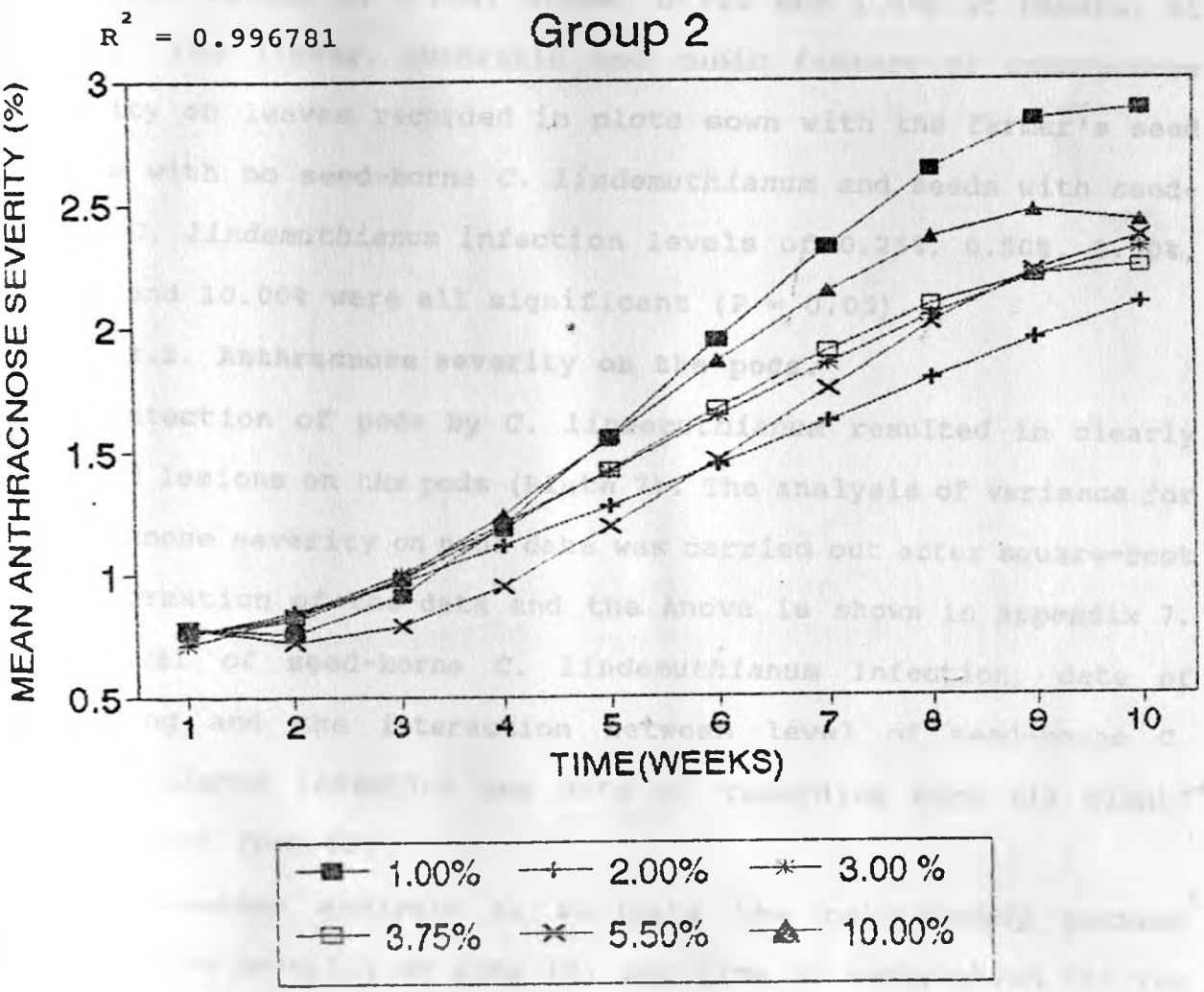

Fig. 4b. Regression curves for anthracnose severity on leaves on cv. Rosecoco-GLP-2 plants during the long rains at Tigoni (group 2).

C. lindemuthianum infection level of 3.00% was not significant (P = 0.05), while the quadratic and cubic factors were significant (P = 0.05) at Kabete. The linear, quadratic and cubic factors were all significant (P = 0.05) for anthracnose severity on leaves recorded in plots sown with the farmer's seed sample with no seed-borne *C. lindemuthianum* and seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%, 0.50%, 0.75% and 1.00% at Kabete. At Tigoni, the linear, quadratic and cubic factors of anthracnose severity on leaves recorded in plots sown with the farmer's seed sample with no seed-borne *C. lindemuthianum* and seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%, 0.50%, 1.00%, 5.50% and 10.00% were all significant (P = 0.05).

4.3.2.2.2. Anthracnose severity on the pods.

Infection of pods by *C. lindemuthianum* resulted in clearly defined lesions on the pods (Plate 7). The analysis of variance for anthracnose severity on pods data was carried out after square-root transformation of the data and the Anova is shown in appendix 7. The level of seed-borne *C. lindemuthianum* infection, date of recording and the interaction between level of seed-borne *C. lindemuthianum* infection and date of recording were all highly significant (P=0.05).

Regression analysis to estimate the relationship between anthracnose severity on pods (Y) and time of observation (X) for each treatment is shown in appendix 8a and 8b and represented graphically in figs 5(a&b) and 6(a&b) for the two sites ie.

Regression equations for the graphs are:

PFS = 1.000

CS = 1.000

FS = $0.886 + 0.171X - 0.092X^2 + 0.012X^3$

0.25% = $1.245 - 0.383X + 0.158X^2 - 0.016X^3$

0.50% = $0.895 + 0.185X - 0.102X^2 - 0.125X^3$

0.75% = $1.098 - 0.221X + 0.143X^2 - 0.125X^3$

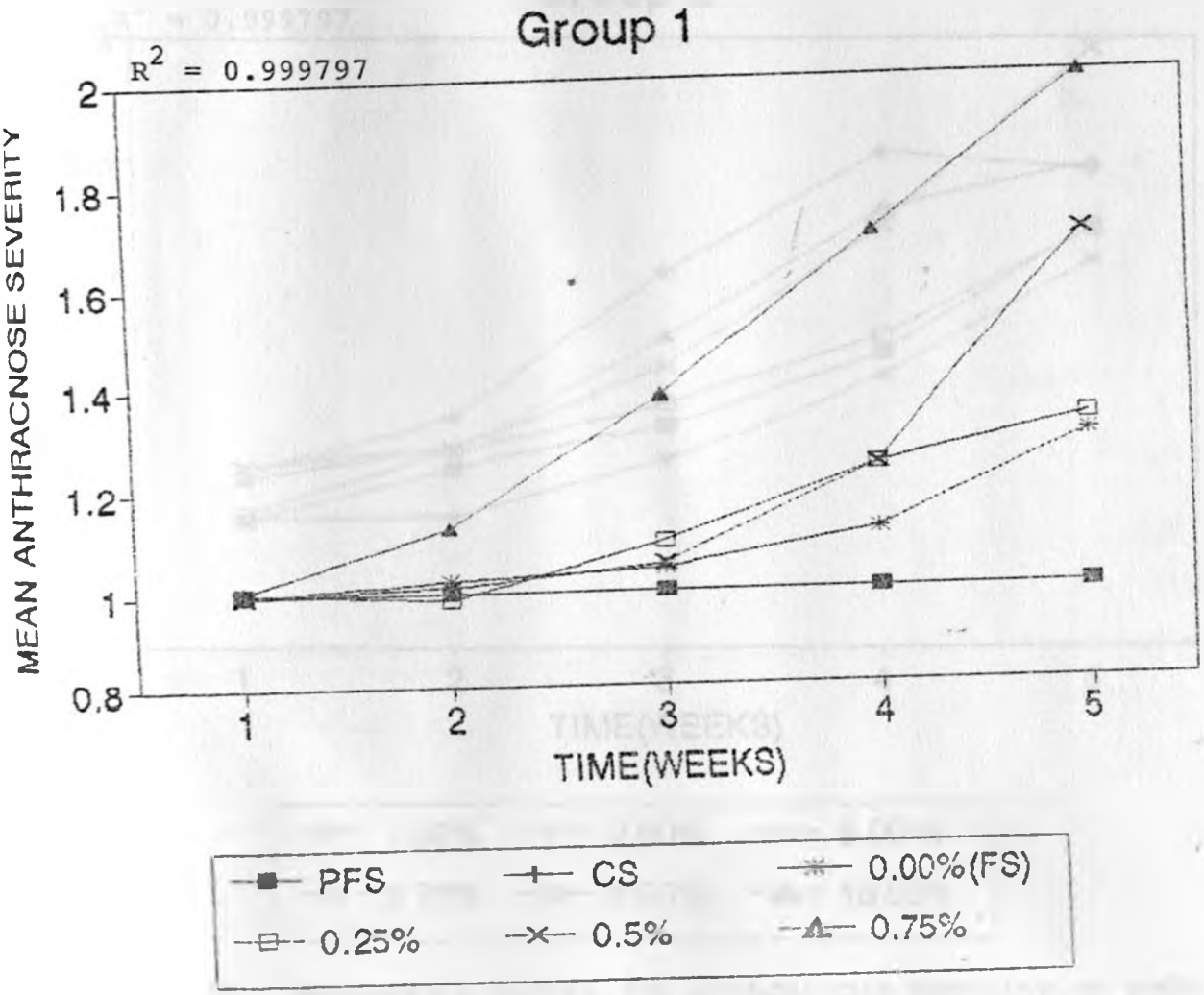

Fig 5a. Regression curves for anthracnose severity on pods on CV. Rosecoco-GLP-2 plants during the long rains at Kabete (Group 1).

Regression equations for the graphs are:

$1.00\% = 0.692 = 0.383X - 0.097X^2 + 0.016X^3$

$2.00\% = 1.668 - 1.022X + 0.604X^2 + 0.074X^3$

$3.00\% = 1.271 - 0.435X + 0.174X^2 - 0.012X^3$

$3.75\% = 0.626 + 0.481X - 0.107X^2 + 0.015X^3$

$5.50\% = 1.439 - 0.429X + 0.200X^2 + 0.012X^3$

$10.00\% = 1.735 - 1.050X + 0.529X^2 + 0.058X^3$

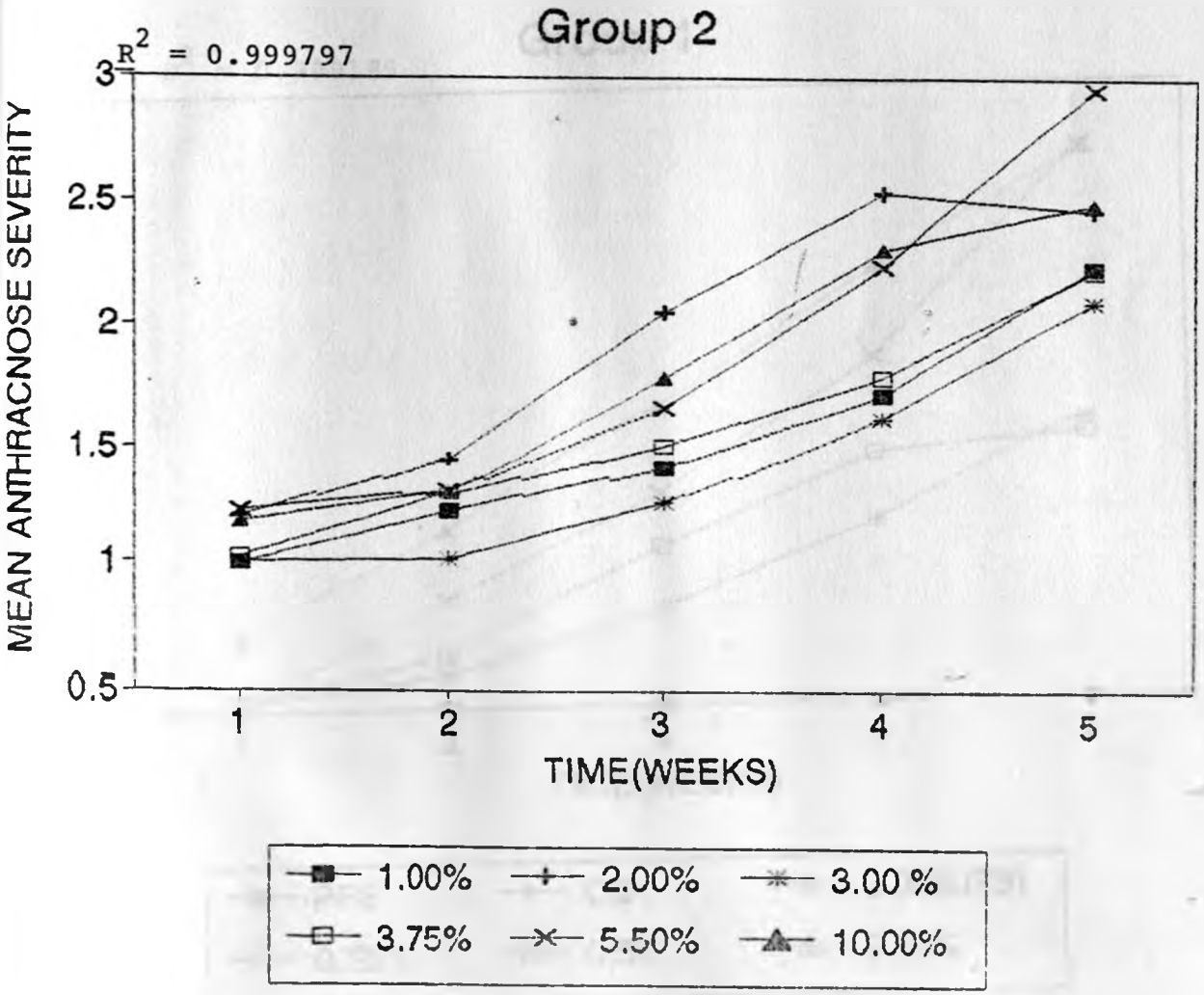

Fig. 5b. Regression curves for anthracnose severity on pods on CV. Rosecoco-GLP-2 plants during the long rains at Kabete (Group 2).

Regression equations for the graphs are:

PFS = 1.00

CS = 1.00 + 0.100X

FS = $1.017 - 0.036X + 0.026X^2 - 0.001X^3$

0.25% = $1.104 - 0.196X + 0.116X^2 - 0.014X^3$

0.50% = $0.863 - 0.174X - 0.033X^2 - 0.006X^3$

0.75% = $1.025 + 0.023X + 0.048X^2 - 0.005X^3$

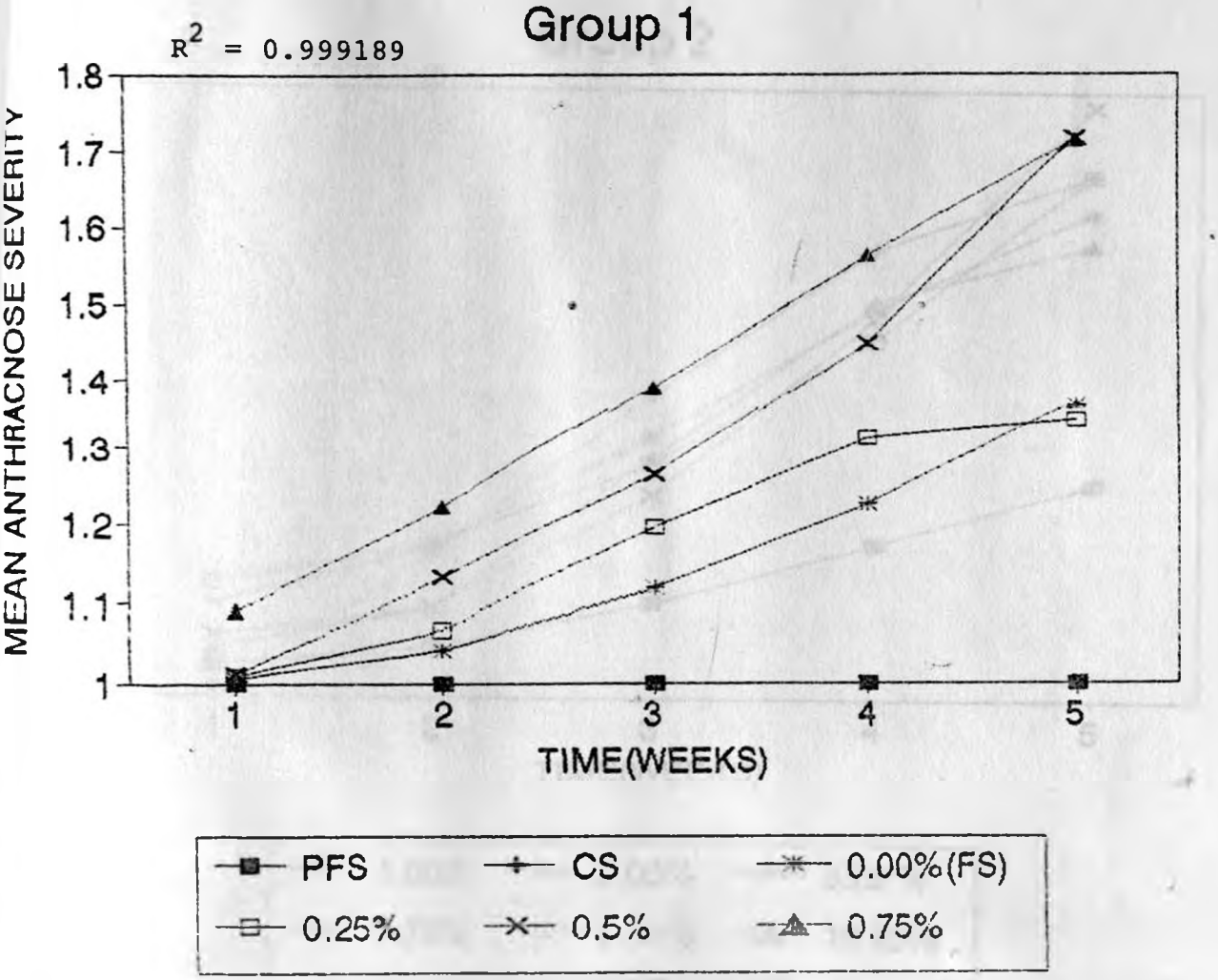

Fig. 6a: Regression curves for anthracnose severity on pods on CV. Rosecoco-GLP-2 plnts during the long rains, at Tigoni (Group 1).

Regression equations for the graphs are:-

$1.00\% = 1.181 - 0.164X + 0.092X^2 - 0.008X^3$

$2.00\% = 0.872 - 0.037X + 0.222X^2 - 0.028X^3$

$3.00\% = 1.449 - 0.355X + 0.235X^2 - 0.024X^3$

$3.75\% = 1.372 - 0.069X + 0.068X^2$

$5.50\% = 1.475 - 0.486X + 0.224X^2 - 0.014X^3$

$10.00\% = 2.735 - 1.050X + 0.529X^2 - 0.058X^3$

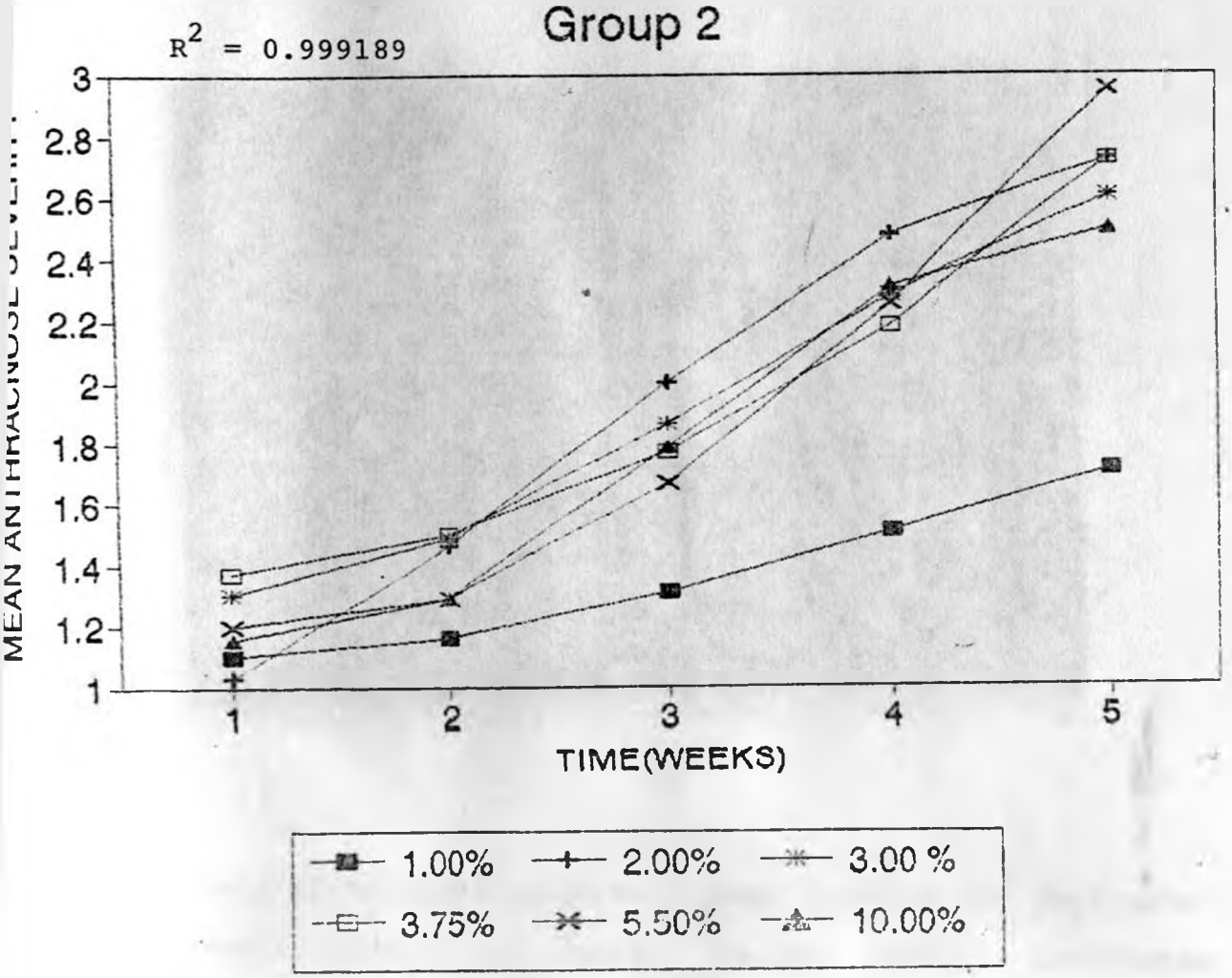

Fig. 6b. Regression curves for anthracnose severity on pods on CV. Rosecoco-GLP-2 plants during the long rains at Tigoni (Grou; 2).

Plate 7. Bean anthracnose lesions on pods (alp) on cv. Rose coco-GLP-2 plants grown from seeds, having initial seed-borne *Colletotrichum lindemuthianum* infection level of 5.50% at Kabete. note alp= anthracnose on pods

Kabete and Tigoni respectively. Regression coefficients computed for anthracnose severity on pods recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 0.50%, 0.75%, and 2.00% were all not significant (P = 0.05) at Tigoni while at Kabete, the intercept was the only factor found to be significant (P = 0.05). All the regression coefficient factors computed for anthracnose severity on pods recorded in plots sown with pathogen free, certified seeds, the farmer's seed samples with no seed-borne *C. lindemuthianum* infection and seeds with seed-borne *C. lindemuthianum* infection levels of 0.50%, 0.75% and 2.00% were found not to be significant (P = 0.05) at Tigoni. At Kabete the linear, quadratic and cubic regression coefficients computed for anthracnose severity on pods recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 2.00% and 10.00% were all significant (P = 0.05). While at Tigoni, the linear, quadratic and cubic factors computed for anthracnose severity on pods recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 2.00% were not significant (P=0.05). However both the quadratic and cubic regression factors computed for anthracnose severity on pods recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 10.00% were found to be significant (P = 0.05) at Tigoni.

4.3.3. Yield and yield components.

4.3.3.1. Yield per hectare.

The anova for yield per hectare for kabete and Tigoni is shown in appendix 9. It was observed that yields realised at Kabete were

about 4 times more than the yields realised at Tigoni.

At both Kabete and Tigoni, yields obtained in plots sown with pathogen free seeds and certified seeds were not significantly (p=0.05) from each other, but were significantly (p=0.05) higher than yields obtained in plots sown with seeds collected from the farmers (Table 6a and 6b)

At Tigoni, it was observed that yields obtained from plots sown with farmers' seed samples with different levels of seed-borne *C. lindemuthianum* infection were not significantly different (P = 0.05) amongst each other. However these yields were significantly (P=0.05) lower than yields obtained from plots sown with pathogen free and certified seeds (Table 6a).

4.3.3.2. Number of pods per plant.

The Anova for the number of pods per plant is shown in appendix 10.

At both locations, the number of pods per plant recorded in plots sown with certified and pathogen free seeds did not differ significantly (P = 0.05) amongst each other, but were significantly (P=0.05) higher than the number of pods per plant recorded in plots sown with farmers seeds, with varying levels of seed-borne *C. lindemuthianum* infection. However, the number of pods per plant recorded in plots sown with farmer's seed sample with no seed-borne *C. lindemuthianum* infection did not differ significantly (P=0.05) from the number of pods per plant recorded in plots sown with pathogen seeds and certified seeds (Table 6a and 6b). Among the farmers' seed samples the number of pods per plant recorded in

Table 6a. Yield/ha, number of pods/plant, number of seeds/pod and 100-seed weight of cv. rosecoco-GLP-2 plants attained at Kabete during the long rains (April-July 1992).

Level of seed infection(based on rolled paper towel test) (%)	Yield/ha (Kg/ha)	No. of pods/plant	No. of seeds/plant	100-seed weight
1. 0.00(pfs)	3555.3^{e}	11^{c}	4^{a}	60.3
2. 0.00(cs)	3149.2^{e}	11^{c}	4^{a}	57.8
3. 0.00(fs)	2757.1^{d}	11^{c}	4^{a}	55.4^{c}
4. 0.25	2904.2^{d}	9^{a}	4^{a}	55.0^{c}
5. 0.50	2445.5	8^{b}	3^{a}	54.8^{c}
6. 0.75	2166.6^{c}	8^{b}	3^{a}	48.9^{a}
7. 1.00	2190.8^{c}	7^{a}	3^{a}	51.0^{ab}
8. 2.00	2085.2^{bc}	6^{a}	3^{a}	50.8^{ab}
9. 3.00	2108.7^{bc}	6^{a}	3^{a}	51.1^{ab}
10. 3.75	1918.2^{ab}	6^{a}	3^{a}	52.2^{b}
11. 5.50	1713.6^{a}	7^{a}	3^{a}	51.0^{ab}
12. 10.00	1839.9^{a}	7^{a}	3^{a}	50.4^{ab}

note: pfs = pathogen free seeds, cs = certified seeds, fs = farmer's seeds

Means followed by the same letter are not significantly different from each other at 95% level of significance.

Table 6b. Yield/ha, number of pods/plant, number of seeds/pod and 100-seed weight of cv. rosecoco-GLP-2 plants attained at Tigoni during the long rains (April-July 1992).

Level of seed infection(based on rolled paper towel test) (%)	Yield/ha (Kg/ha)	No. of pods/plant	No. of seeds/plant	100-seed weight
1. 0.00(pfs)	938.3^{b}	5^{c}	3^{b}	59.4^{g}
2. 0.00(cs)	926.8^{b}	5^{c}	3^{b}	58.6^{g}
3. 0.00(fs)	512.7^{a}	3^{b}	2^{a}	55.4^{f}
4. 0.25	374.7^{a}	3^{a}	2^{a}	55.1^{ef}
5. 0.50	520.0^{a}	3^{b}	2^{a}	51.8^{de}
6. 0.75	533.3^{a}	3^{b}	2^{a}	52.4^{de}
7. 1.00	498.4^{a}	2^{a}	2^{a}	51.5^{cd}
8. 2.00	485.3^{a}	2^{a}	2^{a}	52.3^{def}
9. 3.00	451.7^{a}	2^{a}	2^{a}	48.4^{bc}
10. 3.75	500.4^{a}	2^{a}	2^{a}	44.8^{a}
11. 5.50	443.9^{a}	2^{a}	2^{a}	46.8^{ab}
12. 10.00	416.0^{a}	2^{a}	2^{a}	45.3^{ab}

note: pfs = pathogen free seeds, cs = certified seeds, fs = farmer's seeds

Means followed by the same letter are not significantly different from each other at 95% level of significance.

plots sown with seeds with seed-borne *C.lindemuthianum* infection levels of 0.25%, 0.50%, and 0.75% were not significantly different (P = 0.05) amongst each other, but were significantly higher (P=0.05) than the number of pods/plant recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 1.00%-10.00%.

4.3.3.3. Number of seeds per pod:

The ANOVA for number of seeds per pod for the two locations is shown in appendix 11.

The number of seeds per pod were affected by the level of seed-borne *C. lindemuthianum* infection only at Tigoni (Table 6b). At Kabete, the number of seeds per pod recorded for all the treatments did not differ significantly (P=0.05) (Table 6a).

At Tigoni, the number of seeds per pod recorded in plots sown with pathogen free and certified seeds did not differ significantly (P=0.05) but were significantly (p=0.05 & p=0.01) higher than the number of seeds per pod recorded in plots sown with seeds obtained from the farmers. The number of seeds per pod recorded in plots sown with the farmer's seed sample with no seed-borne *C. lindemuthianum* infection and seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%-10.00% did not differ significantly (P=0.05) amongst each other.

4.3.3.4. 100 seed weight.

The ANOVA for 100 seed weight for Kabete and Tigoni is shown in the appendix 12.

100-seed weight recorded from plots sown with pathogen free and certified seeds at Tigoni did not differ from each other significantly (P = 0.05) (Table 6b) but were found to differ

significantly (P=0.05) at Kabete (Table 6a). 100-seed weight recorded from plots sown with farmers' seeds with seed-borne *C. lindemuthianum* infection levels of 0.25% and 0.50% and the farmer's seed sample with no seed-borne *C. lindemuthianum* infection were not significantly different (P=0.05) amongst each other at Kabete. At Tigoni, plants from plots sown with the farmer's seed sample with no *C. lindemuthianum* infection and seeds with seed-borne *C. lindemuthianum* infection levels of 0.25% and 2.00% produced 100-seed weight which did not differ significantly amongst each other (P = 0.05).

4.3.3.5. Yield Reduction.

The ANOVA for yield reduction for Kabete and Tigoni is shown in the appendix 13.

At both Kabete and Tigoni sites reduction in yield recorded in plots sown with seeds collected from farmers were significantly high when compared to the yields recorded in plots sown with pathogen free seeds and certified seeds (Table 7). Yield reductions recorded in plots sown with the farmer's seed sample with no seed-borne *C. lindemuthianum* infection and seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%, 0.50%, 1.00% 2.00% 3.00%, 3.75% 5.50% and 10.00% did not significantly differ (P=0.05) amongst each other.

At Tigoni yield reductions recorded in plots sown with farmers' seeds increased with increase in level of seed-borne *C. lindemuthianum* infection. However the reduction was not significant (p=0.05) (Table 7).

Table 7. Yield reduction recorded in plots sown with seeds with varying levels of C. lindemuthianum at Kabete and Tigoni during the long rains (April-August 1992).

Level of seed infection (based on rolled paper towel test)	Kabete Kg/ha	Percent yield reduction (%)	Tigoni Kg/ha	Percent yield reduction (%)
1. 0.00% (pfs)	0.00^{a}	0.00	0.00^{a}	0.00
2. 0.00% (cs)	47.67^{a}	1.40	11.45^{a}	1.22
3. 0.00% (fs)	598.25^{bc}	19.83	425.51^{b}	45.36
4. 0.25%	451.17^{b}	13.45	363.62^{b}	38.75
5. 0.50%	909.92^{cd}	27.12	418.30^{b}	44.58
6. 0.75%	1188.75^{de}	35.43	405.02^{b}	43.16
7. 1.00%	1164.50^{de}	34.71	439.87^{b}	46.88
8. 2.00%	1269.83^{def}	37.84	452.99^{b}	48.28
9. 3.00%	1241.67^{def}	37.01	486.59^{b}	51.86
10. 3.75%	1437.17^{ef}	42.83	437.86^{b}	46.66
11. 5.50%	1641.75^{f}	48.93	494.42^{b}	52.69
12. 10.00%	1515.42^{ef}	45.16	522.24^{b}	55.66

note. pfs = Pathogen free seeds, cs = Certified seeds, fs = Farmer's seeds

Means followed by the same letter are not significantly different from each other at 95% level of significance

4.3.4. Area Under Disease Progress Curves (AUDPC).

4.3.4.1. AUDPC-Anthracnose incidence (AUDPC-AI).

The ANOVA for AUDPC-AI for Kabete and Tigoni is shown in the appendix 14.

AUDPC-AI recorded in plots sown with pathogen free seeds and certified seeds were not significantly different (p=0.05) from AUDPC-AI recorded in plots sown with seeds with seed-borne infection levels of 0.5%, 0.75%, and 1.00% but were significantly lower than AUDPC-AI recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 0.25% at Kabete (Table 8). At Tigoni AUDPC-AI attained in plots sown with seed-borne *C. lindemuthianum* infection level of 0.75% was not significantly different from AUDPC-AI recorded in plots sown with pathogen free seeds, certified seeds, the farmer's seed sample with no anthracnose infection and seed samples with seed-borne *C. lindemuthianum* infection levels of 0.25%, 0.50%, 1.00%, 2.00% and 3.00%.

AUDPC-AI recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 3.75% was not significantly different from AUDPC-AI recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%, 2.00%, 3.00%, 5.50% and 10.00% at Kabete and 5.50% and 10.00% at Tigoni (Table 8).

4.3.4.2. AUDPC - Anthracnose Severity on Leaves (AUDPC-ASL)

The ANOVA for AUDPC-ASL for Kabete and Tigoni is shown in the appendix 15. AUDPC-ASL recorded in plots sown with seeds with seed

Table 8. Area Under Disease Progress Curve -Anthracnose incidence (AUDPC-AI) and Anthracnose Severity on leaves (AUDPC-ASL) recorded in plots sown with seeds with varying levels of C. lindemuthianum infection levels at Kabete and Tigoni during the long rains (April-July 1992)

Level of seed infection (based on the rolled paper towel test) (%)	Kabete			Tigoni		
	AUDPC-AI	AUDPC-ASL	AUDPC-ASP	AUDPC-AI	AUDPC-ASL	AUDPC-ASP
1. 0.00(pfs)	0.0^{a}	0.0^{a}	4.5^{a}	0.0^{a}	0.0^{a}	4.5^{a}
2. 0.00(cs)	0.0^{a}	0.0^{a}	4.5^{a}	0.0^{a}	2.74^{ab}	4.5^{a}
3. 0.00(fs)	19.17^{ab}	11.55^{ab}	4.88^{ab}	22.17^{ab}	9.02^{abc}	5.07^{a}
4. 0.25	70.00^{bcd}	37.58^{c}	4.99^{ab}	83.00^{cd}	17.32^{bcd}	5.26
5. 0.50	47.83^{abc}	7.57^{ab}	4.99^{ab}	52.00^{bc}	12.42^{abcd}	5.72^{a}
6. 0.75	51.83^{abc}	12.24^{ab}	6.21^{cd}	57.67^{bc}	27.03^{d}	6.11^{ab}
7. 1.00	56.17^{abc}	46.49^{c}	6.44^{d}	73.30^{cd}	20.04^{cd}	5.93^{ab}
8. 2.00	83.00^{cd}	10.49^{ab}	8.44^{e}	103.67^{cd}	20.90^{cd}	8.31^{c}
9. 3.00	63.50^{bcd}	12.89^{ab}	5.92^{bcd}	78.17^{cd}	26.84^{d}	8.43^{c}
10. 3.75	103.33^{cde}	14.95^{ab}	6.70^{d}	128.50^{ef}	23.86^{cd}	8.10^{c}
11. 5.50	120.33^{de}	12.09^{ab}	7.88^{e}	131.17^{ef}	22.01^{cd}	7.69^{bc}
12. 10.00	152.00^{e}	19.86^{b}	7.89^{e}	149.33^{f}	29.88^{d}	9.04^{c}

Note: pfs = pathogen free seeds, cs = certified seeds, fs = farmer's seeds

Means followed by the same letter are not significantly different from each other at 95% level of significance.

-borne *C. lindemuthianum* infection level of 1.00% was the highest at Kabete but was not significantly different (p=0.05) from AUDPC-ASL recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 0.25%. At Tigoni the highest AUDPC-ASL was attained in plots sown with seeds with seed-borne *C. lindemuthianum* 10.00%, but was not significantly (p=0.05) different from AUDPC-ASL recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%-5.50% (Table 8).

At both Kabete and Tigoni there was no significant (p=0.05) increase in AUDPC-ASL recorded in plots sown with pathogen free seeds, certified seeds and the farmer's seed sample with no seed-borne anthracnose infection. The same trend was observed in AUDPC-ASL recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 0.25% and 1.00% at Kabete and 0.25%, 0.50% and 1.00%-5.50% infection levels at Tigoni (Table 8).

4.3.4.3. AUDPC-Anthracnose severity on pods (AUDPC-ASP).

The Anova for AUDPC-ASP for Kabete and Tigoni is shown in appendix 16.

The highest AUDPC-ASP were recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 2.00% and 10.00% at Kabete and Tigoni respectively.

At Kabete there was no significant (p=0.05) increase in AUDPC-ASP recorded in plots sown with pathogen free seeds, certified seeds, the farmer's seed sample with no seed-borne *C. lindemuthianum* and with seed-borne *C. lindemuthianum* infection

levels of 0.25% and 0.50%. At Tigoni, AUDPC-ASP did not increase significantly in plots sown with pathogen free seeds, certified seeds, the farmer's seed sample with no seed-borne *C. lindemuthianum* infection and seeds with seed-borne infection levels of 0.50%, 0.75% and 10.00% (Table 8).

4.3.5. Correlation analysis.

The correlation matrix analysis for Yield and Yield components, level of seed-borne *C. lindemuthianum* infection, AUDPC-Anthracnose incidence (AUDPC-AI), AUDPC-Anthracnose severity on leaves (AUDPC-ASL), AUDPC-Anthracnose severity on pods (AUDPC-ASP) and reduction in yield for Kabete and Tigoni are shown in tables 9a and 9b respectively..

There was a significant correlation (P=0.01) between yield and its components i.e. number of pods per plant, number of seeds per plant and 100 seed weight at both locations. The same correlation was observed among the yield components at both locations (P = 0.01) (Table 9a and 9b).

The correlation between yield per hectare and AUDPC-ASL was only significant (p=0.01) at Tigoni . Also no significant (p=0.01) correlations were established between AUDPC-ASL and number of pods/plant, number of seeds/pod and 100-seed weight at Kabete whereas the correlations were significant (p=0.01)at Tigoni.

At both Kabete and Tigoni sites the correlations between AUDPC-AI and yield/hectare, number of pods/plant, number of seeds/pod and 100-seed weight were all significant (p=0.01). Also significant (p=0.01) correlations were established between level of

Table 9a. Correlation analysis matrix for Yield and Yield components, AUDPC-ASL, AUDPC-AI, AUDPC-ASP, level of seed-borne Colletotrichum lindemuthianum, and Yield Reduction at Kabete.

	Yield	No. of pods	No. of seeds	100-seed weight	AUDPC -ASL infection	Level of Seed-borne C. lindemuthianum	AUDPC -AI	AUDPC -ASP
Yield								
No. of pods	0.88**							
No. of seeds	0.60**	0.56**						
100-seed weight	0.82**	0.73**	0.44*					
AUDPC-ASL	-0.23	-0.30	-0.16	-0.37				
Level of Seed-borne C. lindemuthianum infection	-0.68**	-0.64**	-0.33	-0.48*	0.07			
AUDPC-AI	-0.74**	-0.73**	-0.39*	-0.60**	0.32	0.81**		
AUDPC-ASP	-0.82**	-0.75**	-0.42*	-0.70**	0.13	0.68**	0.76**	
Yield reduction	-0.97**	-0.85**	-0.56**	-0.83**	0.23	0.68**	0.76**	0.82**

Table 9b. Correlation analysis matrix for Yield and Yield components, AUDPC-ASL, AUDPC-AI, AUDPC-ASP, level of seed-borne Colletotrichum lindemuthianum, and Yield Reduction at Tigoni.

	Yield	No. of pods	No. of seeds	100-seed weight	AUDPC -ASL	Level of Seed-borne C. lindemuthianum infection	AUDPC -AI	AUDPC -ASP
Yield								
No. of pods	0.79**							
No. of seeds	0.66**	0.64**						
100-seed weight	0.66**	0.67**	0.47*					
AUDPC-ASL	-0.62**	-0.70**	-0.58**	-0.67**				
Level of Seed-borne C. lindemuthianum infection	-0.45*	-0.55**	-0.26	-0.74**	0.54*			
AUDPC-AI	-0.65**	-0.78**	-0.54*	-0.82**	0.65**	0.78**		
AUDPC-ASP	-0.57**	-0.66**	-0.26	-0.77**	0.53**	0.75**	0.75**	
Yield reduction	-0.72**	-0.59**	-0.32	-0.55**	0.48*	0.43*	0.57**	0.66**

seed-borne *C. lindemuthianum* infection in seeds and yield/hectare, number of pods/plant and 100-seed weight at both Kabete and Tigoni. However no correlation was established between level of seed-borne *C. lindemuthianum* infection in seeds and number of seeds/pod at both sites.

The correlation between level of seed-borne *C. lindemuthianum* infection in seeds and AUDPC-ASL was significant (p=0.01) only at Tigoni. Also the correlation between AUDPC-AI was significant (p=0.01) at Kabete only.

The correlation between level of seed-borne *C. lindemuthianum* infection in seeds and reduction in yield/hectare were significant (p=0.01) at both Kabete and Tigoni.

4.4.0. Artificially inoculated plants.

4.4.1. Anthracnose incidence.

The Anova for anthracnose incidence on cv. Rose coco-GLP-2 plants during the short and long rains at Kabete is shown in appendix 17. The time of inoculation, date of recording and the interaction between the time of inoculation and date of recording were all highly significant (P=0.05). The climatic conditions which prevailed during the short and long rains cropping seasons is shown in appendix 2a and 18.

Regression analysis to estimate the relationship between anthracnose severity on leaves (Y) and time of observation (X) for each treatment is shown in appendix 19a and 19b and represented graphically in figs 7 (a&b). Regression analysis for anthracnose

Regression equations of the graphs are:-

Control = 0.000

2 weeks = $-75.633 + 70.480X - 8.993X^2 + 0.369X^3$

4 weeks = $30.583 - 41.054X + 12.718X^2 - 0.798X^3$

6 weeks = $10.554 - 7.801X + 0.674X^2 - 0.087X^3$

PF stage = $-0.058 + 1.397X - 0.880X^2 + 0.112X^3$

Maturity = 0.00

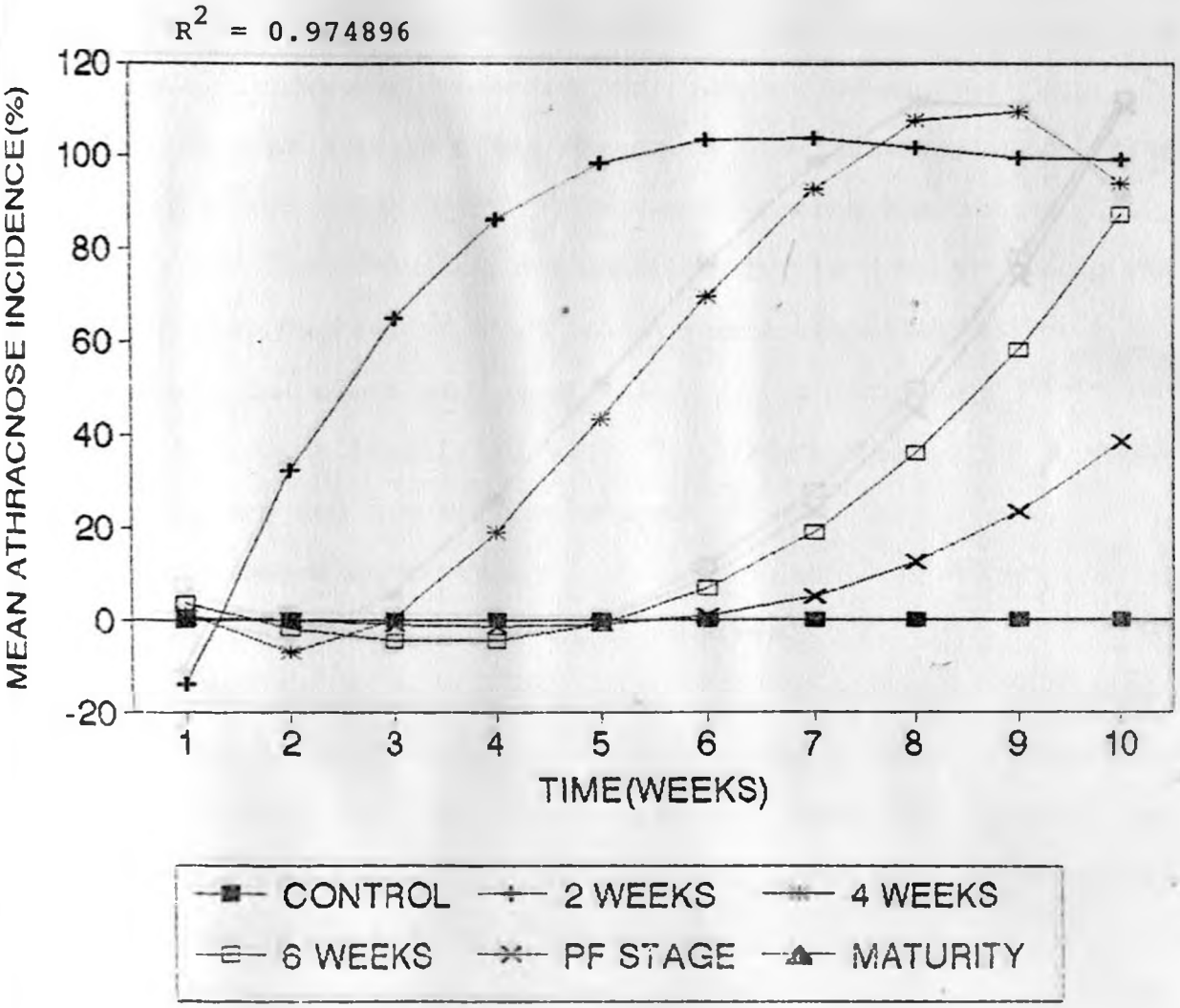

Fig. 7a. Regression curves for anthracnose incidence on CV. Rosecoco-GLP-2 plants inoculated with Colletotrichum lindemuthianum during the short rains at Kabete.

Regression equations for the graphs are:

Control = 0.00

2 weeks = $-73.575 + 68.816X - 8.705X^2 + 0.355X^3$

4 weeks = $23.583 - 35.971X + 12.235X^2 - 0.796X^3$

6 weeks = $17.829 - 14.465X + 1.956X^2 - 0.044X^3$

PF stage = $11.446 - 8.057X + 0.441X^2 + 0.136X^3$

Maturity = 0.00

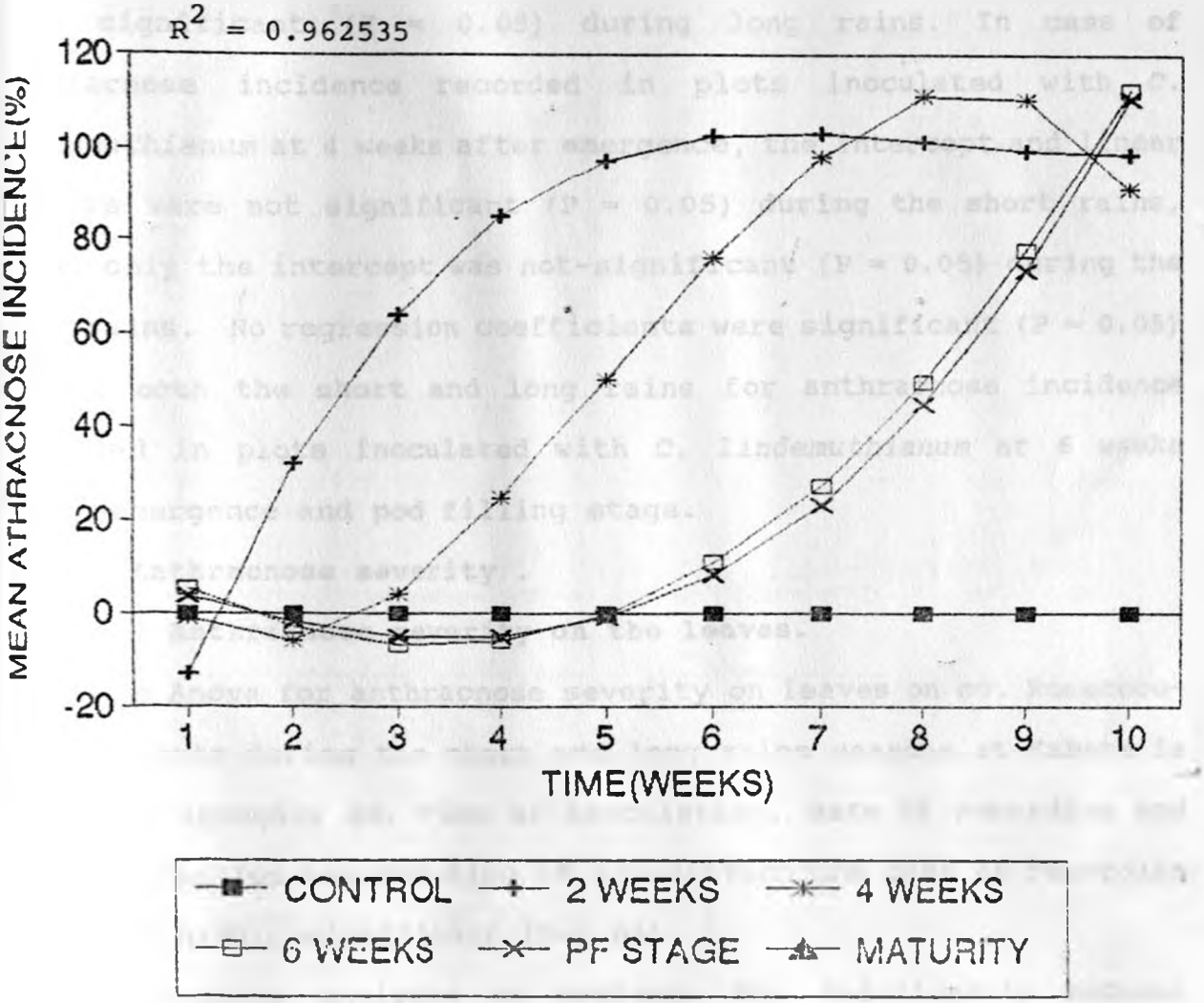

Fig 7b. Regression curves for anthracnose incidence on CV. Rose-coco-GLP-2 plants inoculated with Colletotrichum lindemuthianum at various stages during the long rains at Kabete.

incidence recorded in plots sprayed with sterile distilled water and inoculated with *C. lindemuthianum* at maturity represented a straight line during both the short and long rains seasons. Only the cubic factor was not significant (P = 0.05) for anthracnose incidence recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence during the short rains, but all the factors were significant (P = 0.05) during long rains. In case of anthracnose incidence recorded in plots inoculated with *C. lindemuthianum* at 4 weeks after emergence, the intercept and linear factors were not significant (P = 0.05) during the short rains, while only the intercept was not-significant (P = 0.05) during the long rains. No regression coefficients were significant (P = 0.05) during both the short and long rains for anthracnose incidence recorded in plots inoculated with *C. lindemuthianum* at 6 weeks after emergence and pod filling stage.

4.4.2. Anthracnose severity .

4.4.2.1. Anthracnose severity on the leaves.

The Anova for anthracnose severity on leaves on cv. Rosecoco-GLP-2 plants during the short and long rains seasons at Kabete is shown in appendix 20. Time of inoculation, date of recording and the interaction between time of inoculation and date of recording were all highly significant (P=0.05).

Regression analysis to estimate the relationship between anthracnose severity on leaves (Y) and time of observation (X) for each treatment is shown in appendix 21a and 21b and represented graphically in figs 8 (a&b). Regressions computed for anthracnose

Regression equations for the graphs are

Control = 0.00

2 weeks = $-17.826 + 14.402X - 0.954X^2 - 0.007X^3$

4 weeks = $8.213 - 8.390X + 1.943X^2 - 0.095X^3$

6 weeks = $-0.370 + 0.614X - 0.246X^2 + 0.026X^3$

PF stage = $-1.194 + 1.343X - 0.379X^2 + 0.030X^3$

Maturity = 0

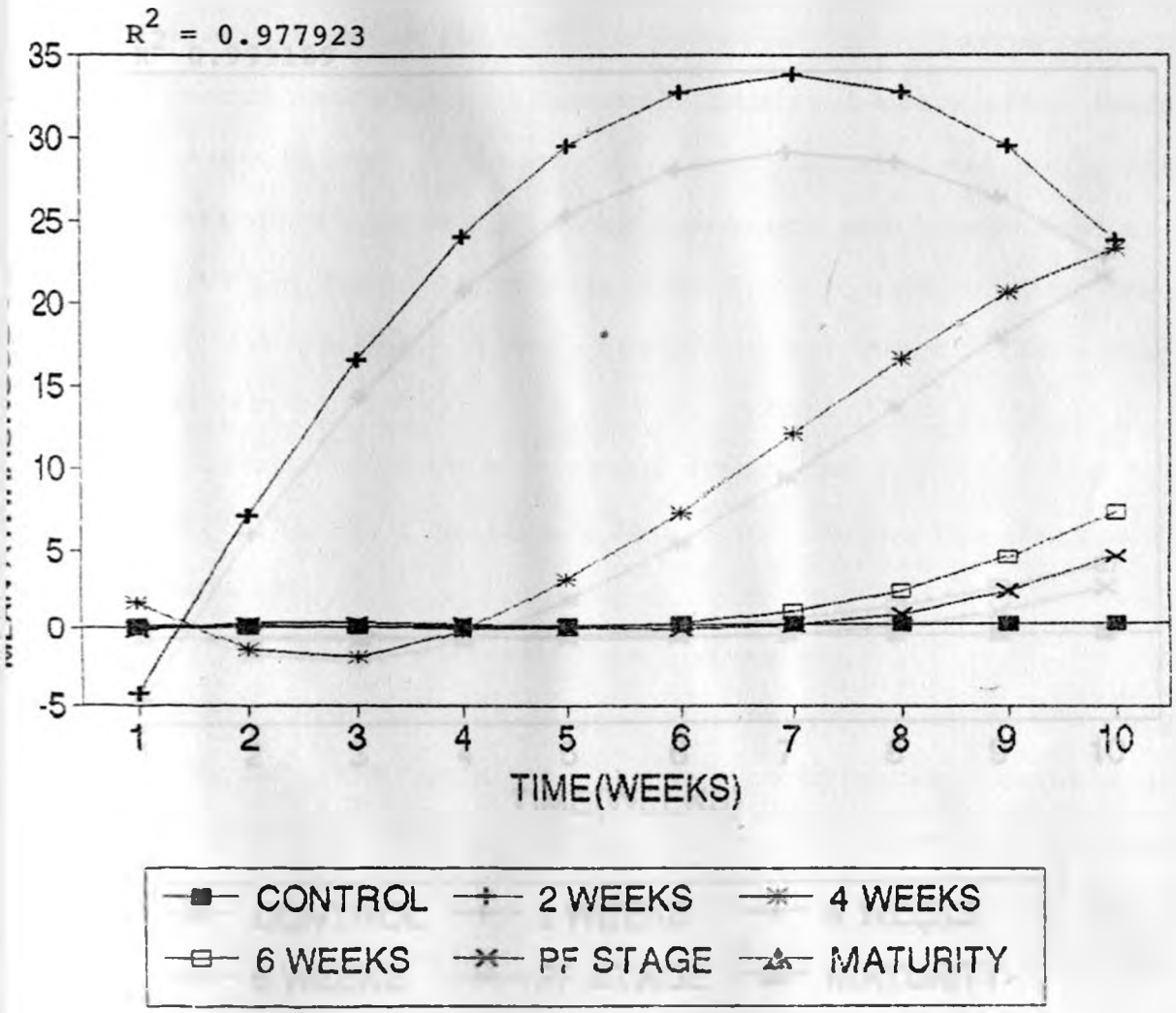

Fig. 8a. Regression curves for anthracnose severity on lines on Cv. Rosecoco-GLP-2 plants inoculated with Colletotrichum lindemuthianum at various stages during the short rains at Kabete.

Regression equations for the graphs were:

Control = 0

2 weeks = $-18.803 + 23.643X - 1.894X^2 + 0.022X^3$

4 weeks = $10.179 - 10.222X + 2.279X^2 - 0.098X^3$

6 weeks = $0.336 - 0.186X - 0.033X^2 + 0.012X^3$

PF stage = $-1.011 + 1.191X - 0.355X^2 + 0.029X^3$

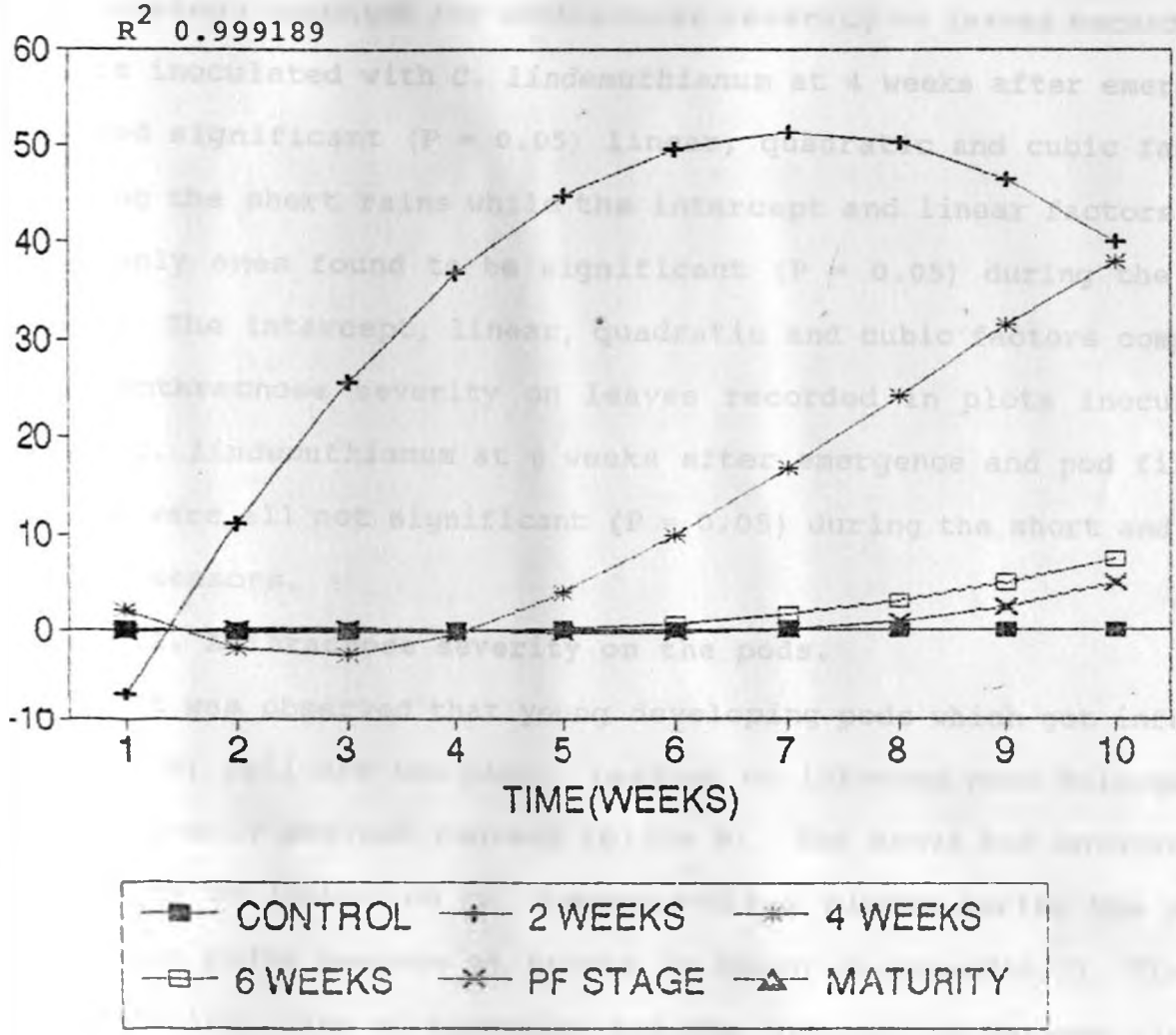

Fig. 8b. Regression curves for anthracnose severity on leaves on CV. Rosecoco-GLP-2 plants inoculated with Colletotrichum lindemuthianum at various stages during the long rains at Kabete.

severity on leaves recorded in plots sprayed with sterile distilled water (control) and inoculated with *C. lindemuthianum* at maturity represented a straight line. The regression computed for anthracnose severity on leaves recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence showed significant (P=0.05) intercept and linear factors during both seasons. The regressions computed for anthracnose severity on leaves recorded in plots inoculated with *C. lindemuthianum* at 4 weeks after emergence showed significant (P = 0.05) linear, quadratic and cubic factors during the short rains while the intercept and linear factors were the only ones found to be significant (P = 0.05) during the long rains. The intercept, linear, quadratic and cubic factors computed for anthracnose severity on leaves recorded in plots inoculated with *C. lindemuthianum* at 6 weeks after emergence and pod filling stage were all not significant (P = 0.05) during the short and long rains seasons.

4.4.2.2. Anthracnose severity on the pods.

It was observed that young developing pods which got infected (plate 8) fell off the plant. Lesions on infected pods enlarged to give clearly defined cankers (plate 9). The Anova for anthracnose severity on leaves on cv. Rosecoco-GLP-2 plants during the short and long rains seasons at Kabete is shown in appendix 22. Time of inoculation, date of recording and the interaction between time of inoculation and date of recording were all highly significant (P=0.05).

Regression analysis to estimate the relationship between

Plate 8. Anthracnose infection (a) on a young developing pod of cv. Rose coco-GLP-2 plant inoculated with *C. lindemuthianum* at pod filling stage at Kabete.

note a= anthracnose lesions on a developing pod.

Plate 9. Anthracnose infection (a1) on an expanding pod of cv. Rose coco-GLP-2 plant inoculated with *C. lindemuthianum* at 4 weeks at Kabete.

Note a1= anthracnose lesions on an expanding pod.

anthracnose severity on pods (Y) and time of observation (X) for each treatment is shown in appendix 23a and 23b and represented graphically in figs 9 (a&b). No regression factor for anthracnose severity on pods recorded in plots sprayed with sterile distilled water, and inoculated with *C. lindemuthainum* at 2, 4 and 6 weeks after emergence, pod filling stage and maturity were significant (p=0.05) during the short rains. The intercept, linear, quadratic and cubic factors for anthracnose severity recorded in plots inoculated with *C. lindemuthianum* at 6 weeks after emergence and the intercept, quadratic and cubic factors for anthracnose severity recorded in plots inoculated with *C. lindemuthianum* at pod filling stage were the only once which were significant (p=0.05) during the long rains.

4.4.3. Yield and Yield components.

4.4.3.1. Yield per hectare.

The ANOVA for yield per hectare for the short and long rain at Kabete is shown in the appendix 24.

In both seasons, yields realised in plots sprayed with sterile distilled water and inoculated with *C. lindemuthianum* at maturity were not significantly different (P=0.05) from each other. However these yields were significantly (p=0.05) higher than yields realized in plots inoculated with *C. lindemuthianum* at 2, 4, and 6 weeks after emergence and pod filling stage in both seasons (Table 10). Plots Inoculated 4 and 6 weeks after emergence and pod filling stage recorded yields which did not differ significantly (P=0.05) from each other. The least yields were attained in plots

Regression equations for the graphs were:

Control = 1.000

2 weeks = $0.418 + 0.732X + 0.020X^2 - 0.014X^3$

4 weeks = $0.756 + 0.226X + 0.045X^2 - 0.007X^3$

6 weeks = $1.138 - 0.250X + 0.123X^2 - 0.014X^3$

PF stage = $1.630 - 1.294X + 0.707X^2 - 0.088X^3$

Maturity = 1.000

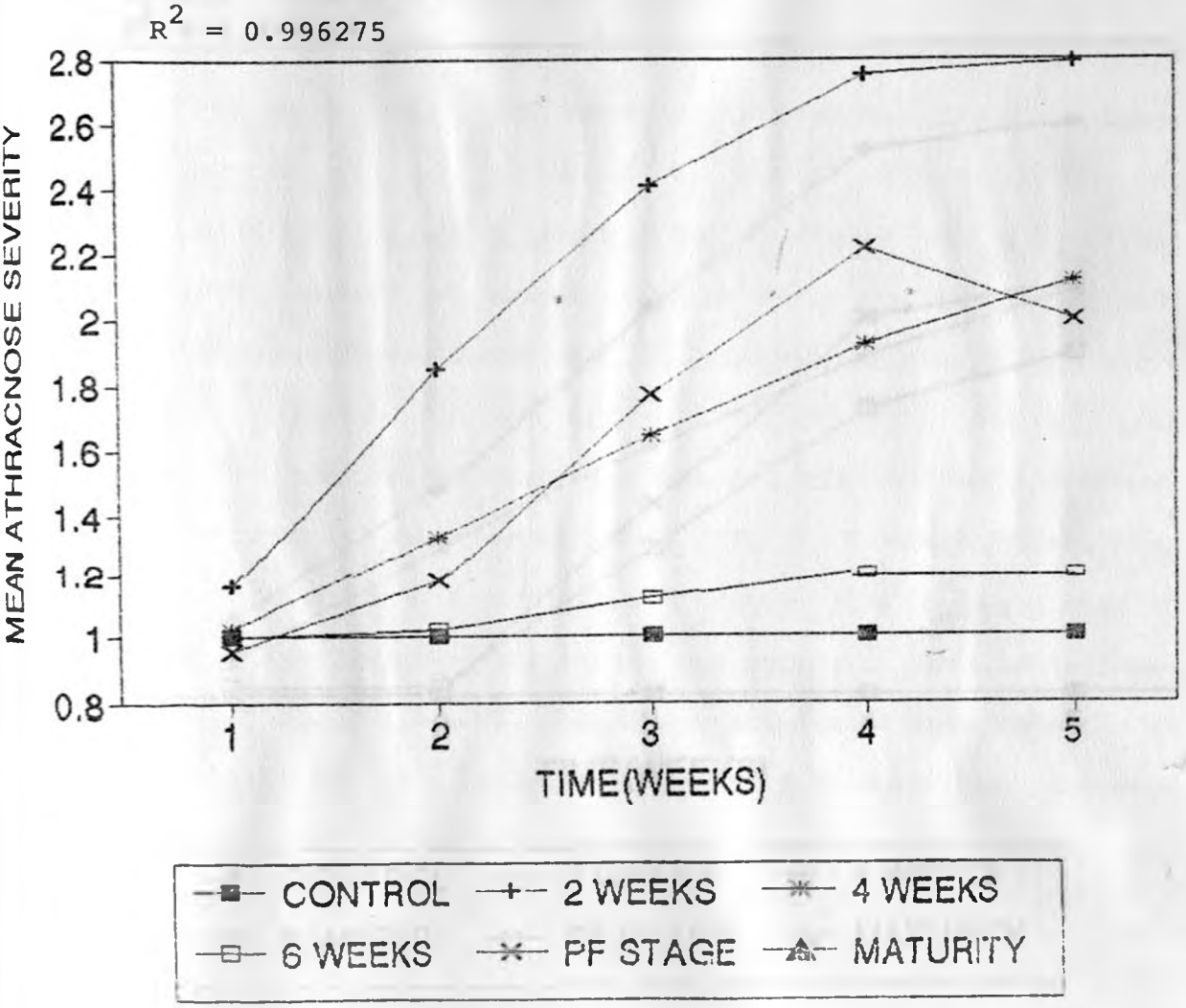

Fig 9a. Regression curves for anthracnose severity on pods on CV. Rosecoco-GLP-2 plants inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains at Kabete.

The regression equations for the graphs are:

Control = $1.574 - 0.819X + 0.765X^2 - 0.097X^3$

4 weeks = $0.574 + 0.540X + 0.078X^2 - 0.014X^3$

6 weeks = $2.522 - 2.452X + 1.086X^2 - 0.114X^3$

PF stage = $3.715 - 3.612X + 1.61X^2 - 0.176X^3$

Maturity = 1.00

$R^2 = 0.999024$

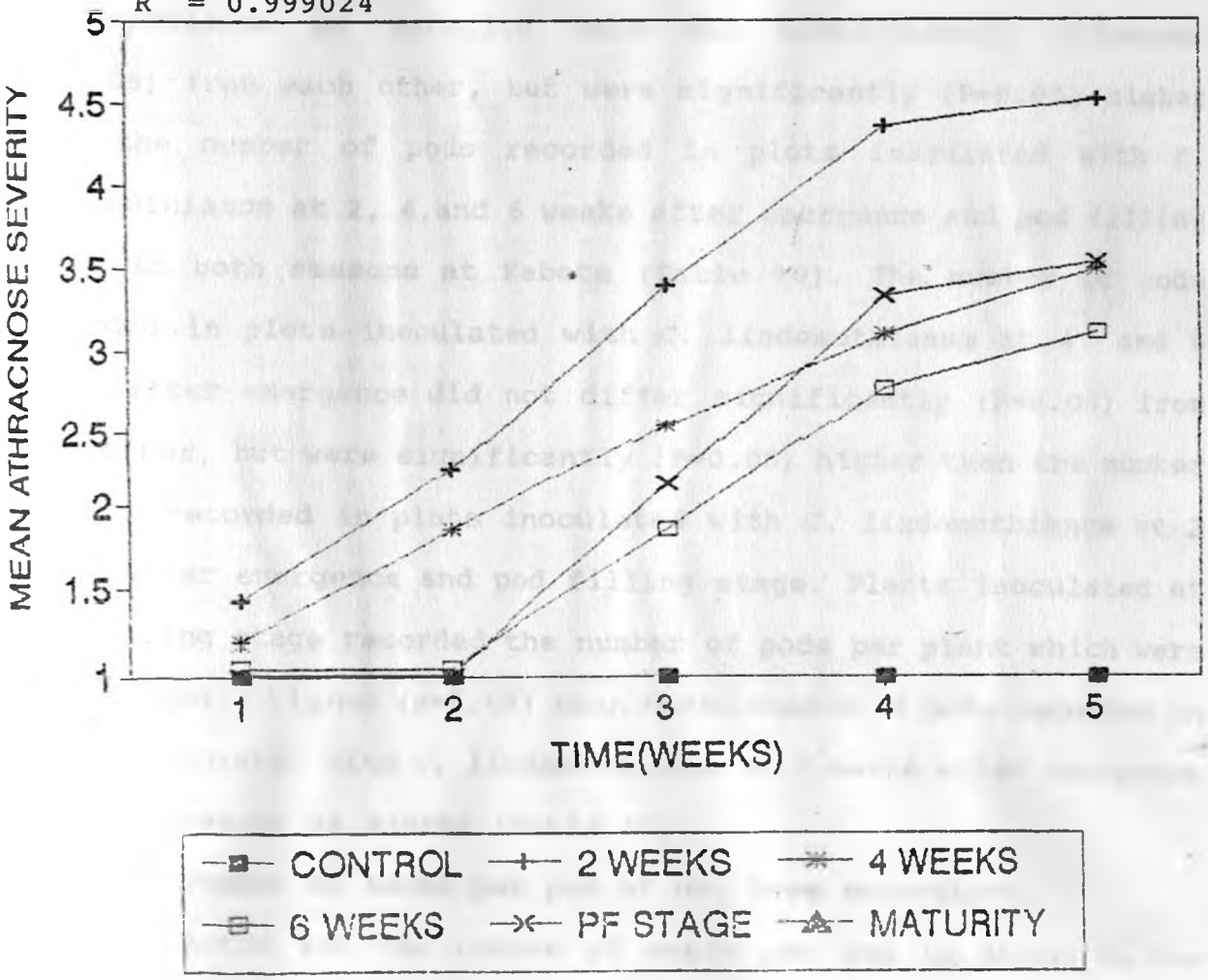

Fig. 9b. Regression curves for anthracnose severity on pods on CV. Rosecoco-GLP-2 plants inoculated with Colletotrichum lindemuthianum at various growth stages during the long rains at Kabete.

inoculated with *C. lindemuthianum* at 2 weeks after emergence in both seasons.

4.4.3.2. Number of pods per plant.

The Anova for the number of pods per plant is shown in the appendix 25 for both the short and long rains.

The number of pods of cv. Rose coco-GLP-2 recorded in plots sprayed with sterile distilled water and inoculated with *C. lindemuthianum* at maturity were not significantly different (P=0.05) from each other, but were significantly (P=0.05) higher from the number of pods recorded in plots inoculated with *C. lindemuthianum* at 2, 4,and 6 weeks after emergence and pod filling stage in both seasons at Kabete (Table 10). The number of pods recorded in plots inoculated with *C. lindemuthianum* at 4 and 6 weeks after emergence did not differ significantly (P=0.05) from each other, but were significantly (P=0.05) higher than the number of pods recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence and pod filling stage. Plants inoculated at pod filling stage recorded the number of pods per plant which were significantly higher (p=0.05) than those number of pods recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence in both seasons at Kabete (Table 10).

4.4.3.3. Number of seeds per pod of cv. Rose coco-GLP-2.

The Anova for the number of seeds per pod is shown in the appendix 26 for both the short and long rains. The number of seeds/pod recorded during the short rains for all the treatments were not significantly (p=0.05) different from each other. During

Table 10. Yield/hectare, number of pods/plant, number of seeds/pod and 100-seed weight of cv. Rosecoco-GLP-2 plants inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July-1992) at Kabete.

(a) Short rains.

Time of inoculation	Yield/ha (Kg)	No. of pods per plant	No. of seeds per pod	100-seed weight (gm)
1. Control	2255.6^{b}	13^{c}	3^{a}	47.25
2. 2 weeks	819.2	4	3^{a}	37.68^{a}
3. 4 weeks	1276.8^{a}	8^{b}	3^{a}	39.24^{ab}
4. 6 weeks	1509.9^{a}	9^{b}	3^{a}	40.42^{b}
5. Pod filling stage	1333.0^{a}	6^{a}	3^{a}	39.28^{ab}
6. Maturity	2163.2^{b}	12^{c}	3^{a}	46.61

Means followed by the same letter are not significantly different from each other at 95% level of significance.

(b). Long rains.

Time of inoculation	Yield/ha (Kg)	No. of pods per plant	No. of seeds per pod	100-seed weight (gm)
1. Control	2123.1^{b}	12^{c}	3^{a}	56.89^{c}
2. 2 weeks	890.6	4	2	41.89^{a}
3. 4 weeks	1324.4^{a}	8^{b}	3^{a}	41.89^{b}
4. 6 weeks	1520.1^{a}	6^{b}	3^{a}	47.69^{b}
5. Pod filling stage	1405.6^{a}	5^{a}	3^{a}	45.74^{ab}
6. Maturity	2018.5^{b}	11^{c}	3^{a}	56.00^{c}

Means followed by the same letter are not significantly different from each other at 95% level of significance.

the long rains the number of seed/pod recorded in plots sprayed with sterile distilled water and inoculated with *C. lindemuthianum* at 4 and 6 weeks after emergence, pod filling stage and maturity were not significantly (p=0.05) different from each other but were significantly higher than the number of seeds/pod recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence (Table 10)

4.4.3.4. 100 seed weight.

Anova for 100-seed weight for both seasons is shown in appendix 27.

In both seasons, the 100-seed weight recorded in plots sprayed with sterile distilled water and plots inoculated with *C. lindemuthianum* at maturity were not significantly different (P=0.05) from each other, but were significantly higher than 100-seed weight recorded in plots inoculated with *C. lindemuthianum* at 2, 4 and 6 weeks and pod filling stage (Table 10). During the short rains, 100-seed weights recorded in plots inoculated with *C. lindemuthianum* at 2 and 4 weeks and pod filling stage were not significantly different (P=0.05) from each other. However during the long rains 100-seed weight recorded in plots inoculated with *C. lindemuthianum* at 4 weeks after emergence were significantly (p=0.05) higher than 100-seed weight recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence at Kabete. 100-seed weight recorded in plots inoculated with *C. lindemuthianum* at 6 weeks after emergence were not significantly different (p=0.05) from 100-seed weight recorded in plots inoculated with *C.*

lindemuthianum at 4 weeks after emergence and pod filling stage in both seasons but was significantly (P=0.05) higher than 100-seed weight recorded in plots inoculated at 2 weeks after emergence.

4.4.3.5. Yield reduction per hectare.

Anova for yield reduction using the yield recorded in plots sprayed with sterile distilled water as the base for both seasons is shown in appendix 28.

Mean yield reductions recorded in plots inoculated with *C. lindemuthianum* at 2 and 4 weeks after emergence were not significantly different (P=0.05) from each other and were the highest in both seasons (Table 11). Also mean yield reductions recorded in plots inoculated with *C. lindemuthianum* at 4 and 6 weeks after emergence and pod filling stage were not significantly higher (P=0.05) from each other, but were significantly higher than yield reductions recorded in plots inoculated with *C. lindemuthianum* at maturity. Mean yield reductions recorded in plots inoculated with *C. lindemuthianum* at maturity were not significant higher (P=0.05) when compared to yield recorded in plots sprayed with sterile distilled water (control) in both seasons

4.4.4. Area Under Disease Progress Curves (AUDPC).

4.4.4.1. AUDPC - Anthracnose incidence (AUDPC-AI).

The anova for AUDPC-AI for both seasons is shown in appendix 29.

AUDPC-AI recorded in plots inoculated with *C. lindemuthianum* at 2, 4 and 6 weeks after emergence and pod filling stage were all significantly (p=0.05) different from each other during the short

Table 11. Yield reductions per hectare recorded in plots sown with beans (cv. Rose coco-GLP-2) inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-August 1992) at Kabete.

Time of inoculation	short rains Kg/ha	short rains % yield reduction	Long rains Kg/ha	Long rains % yield reduction	Time of inoculation means Kg/ha	% Yield reduction Means
1. Control	0.0[a]	0.0	0.0[a]	0.0	0.0	0.0
2. 2 weeks	1232.5[c]	58.0	1436.4[c]	63.7	1334.4	60.8
3. 4 weeks	798.7[bc]	37.6	978.7[bc]	43.4	888.7	40.5
4. 6 weeks	603.0[b]	28.4	745.7[b]	33.1	674.4	30.8
5. pod filling stage.	717.5[b]	33.4	922.6[b]	40.9	820.0	37.2
6. maturity.	104.6[a]	4.1	91.8[a]	5.0	98.2	4.6
Seasons means	576.0	26.9	695.9	31.0		

Means followed by the same letter are not significantly different from each other at 95% level of significance.

rains (Table 12). However, during the long rains, AUDPC-AI recorded in plots inoculated with *C. lindemuthianum* at 6 weeks after emergence and pod filling stage were not significantly (p=0.05) different from each other but were in significantly (p=0.05) higher different from AUDPC-AI attained in plots sprayed with sterile distilled water and inoculated with *C. lindemuthianum* at 2 and 4 after emergence and maturity.

4.4.4.2. AUDPC-Anthracnose Severity on Leaves (AUDPC-ASL).

The anova for AUDPC-ASL for both seasons is shown in appendix 30. AUDPC-ASL recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence were the highest and were during the short rains and long rains cropping seasons. AUDPC-ASL recorded in plots sprayed with sterile distilled water and inoculated with *C. lindemuthianum* at 6 weeks after emergence, pod filling stage and maturity were not significantly (P=0.05) different from each other during both the short and long rains cropping seasons (Table 12).

4.4.4.3. AUDPC-Anthracnose Severity on Pods (AUDPC-ASP).

The ANOVA for AUDPC-ASP for both seasons is shown in appendix 31.

AUDPC-ASP recorded in plots inoculated with *C.lindemuthianum* at 2 weeks after emergence were the highest and were significantly (p=0.05) higher than AUDPC-ASP recorded in other treatments during both the short and long rains cropping seasons (Table 12).

4.4.5. Correlation analysis.

The correlation matrix analysis for Yield and Yield components, time of inoculation, AUDPC-AI, AUDPC-ASL, AUDPC-ASP and

Table 12. Area Under Disease Progress Curve-Anthracnose incidence and Anthracnose Severity recorded on cv. Rosecoco-GLP-2 inoculated with Colletotrichum lindemuthianum during the short rains (November 1991-February 1992) and long rains (April-August 1992) at Kabete.

	AUDPC-AI		AUDPC-ASL		AUDPC-ASP	
Time of inoculation	Short rains	Long rains	Short rains	Long rains	Short rains	Long rains
1. Control	0.00[a]	0.00[a]	0.00[a]	0.00[a]	4.50[a]	4.50[a]
2. 2 weeks	727.38	721.23	212.28	328.21	9.54	13.50
3. 4 weeks	482.88	509.38	69.43	102.68	6.66[a]	10.39
4. 6 weeks	161.00	218.25[b]	10.58[a]	13.70[a]	5.04[a]	7.92
5. Pod filling stage	60.75	201.88[b]	4.21[a]	7.33[a]	7.09[b]	9.20
6. Maturity	0.00[a]	0.00[a]	0.00[a]	0.00[a]	4.50[a]	4.50[a]

Means followed by the same letter are not significantly different from each other at 95% level of significance.

reduction in yield for the short and long rains are shown in tables 13a and 13b respectively.

The correlation between yield and the yield components (number of pods/plant, number of seeds/pod, and 100-seed weight) were all positive and significant (P = 0.01) during both the short and long rains cropping seasons (Table 13a and b). However no significant correlation was established between the number of seeds/pod and number of pods/plant during the short rains (Table 13a).

The correlation between AUDPC-ASL and yield/hectare and AUDPC-AI and yield/hectare were all highly significant (P=0.01) during both cropping seasons. Also a significant (P=0.05) correlation was established between AUDPC-ASP and yield/hectare.

No significant correlation was established between time of inoculation and yield/hectare, number of pods/plant, number of seeds/pod, and 100-seed weight during both cropping seasons. During both the short and long rains cropping seasons, a positive and significant (P=0.01) correlation was established between AUDPC-AI, AUDPC-ASL and eventual level of seed infection by *C. lindemuthianum*

Table 13a. Correlation analysis matrix for Yield and Yield components, AUDPC-ASL, AUDPC-AI, Time of inoculation and Seed-borne Colletotrichum lindemuthianum infection levels of the harvested seeds of cv. Rose coco-GLP-2 during the Short rains at Kabete.

	Yield	No. of pods	No. of seeds	100-seed weight	AUDPC -ASL	Time of inoculation	Seed-borne C. lindemuthianum infection on harvested seeds	AUDPC -AI	AUDPC -ASP
Yield									
No. of pods	0.78**								
No. of seeds	0.61**	0.38							
100-seed weight	0.78**	0.93**	0.37						
AUDPC-ASL	-0.68**	-0.67**	-0.38	-0.57*					
Time of inoculation	0.12	0.04	0.10	0.03	-0.43				
Seed-borne C. lindemuthianum infection on harvested seeds	-0.85**	-0.93**	-0.41	-0.86**	0.77**	-0.15			
AUDPC-AI	-0.75**	-0.71**	-0.42	-0.69**	0.94**	-0.41	0.81**		
AUDPC-ASP	-0.74**	-0.80**	-0.44	-0.76**	0.83**	-0.23	0.79**	0.79**	
Yield reduction	-0.71**	-0.79**	-0.38	-0.78**	-0.62**	-0.11	0.75**	0.70**	0.72**

Table 13b. Correlation analysis matrix for Yield and Yield components, AUDPC-ASL, AUDPC-AI, Time of inoculation and Seed-borne Colletotrichum lindemuthianum infection levels of the harvested seeds of cv. Rose coco-GLP-2 during the Long rains at Kabete.

	Yield	No. of pods	No. of seeds	100-seed weight	AUDPC -ASL	Time of inoculation	Seed-borne C. lindemuthianum infection on harvested seeds	AUDPC -AI	AUDPC -ASP
Yield									
No. of pods	0.73**								
No. of seeds	0.62**	0.52**							
100-seed weight	0.90**	0.80**	0.57**						
AUDPC-D	-0.64**	-0.68**	-0.45	-0.61**					
Time of inoculation	0.15	0.14	0.26	0.10	-0.43				
Seed-borne C. lindemuthianum infection on harvested seeds	-0.84**	-0.93**	-0.54*	-0.86**	0.64**	-0.12			
AUDPC-ASL	-0.79**	-0.79**	-0.53*	-0.77**	0.90**	-0.37	0.84**		
AUDPC-ASP	-0.84**	-0.91**	-0.54*	-0.84**	0.83**	-0.29	0.93**	0.96**	
Yield reduction	-0.72**	-0.76**	-0.42	-0.75**	-0.63**	-0.14	0.77**	0.76**	0.84**

CHAPTER FIVE:

DISCUSSION:

Heavy reliance upon the common bean (*P. vulgaris* L.) seed as a source of high-quality food in Kenya and the increasing demand for high-protein foods, due to increasing human population now draw attention to the necessity of minimizing disease-induced yield losses.

Use of healthy certified seeds is an important disease control measure because seed transmits plant pathogens and seed is normally exchanged worldwide. In Kenya, the menace posed by anthracnose in bean production appear to be of great consequence particularly because their primary inoculum source and consequent dissemination is mainly the planting seed. Furthermore, with many races of the pathogen known to exist in Kenya (Mukunya, 1974a; 1974b) varieties with vertical resistance are not likely to provide a permanent solution to the control of this disease.

It was therefore imperative to study the level of seed-borne *C. lindemuthianum* which occurs in the farmers' seed, and the epidemiology of the disease on artificially inoculated cv. Rose cocco-GLP-2 plants at various growth stages and its effect on the resultant seed. The epidemiology of the anthracnose as influenced by planting seed with varying levels of seed-borne *C. lindemuthianum*, as commonly practised by small scale farmers in Kenya comparison with non-infected seed was also studied.

5.1.0. Assessment of seed for seed-borne *Colletotrichum lindemuthianum* infection.

5.1.1 Farmers' seed.

This study has shown that *C. lindemuthianum* incidence in cv. Rosecoco-GLP-2 seeds occurred at higher levels in some seed samples than in others. Visual observation of the seed samples from the three districts revealed the presence of sunken brown discoloured patches on some seeds in some seed samples. Bean seeds with sunken or brown discoloration usually indicate infection by *Colletotrichum* spp. Plating of sunken, brown discoloured bean seeds on PDA have been shown to yield *C. lindemuthianum* (Esele, 1982). On examination of bean seed washings, the conidia of *C. lindemuthianum* were noted to be present in the suspension.

Regardless of which incubation technique was used to assess cv. Rosecoco-GLP-2 for anthracnose infection, seeds from Metembe area in Kisii district had the highest incidence of seeds with seed-borne *C. lindemuthianum*. Bean seeds from Kisii district showed the highest percent seed-borne anthracnose infection, followed by those from Kiambu district and finally by those from Meru district. The variability in the distribution of the anthracnose infection in seed in each district probably indicates the importance of the disease in those areas.

The anthracnose fungus was recorded from 77% of the cv. Rosecoco-GLP-2 seed samples when rolled paper towel test was used. While the agar plate and blotter tests recorded anthracnose pathogen in 63% and 33% of the cv. Rosecoco-GLP-2 seed samples

respectively. The rolled paper towel test involves the use of relatively cheap materials and gives results within a week (Anon., 1985). The incidences of seed infection by *C. lindemuthianum* recorded by rolled paper towel test were much higher when compared to those recorded in agar plate and blotter tests for the same seed samples. These results indicate the suitability of rolled paper towel test for use in routine health testing of bean seeds for infection by *C. lindemuthianum*. Similar comparable results of seed health testing using the rolled paper towel test on bean seeds have been obtained by Wendt (1986) who applied the test on 44 bean samples and 98% of these were found to be contaminated by *C. lindemuthianum*.

5.1.2. Bean seed from artificially inoculated crop.

The time of infection of seed crop in relation to the developmental stage is decisive with regard to the extent of seed infection (Neergaard, 1979). Thus inoculation of wheat at various growth stages, as defined by the Feeke's scale, by *Septoria nodurum* which causes glome blotch of wheat by Bronnimann (1969) established a clear relationship between the growth stage of the host at the time of infection with the rate of seed infection in term of infected ears. Inoculation of cv. Rosecoco-GLP-2 with *C. lindemuthianum* 2 and 4 weeks after emergence and pod filling stage had a significantly high level of seed-borne *C. lindemuthianum* infection. The infection was higher in plots inoculated during the long rains than the short rains. Similar observations of high seed infection by *C. lindemuthianum* have been obtained by Araya *et al.*,

(1986) who inoculated an established number of seedlings which acted as an initial source of inoculum and found a high incidence and seed transmission of *C. lindemuthianum* during the rainy season.

5.2.0. FIELD EXPERIMENTS.

5.2.1. Anthracnose incidence, severity on leaves and pods.

5.2.1. Farmer's seeds contamination/infection by *Colletotrichum lindemuthianum*.

Anthracnose incidence varied greatly among the treatments. Development of seed-borne disease is dependent primarily on three principal factors according to Neergaard (1979). These factors are (i) amount or rate of seed-borne inoculum (ii) the extent of transmission of this inoculum to the seedling at any stage of its development or the amount of active inoculum under field conditions or the rate of seed transmission; and (iii) the rate of increase in the subsequent development of the inoculum or disease in the field.

Regression analysis showed that anthracnose incidence recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 0.50% and 2.00% had a significant linear factor at Kabete. Also a significant linear factor was established for anthracnose incidence recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%, 0.75%, 1.00%, 2.00%, 3.00%, 3.75%, 5.50% and 10.00% at Tigoni. This suggested that anthracnose incidence in the above named plots increased linearly with time. Anthracnose incidence recorded in plots sown

with seeds with seed-borne *C. lindemuthianum* infection level of 3.75%, showed a non-significant linear factor but significant quadratic and cubic factors at both Kabete and Tigoni.

Plots sown with seeds with high seed-borne *C. lindemuthianum* gave rise to high AUDPC-AI, AUDPC-ASL and AUDPC-ASP values at both Kabete and Tigoni sites. There was a progressive increase in AUDPC-AI, AUDPC-ASL and AUDPC-ASP as percent seed infection increased. This increase in AUDPC-AI, AUDPC-ASL and AUDPC-ASP was expected since higher for a higher percentage of primary inoculum, even though a low percentage of infected seeds can result in a high disease incidence during the rainy season due to high infection rate (Fernandez *et al.*, 1987). Such high AUDPC could have not been attained from seeds with low percentage of infected seeds as the transmission rate as well as rate of increase of seed-borne diseases depends largely on adaphic and climatic conditions (Neergaard, 1979). At both Kabete and Tigoni, the sporadic rainfall which occurred throughout the growing season was not conducive for rapid spread of the fungus. This is because rain promotes the release of many types of fungal spores (Hirst and Steadman, 1963) and is particularly important in the release of anthracnose spores because they are embedded in a gelatinous substance in the acervuli. Rain has been shown to play a major role in the spread of stem anthracnose (*C. truniutum*) of lima beans (Champers, 1969). Hence the spread of bean anthracnose from an infection focus provided by an infected seedlings could appear to have been limited by the absence of splashing raindrops (Tu, 1981), hence the

observation that at later stages of plant growth, infection of subsequent non-infected bean plants and the spread of the anthracnose fungus could have been mainly by contact.

Anthracnose infection on leaves was generally low at both locations. Although the seeds which germinated showed infection, the sporadic rainfall throughout the growing season at both locations was not conducive for severe infection of the plants. Anthracnose severity on leaves recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 3.00% showed a non-significant linear factor but significant quadratic and cubic factors at Kabete. This suggested that anthracnose severity on leaves did not increase linearly with time in plots sown with seeds with seed-borne *C. lindemuthianum* infection level of 3.00%. Anthracnose severity on leaves recorded in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%, 0.75% and 1.00% showed a significant linear, quadratic and cubic factors at Kabete. Also anthracnose severity on leaves recorded in plots sown with the farmer's seed sample with no seed-borne *C. lindemuthianum* infection and seeds with seed-borne *C. lindemuthianum* infection levels of 0.25%, 0.50%, 1.00%, 5.50% and 10.00% at Tigoni showed a significant linear, quadratic and cubic factors.

The anthracnose fungus requires moderate temperatures of between 13°-26°C, with an optimum at 17°C, and high humidity (greater than 92%) for infection to develop successfully (Harter and Zaumeyer, 1944; Chaves, 1980). If dry weather predominates as

it happened during the later part of the growing season, no anthracnose results even though infected seed is planted (Harter and Zaumeyer, 1944). Also under field conditions, however, many bean plants are only partially infected, and various portions of the plant remain visibly unaffected (Kerr,*et al.*,1978). This phenomena also accounted for the low anthracnose infection on the leaves. Vertical spread of the disease from infected leaves to the new growth was not achieved since such spread requires splashing raindrops (Tu, 1981). Thus the new growth remained unaffected as long as the dry weather prevailed.

Anthracnose severity on leaves started declining after the 7th week after crop emergence. This could be attributed to leaf defoliation which started off immediately after the 6th week. Similar phenomena has been observed by Fernandez *et al.*,(1987), who observed that disease ratings could not be taken after six weeks due to leaf senescence.

Anthracnose infection on pods was generally not high. Infection grades of 2 and above were only obtained in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 1.00% and above, at Kabete. Whereas at Tigoni, infection grades of 2 and above were obtained in plots sown with seeds with seed-borne *C. lindemuthianum* infection levels of 2.00% and above. Regression analysis showed that the increase in anthracnose severity on pods with time varied greatly among the treatments.

Correlations between level of seed-borne *C. lindemuthianum* infection and AUDPC-AI, AUDPC-ASL and AUDPC-ASP were found to be

highly significant at both Kabete and Tigoni. Thus plots sown with seeds with high seed-borne *C. lindemuthianum* infection recorded high levels of AUDPC. This increase in AUDPC was expected since high AUDPC have been recorded in plots sown with seeds with varying levels of primary inoculum (Fernandez, *et al.*, 1987).

Lack of correlations between AUDPC-ASL and AUDPC-ASP suggested that anthracnose infection on pods was independent of leaf infection. Similar observations even though unexpected have been observed in bean plants inoculated with *C. lindemuthianum* simulating the percentage of seeds transmitting *C. lindemuthianum* in which it was observed that infection of pods was independent of leaf infection (Fernandez *et al.*, 1987).

5.2.1.2. Artificially inoculated plants.

Warm dry weather, during the short rains, was unfavourable for the development of the disease in plots inoculated with *C. lindemuthianum* during the later part of the cropping season. This resulted in high values of AUDPC-AI being recorded in plots inoculated with *C. lindemuthianum* at 2 and 4 weeks after emergence, when there was enough precipitation to provide the 10 hour period necessary for the anthracnose fungus to establish infection (Tu and Aylesworth, 1980). Hence anthracnose incidence reached 100%, 2 weeks after inoculations with *C. lindemuthianum* in plots inoculated 2 weeks and 4 weeks after emergence during both seasons. This situation however, was rarely attained in later inoculations carried out at 6 weeks after emergence and pod filling stage, hence the low anthracnose incidences observed in these treatments.

Conditions for the establishment and spread of *C. lindemuthianum* include a minimal moisture period of 24 hours and 48 hours, necessary to establish 85% and 90% leaf infection respectively (Tu and Aylesworth, 1980). This conditions were met when bean plants were inoculated with *C. lindemuthianum* at 2 and 4 weeks, after emergence resulting in high AUDPC-ASL values. However the sporadic rainfall during the later part of the growing seasons, was not conducive for severe infection resulting in AUDPC-ASL values which were not significantly (P=0.05) different from AUDPC-ASL values recorded in plots sprayed with sterile distilled water (control). Schwartz *et al.* (1981) obtained similar results when inoculation of susceptible bean plants with *C. lindemuthianum* and *Ascochyta* fungi under different conditions of sporadic rainfall during the later part of the growing season could lead to the of the spread of the pathogens, despite the inoculations initiating successful infection. Also the significantly high values of AUDPC-AI, AUDPC-ASL and AUDPC-ASP obtained when bean plants were inoculated with *C. lindemuthianum* at 2 and 4 weeks after emergence could demonstrate the differential susceptibility of the bean plant at various growth stages to infection by anthracnose. At 2 and 4 weeks after emergence there was the availability of highly susceptible stages for anthracnose infection (Wheeler, 1969). Similarly soybeans inoculated with *Pseudomonas syringae* p.v. *glycinea* the causal agent of bacterial blight of soybean resulted in high AUDPC values being recorded from plants inoculated at early stages of growth compared to plants inoculated at later stages of

growth development. The high AUDPC were associated with rapid spread of the disease in soybeans which are highly susceptible when young (Park and Lim, 1986).

5.2.2. Yield and Yield components.

5.2.2.1. Fields sown with Farmer's seeds with seed contaminated/infected by *Colletotrichum lindemuthianum*.

At both locations yields recorded in plots sown with pathogen free seeds were the highest followed by yields recorded in plots sown with certified seeds. However, the yields recorded at Kabete were about 4 times the yields recorded at Tigoni for all the treatments. This high differences in yields recorded at the two locations was attributed to the low environmental temperatures which prevailed at Tigoni and hence affected the growth of the crop. As indicated by Kay (1979), a reduction in photosynthetic efficiency has been observed in some bean cultivars when night temperatures fall between 10-18°C. This fall in photosynthate efficiency could have lead to the observed yield differences recorded from the two locations.

As shown by this study a bean crop grown from pathogen free seeds and certified seeds gave significantly (P=0.05) higher yields whereas those grown from infected seeds gave significantly (P=0.05) lower yields regardless of the level of seed infection by *C. lindemuthianum*. The negative and significant correlation between yield and AUDPC-AI at both Kabete and Tigoni indicated the influence of anthracnose incidence on yield. Similar significant correlations have been observed between haloblight severity and

yields by Mukunya and Keya (1979) when seeds having various levels of seed infection by haloblight pathogen (*P. syringae* p.v. *phaseolicola*) were planted.

The reduction in yield recorded in both locations due to anthracnose developing from the farmer's seed sample with no seed-borne *C. lindemuthianum* and the seed samples with seed-borne *C. lindemuthianum* infection levels 0.25%-10.00% was significant (P=0.05) compared to yields obtained in plots sown with plots sown with pathogen free seeds and certified seeds. The reduction in yield ranged between 13.45%-48.93% at Kabete and 38.75-55.66% at Tigoni. The reduction in yields was observed to increase with increase in level of seed-borne inoculum. As observed by Guant and Liew (1981) significant yield reduction are observed when seeds with increasing levels of seed infection are sown in the field. For instance in an experiment comparing the effects of varying levels of *Ascochyta fabae* in beans it was observed that yield reduction of 44% was observed due to the level of disease developing from seed with a 12% level of seed infection compared to a seed-line with 0.2% seed infection.

The reduction in number of pods and 100-seed weight (seed size) were significantly affected by anthracnose developing from seeds with varying levels of seed-borne *C. lindemuthianum*. The correlation between AUDPC-ASP and the number of pods and 100-seed weight were all negative and significant (P=0.001). The reduction in the number of pods was mainly due to infected plants developing few pods (Wheeler, 1969) and the dropping off of young developing

pods after infection (Fernandez *et al.*, 1987). Seed size (100-seed weight) reduction was apparently a result of formation of smaller seeds by pods of infected plants compared to pods of healthy plants (Hampton, 1975). This could have been due to deviation of photosynthate to infection sites instead of the developing seed (Pataky, 1981).

There was no apparent effect of anthracnose on the number of seeds per pod. This could have been as a result of component compensation exhibited by beans (Adams, 1967).

5.2.1.2. Bean crop artificially inoculated with *Colletotrichum lindemuthianum*.

Inoculation of cv. Rose coco-GLP-2 plants with *C. lindemuthianum* at 2 weeks after emergence gave rise to significantly (P=0.05) lower yields/hectare compared to yields attained in plots inoculated with *C. lindemuthianum* at 4 and 6 weeks after emergence, pod filling stage and maturity and sprayed with sterile distilled water, during both the short and long rains seasons. This suggests that infection of bean plants with *C. lindemuthianum* at an early stage of growth gives rise to lower yields. These observations are in agreement with observation of Wheeler (1969) who has indicated that bean plants infected with *C. lindemuthianum* at an early stage of growth, give rise to low yields.

Yields recorded in plots inoculated with *C. lindemuthianum* at 4 and 6 weeks after emergence and pod filling stage were not significantly different (P=0.05) from each other but were

significantly (P=0.05) lower than yields recorded in plots inoculated with *C. lindemuthianum* at maturity and sprayed with sterile distilled water. This suggested that anthracnose infection occurring at 4 and 6 weeks after emergence and pod filling stage leads to a similar effect on yield. This suggested that anthracnose infection occurring at 4 and 6 weeks after emergence and pod filling stage leads to a similar effect on yields. Also yield recorded in plots inoculated with *C. lindemuthianum* at maturity and sprayed with sterile distilled water were not significantly different (P=0.05) amongst each other. This suggested that anthracnose occurring late in crop development has little effect on yield. These observations agree with those of Grainger (1949), that disease occurring late in crop development even when severe has little effect on yield.

The number of pods/plant recorded in plots inoculated with *C. lindemuthianum* at 2 weeks after emergence of the bean plants and pod filling stage were the lowest even though they were significantly (P = 0.05) different from each other. The correlations between number of pods and AUDPC-AI, AUDPC-ASL and AUDPC-ASP for both seasons were high and negative. This implies that anthracnose incidence, severity on leaves and pods affected the number of pods per plant. This was expected because plots inoculated early (i.e. 2 and 4 weeks after emergence) few pods per plant were formed. This is because plants inoculated early had a retarded growth. The same case was observed for plants inoculated at pod filling stage. Bean plants which are retarded in growth have

been reported to develop few pods per plant (Heald, 1981). In plots inoculated at pod filling stage, it was observed that the young developing pods which got infected by anthracnose fell off the plant. These results agree with those of Fernandez *et al.*(1987), observed that when developing pods on beans got infected by *C. lindemuthianum* they fell off the plant.

The correlation between number of pods per plant and AUDPC-AI, AUDPC-ASL and AUDPC-ASP were highly significant (P = 0.001) and negative. The correlation between the number of pods per plant and AUDPC-ASP (-0.80 and -0.91 for the short and long rains respectively) was higher than the correlation between the number of pods per plant and AUDPC-AI (-0.75 and -0.79 for the short and long rains respectively) and AUDPC-ASL (-0.67 and -0.68 for the short and long rains respectively). This suggested that anthracnose severity on pods had a higher effect on reducing the number of pods/plant than anthracnose incidence and anthracnose severity on leaves.

The Correlations between number of pods per plant and AUDPC-ASL, AUDPC-AI and AUDPC-ASP for both seasons were high and negative. This implies that the anthracnose severity on leaves, anthracnose incidence and anthracnose severity on the pods affected the number of pods per plant. This was expected, because in plots inoculated early, i.e. (two weeks and 4 weeks) few number of pods were formed per plant. This was because plants inoculated early had a retarded growth and the young developing pods which got infected fell off the plant. The same case was observed for plants

inoculated at pod filling stage. Bean plants which are retarded in growth have been reported to develop few pods per plant (Heald, 1981). In plots inoculated at pod filling stage, it was observed that the young infected pods dropped off the plants. These results agree with those of Fernandez *et al* (1987) who observed that when developing pods on beans got infected by *C. lindemuthianum* they fall off the plant.

The number of seeds per pod recorded during the short rains did not differ from each other significantly (P=0.05), among the treatments. The correlations between the number of seeds per pod and AUDPC-ASL, AUDPC-AI and AUDPC-ASP were all not significant (P=0.001). This suggests that anthracnose severity on leaves, anthracnose incidence and anthracnose severity on pods had no effect on the number of seeds per pod during the short rains. The lack of anthracnose to cause any detectable effect on the number of seeds per pod can be as a result of component compensation exhibited by beans (Adams, 1967) where by the effect of the disease on or two yield components is compensated by increase in the other.

During the long rains, the number of seeds/pod recorded in plots inoculated with *C. lindemuthianum* at 2,4 and 6 weeks after emergence and pod filling stage were not significantly (P=0.05) different but were significantly less than those recorded in plots sprayed with sterile distilled water (control) and inoculated with *C. lindemuthianum* at maturity. Correlation between the number of seeds/pod and AUDPC-AI, AUDPC-ASL and AUDPC-ASP were negative and significant (P = 0.01) but low. This implied that anthracnose

incidence, severity on leaves and pods affected the number of seeds per pod during the long rains. The negative correlations indicated that early inoculations of plants by *C. lindemuthianum* resulted in less number of seeds per pod than in later inoculations.

100-seed weight is a measure of the average seed size (Adams, 1967). The correlation between 100-seed weight and AUDPC-ASL, AUDPC-AI and AUDPC-ASP were significant (P=0.05) and negative in both seasons. This implies that anthracnose severity on leaves, anthracnose incidence and anthracnose severity on pods had profound effects on 100-seed weight or seed size. The negative correlations between 100-seed weight and AUDPC-ASL, AUDPC-AI and AUDPC-ASP indicates that early infection resulted in more effect on a 100-seed weight than later infections. The effect of anthracnose infection on 100-seed weight which was observed in this study could be were apparently as a result of physiological changes of infected plants. This could have occurred primarily through reduced photosynthesis and movement of metabolites to infection sites than to developing seed. Similar observations have been made for soybean plants inoculated with septoria brown spot pathogen, *Septoria glycines* (Pataky and Lim, 1981).

Yield reductions for plants inoculated with *C. lindemuthianum* at maturity were not significantly different from the unsprayed control. This data suggests that anthracnose resulting from infection occurring late in the season does not affect yield greatly. These findings are similar to those reported by Botton (1974) and Ayers *et al.*, (1976) for maize inoculated with

Dreschlera maydis race T, who found that after the dough stage, the disease had little influence on either the rate of accumulation or the amount of photosynthate translocated to the grain. The same could probably have occurred where bean plants were inoculated with *C. lindemuthianum* at maturity.

Yield reductions recorded in plots where plants were inoculated with *C. lindemuthianum* at 2 weeks after emergence were the highest followed by those recorded in plots inoculated with *C. lindemuthianum* at 4 weeks after emergence. However, these reductions in yield did not differ significantly (P=0.05) from each other. This suggested that early infections of bean plants by *C. lindemuthianum* results in greatest yield reductions. This data is in agreement with what was observed for soybean plants inoculated at various growth stages using peanut stripe virus in Taiwan (Green and Lee, 1989). It was generally observed that early inoculations of peanuts with the peanut stripe virus generally resulted in greatest yield reductions. The reduction in yield could be attributed to the reduction in the number of pods per plant and 100-seed weight.

5.2.3. Determination of level of tolerance for *Colletotrichum lindemuthianum* in Kenya.

Neergaard (1979) has discussed some basic principles to be adopted in setting up disease tolerances in seed health testing. These principles include consideration of quarantine requirements of the importing country, geographic destination of the seed lot, frequency of occurrence of the pathogen within the seed as well as

the seeding rate and the possibilities of effective disinfection. But the principal factor to be included in such consideration is the degree of correlation between seed-borne inoculum and crop losses. As indicated by this study, correlation between seed-borne *C. lindemuthianum* infection level and the yield losses was positive and significant at both Kabete (0.68) and Tigoni (0.43).

The estimation of the levels of infection of seeds by *C. lindemuthianum* revealed infection levels of between 0.25% and 10.00%. Considering a spacing of 0.10m by 0.50m the bean plant population per hectare would be about 250,000 plants. The 0.25% seed infection would most likely give rise to 625 infected plants per hectare assuming that all infected seeds germinated and seeds which germinate gave rise to infected plants whereas seeds infection level of 10.00% would most likely give rise to 25,000 infected plants. Fernandez *et al.*, (1987) found anthracnose spread from an infected plant to neighbouring plant and such spread was found not to random in plots with 1.5% introduced inoculum. Therefore, 625 infected plants randomly distributed could bring about severe epidemic leading to severe yield reduction. As indicated by the study correlation between seed-borne *C. lindemuthianum* infection level and yield losses was positive and significant ($p=0.05$) at both Kabete and Tigoni. Small scale farmers are the majority growers of beans, usually as an intercrop with maize. Van Rheenen and coworkers (1981) found that the incidence of anthracnose in maize-bean intercop was lower than that of pure stand crop. The small scale farmers usually sort out any abnormally

shaped and discoloured seeds before planting. As shown by Mukunya and Keya (1979) sorting out of such seeds has been observed to reduce anthracnose incidence in the field and improve yields considerably. The farmer's seed sample with no seed-borne *C. lindemuthianum* infection was observed to have developed anthracnose in the field despite, the disease not being detected during seed health testing using the visual,and incubation tests. This could have been due to the fact that the sampling techniques used could not predict a zero level of seed infection and hence some seeds infected escaped detection (Schaad, 1988).

Given the importance of bean anthracnose in bean production and since *C. lindemuthianum* is a compound interest disease with repeating cycles of inoculum production and reinfection, the study recommends zero level of seed infection for planting.

CHAPTER SIX.

CONCLUSION.

In Kenya, beans are subject to severe damage by diseases such as bean anthracnose. These present a major constraint to increased production and more intensive cropping. If the production of edible beans is to be increased in this country, a source of high quality, disease-free seed must be established and maintained. This is because the farmer's seed whether tested and shown not to contain certain seed-borne micro-organisms is usually infected and therefore unfit for planting.

An understanding of the basic problems related to development of seed-borne disease contribute significantly to the control of the disease. The seed intended for planting can be infected by bean anthracnose at any growth stage, as shown by the inoculation of the crop at various growth stages. Also, the results obtained by planting seeds with various levels of infection have shown that such seed is not safe for planting in the field, since it will give rise to infected seedlings which in turn will act as a source of inoculum for subsequent infection of the crop.

It is suggested that farmers should get seed for planting from seed production organizations. These organizations should make sure that they maintain an overall high level of seed health of certified seeds to be sold to the farmers for further seed and crop production. As indicated by this study, pathogen free seeds might be the ideal solution to the problem posed by seed-borne anthracnose, but it has to be realised that production of such seed

is quite expensive. Hence farmers should be encouraged to use certified bean seeds produced by recognized seed companies in the country, so that losses caused by planting of infected bean seeds by the farmers can be minimized.

Further research should be carried out to determine the race distribution of *C. lindemuthianum* in seeds.

CHAPTER SEVEN.

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CHAPTER EIGHTT

APPENDICES:

APPENDIX 1

Percent *Colletotrichum lindemuthianum* incidence on harvested seeds of cv. Rose coco-GLP-2 plants recorded in plots sprayed with sterile distilled water and inoculated with *Colletotrichum lindemuthianum* at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1. Time of inoculation.	5	1681.648	336.330	85.982**	2.90	4.56
2. Block	3	11.466	3.822	0.977**	3.29	5.42
3. Error	15	58.674	3.912			
Total	23	1751.789				

Cv. = 18.78% Se. = 0.4037325

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1. Time of inoculation.	5	4226.023	845.205	88.808**	2.90	4.56
2. Block	3	13.320	4.440	0.467ns	3.29	5.42
3. Error	15	142.758	9.517			
Total	23	4382.102				

Cv. = 16.99% Se. = 0.6297155

Environmental conditions during the long rains cropping season at Kabete

TH APRIL 1992	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
NFALL	2.8	50.7	2.4	0	2.3	5.1	40.5	37.4	16	36.3	0	0	0	0	0	0	0	16.8	0	17.6	14.5	0	0	1.7	0	60.5	12.8	45.2	8.2	30.7
Max °C	26.9	25.6	24.7	25.6	25.9	25	26.2	23	23.4	23.7	22.1	23	23.1	23.9	23.7	24.5	25.5	25.6	24.2	24.2	23.2	23	23.7	24.6	25.5	24.8	23.6	23.1	24.1	23.4
PERATURE Min °C	15.6	13.6	14.5	15.8	15.6	14.4	15.2	14	13.6	14	14.6	13.2	12.4	14.6	15	15.3	15	15.8	15.3	14.6	15.2	14.6	14.7	15	13.6	13.6	15.5	14.1	14.6	14.7

TH MAY 1992	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
NFALL	27.9	33.4	8.8	0.8	0	0	0	0	0	1.1	0	0	8.3	4.4	18.5	3.5	0	0	0	1.9	0	0	0	0	0	0	0	0	6.5	1.3	0
Max °C	23.5	22.4	22.8	24.5	23.4	23.3	23.7	23.9	23.7	22.8	22.4	21.9	21.7	21	22.6	20.8	21.4	21.5	21	21.7	21.1	23.9	23.4	22.8	23.3	24.1	22.7	23.5	21.4	19.3	21.8
PERATURE Min °C	14.2	15.4	14	13.5	13.2	15.8	14.6	11.9	14.2	15	13.4	12.3	11.5	14.1	14.5	14.1	14.1	13.7	13.5	10.1	13.2	11.7	13.5	14.7	14.8	8.5	9.4	9	13.7	13.5	13.5

TH JUNE 1992	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
IFALL	0	0	0	2.8	2.5	0	0	0	0	0	0.8	1.8	2.8	4.8	0	0	0	0	0	2.2	0.8	0	0	0	0	0	0	0	0	0
Max °C	24.2	24.6	24.4	24.4	23	23	20.1	21.3	21.7	19.7	19.6	20.3	21.7	21	20.2	19.9	18.4	20.9	18.2	23.3	22.7	21.8	19.7	20.6	21.8	19.7	21.9	22.1	22.5	19.4
PERATURE Min °C	10.5	9.4	9.6	9.3	13.6	10.6	13.5	13.2	12.4	11.8	13.2	13.5	13.3	14	13.2	13.2	13	11.2	12.7	12.8	13.2	13	12.2	13.8	12.2	14.4	13	12.2	13.4	11.4	

TH JULY 1992	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
IFALL	2.4	14.1	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Max °C	20.2	20.2	20.3	18.8	19.4	17	19.8	20.1	20.2	21.1	19.7	18.8	19	17.2	17.9	20.5	17	17	16.7	17.2	23	20.8	21.4	18.9	23.4	21.3	21.2	20.2	21.2	24.8	20.7
PERATURE Min °C	12.8	12.9	13.9	12.3	11.4	11	11.1	12.4	11.7	12.3	12.7	12.7	9.9	9.2	11.8	11.2	11.2	10.7	10.1	8.8	12.5	12.8	12.2	9.8	12.2	10.2	11	7.8	11	11.6	11.6

Table 2.2b Environmental conditions during the long rains cropping season at Tigoni

MONTH	APRIL 1992																													
DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
RAINFALL		0	6.3	27.5	3.6	0	26.7	0	51.8	61.8	9.3	10.7	0	0	0	0	0	0	0	17.6	0	21.8	16.5	0	0	0.3	0	29	17.1	54.1	14.5	
TEMPERATURE	Max °C	28	27	26	26	25	26	22	22	21	22	21	17	20	22	23	23	24	24	24	22	20	20	22	23	22	23	24	22	22	19	
	Min °C	13	13	13	12	14	13	14	12	13	12	13	11	11	13	13	13	14	13	13	13	13	14	13	13	11	13	15	13	13	14	
MONTH	MAY 1992																															
DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
RAINFALL		66	44.7	73	7.5	3.1	0	0	0	0	0	0	37.7	2.3	30.7	9.3	23	18.7	0	0	0	0	0	0	0	0	0	0	0	17.3	17.3	10.1
TEMPERATURE	Max °C	19.5	21.5	20	23	22	22.5	20.5	22.5	23	22.5	21.5	20	19.5	18.5	18.5	19.5	21	19	18.5	18	22	20	22	22	20	22	21.5	20	22	20	18
	Min °C	14	14.5	15	15	12	14.5	13	12	13	11	11	12.5	12.5	13.5	13.5	13.5	13.5	12.5	13	11.5	13.5	11.5	13	14	11.5	11.5	10.5	9	12	11	14
MONTH	JUNE 1992																															
DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
RAINFALL		0	0	0	0	0	40.7	0	0	0	0	0	0	0	0	10.7	0	0	0	0	0	0	11.3	0	0	0	0	0	0	0	0	
TEMPERATURE	Max °C	18	17	17	17	17.5	18.5	17	18.5	17	16.5	17	16	15	15.5	16	17	16	16.5	16	17.5	16.5	18	16	16	16.5	18.5	17.5	18.5	15.5	17	
	Min °C	13.3	9	11	9	10	12	9	11	11	9	10	8	11	8	9	9	8	10.5	10	10	10.5	12	10.5	11.5	15	9.5	11	9	9	11	
MONTH	JULY 1992																															
DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
RAINFALL		3.9	8.1	9	11.7	8.6	0	0	3.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TEMPERATURE	Max °C	16	16	16	17	17	15.5	16	17.5	16.5	18	17	17.5	18	14	16	16.5	16	15.5	16.5	17.5	17	19	18	18.5	16	16.5	14.5	19	20	17	20
	Min °C	12	11	12	9.5	11	8	9.5	9	11	11.5	9	9	10.5	7.5	11	8.5	9	7.5	9	8	9.5	11.5	10.5	9.5	9	8	9.5	8	10	11	11

APPENDIX 3.

Percent anthracnose infection incidence on cv. Rose coco-GLP-2 recorded in plots sown with seeds with varying levels of *Colletotrichum lindemuthianum* infection during the long rains at Kabete and Tigoni (April-July, 1992).

ANOVA TABLE

(1) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1.Replication	2	3.206	1.603	1.52 ns	3.47	5.78
2.Level of seed infection (S)	11	353.820	32.165	30.53 **	2.26	3.18
3.Error (a)	22	23.181	1.054			
4.Date of recording (D)	9	211.000	23.445	138.32 **	1.92	2.50
5.D x S	99	73.629	0.744	4.39 **	1.32	1.48
6.Error (b)	216	36.611	0.169			
Total	359	701.451				

cv. (a) = 42.46% se_a = 0.0541007

cv.(b) = 17.03% se_b = 0.0216946

(2) Tigoni.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1.Replication	2	7.960	3.980	5.07*	3.47	5.78
2.Level of seed infection (S)	11	372.976	33.907	43.19**	2.26	3.18
3.Error (a)	22	17.272	0.785			
4.Date of recording (D)	9	250.694	27.855	360.37**	1.92	2.50
5.D x S	99	54.826	0.554	7.16**	1.32	1.48
6.Error (b)	216	11.067	0.051			
Total	359	720.424				

cv. (a) = 33.57% se_a =0.0466996

cv.(b) = 10.53% se =0.01193

APPENDIX 4a.

Regression analysis for anthracnose incidence on cv. Rose coco-GLP-2 plants during the long rains (April-July 1992) season at Kabete

Level of Seed infection	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. PFS	Intercept	0.707^{ns}	0.0898	1	0.133	2.96	3.99	7.01
	Linear factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
2. CS	Intercept	0.707^{ns}	0.0898	1	0.133	2.96	3.99	7.01
	Linear factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
3. 0.00% (FS)	Intercept	1.005*	0.0170	1	0.268	5.98	3.99	7.01
	Linear factor	-0.379^{ns}	0.2227	1	0.068	1.51	3.99	7.01
	Quadratic factor	0.113^{ns}	0.0791	1	0.142	3.17	3.99	7.01
	Cubic factor	-0.006^{ns}	0.0944	1	0.129	2.87	3.99	7.01
4. 0.25%	Intercept	1.357**	0.0015	1	0.489	10.89	3.99	7.01
	Linear factor	-0.530^{ns}	0.0895	1	0.133	2.96	3.99	7.01
	Quadratic factor	0.245**	0.0003	1	0.667	14.85	3.99	7.01
	Cubic factor	-0.017**	0.0001	1	0.862	19.21	3.99	7.01
5. 0.50%	Intercept	0.076^{ns}	0.8543	1	0.002	0.03	3.99	7.01
	Linear factor	0.803*	0.0111	1	0.305	6.79	3.99	7.01
	Quadratic factor	-0.088^{ns}	0.1693	1	0.087	1.93	3.99	7.01
	Cubic factor	0.004^{ns}	0.3105	1	0.047	1.04	3.99	7.01
6. 0.75%	Intercept	0.522^{ns}	0.2085	1	0.072	1.61	3.99	7.01
	Linear factor	0.368^{ns}	0.2361	1	0.064	1.43	3.99	7.01
	Quadratic factor	0.005^{ns}	0.9431	1	0.001	0.01	3.99	7.01
	Cubic factor	-0.001^{ns}	0.7384	1	0.005	0.11	3.99	7.01
7. 1.00%	Intercept	0.821^{ns}	0.0497	1	0.178	3.98	3.99	7.01
	Linear factor	0.366^{ns}	0.2387	1	0.063	1.41	3.99	7.01
	Quadratic factor	-0.002^{ns}	0.9749	1	0.001	0.01	3.99	7.01
	Cubic factor	-0.001^{ns}	0.8566	1	0.002	0.03	3.99	7.01
8. 2.00%	Intercept	-0.202^{ns}	0.6254	1	0.011	0.24	3.99	7.01
	Linear factor	1.274**	0.0001	1	0.767	17.08	3.99	7.01
	Quadratic factor	-0.181*	0.0058	1	0.363	8.09	3.99	7.01
	Cubic factor	0.010**	0.0091	1	0.323	7.19	3.99	7.01
9. 3.00%	Intercept	1.169**	0.0058	1	0.363	8.06	3.99	7.01
	Linear factor	0.440^{ns}	0.1575	1	0.092	2.04	3.99	7.01
	Quadratic factor	-0.050^{ns}	0.4378	1	0.027	0.61	3.99	7.01
	Cubic factor	0.003^{ns}	0.4023	1	0.032	0.71	3.99	7.01
10. 3.75%	Intercept	1.064*	0.0117	1	0.300	6.69	3.99	7.01
	Linear factor	0.391^{ns}	0.2083	1	0.072	1.61	3.99	7.01
	Quadratic factor	0.003^{ns}	0.9631	1	0.001	0.01	3.99	7.01
	Cubic factor	0.000^{ns}	0.9553	1	0.001	0.01	3.99	7.01
11. 5.50%	Intercept	0.853*	0.0416	1	0.193	4.30	3.99	7.01
	Linear factor	0.572^{ns}	0.0677	1	0.154	3.44	3.99	7.01
	Quadratic factor	-0.007^{ns}	0.9119	1	0.001	0.01	3.99	7.01
	Cubic factor	-0.001^{ns}	0.8402	1	0.002	0.04	3.99	7.01
12. 10.00%	Intercept	1.928**	0.0001	1	0.987	21.99	3.99	7.01
	Linear factor	0.343^{ns}	0.2692	1	0.056	1.24	3.99	7.01
	Quadratic factor	0.001^{ns}	0.9895	1	0.001	0.01	3.99	7.01
	Cubic factor	0.000^{ns}	0.9295	1	0.001	0.01	3.99	7.01

R^2 = 0.996464

APPENDIX 4b.
Regression analysis for anthracnose incidence on cv. Rose coco-GLP-2 plants during the long rains (April-July 2002) season at Tigoni

Level of Seed Infection	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. PFS	Intercept	0.707**	0.0002	1	0.133	15.51	3.99	7.01
	Linear factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000ns	1.0000	1	0	0	3.99	7.01
2. CS	Intercept	0.707**	0.0002	1	0.166	19.44	3.99	7.01
	Linear factor	-0.112ns	0.4067	1	0.006	0.70	3.99	7.01
	Quadratic factor	0.035ns	0.2157	1	0.134	1.56	3.99	7.01
	Cubic factor	-0.002ns	0.2005	1	0.014	1.67	3.99	7.01
3. 0.00% (FS)	Intercept	0.743**	0.0001	1	0.147	17.12	3.99	7.01
	Linear factor	-0.162ns	0.2340	1	0.012	1.44	3.99	7.01
	Quadratic factor	0.086**	0.0028	1	0.082	9.61	3.99	7.01
	Cubic factor	-0.005**	0.0027	1	0.083	9.65	3.99	7.01
4. 0.25%	Intercept	0.639**	0.0007	1	0.108	12.65	3.99	7.01
	Linear factor	0.595**	0.0001	1	0.168	19.58	3.99	7.01
	Quadratic factor	-0.043ns	0.1221	1	0.021	2.45	3.99	7.01
	Cubic factor	0.002ns	0.1701	1	0.016	1.92	3.99	7.01
5. 0.50%	Intercept	0.927**	0.0001	1	0.228	26.67	3.99	7.01
	Linear factor	0.165ns	0.2244	1	0.128	1.50	3.99	7.01
	Quadratic factor	0.034ns	0.2289	1	0.013	1.47	3.99	7.01
	Cubic factor	-0.002ns	0.1634	1	0.017	1.98	3.99	7.01
6. 0.75%	Intercept	0.659**	0.0005	1	0.115	13.46	3.99	7.01
	Linear factor	0.589**	0.0001	1	0.164	19.18	3.99	7.01
	Quadratic factor	-0.030ns	0.2878	1	0.010	1.15	3.99	7.01
	Cubic factor	0.001ns	0.7349	1	0.001	0.12	3.99	7.01
7. 1.00%	Intercept	0.618**	0.0010	1	0.101	11.84	3.99	7.01
	Linear factor	0.626**	0.0001	1	0.185	21.63	3.99	7.01
	Quadratic factor	-0.044ns	0.1169	1	0.022	2.52	3.99	7.01
	Cubic factor	0.002ns	0.3201	1	0.009	1.00	3.99	7.01
8. 2.00%	Intercept	0.791**	0.0001	1	0.166	19.42	3.99	7.01
	Linear factor	0.489**	0.0005	1	0.113	13.19	3.99	7.01
	Quadratic factor	0.003ns	0.9180	1	0.001	0.01	3.99	7.01
	Cubic factor	-0.001ns	0.4970	1	0.004	0.47	3.99	7.01
9. 3.00%	Intercept	0.618**	0.0010	1	0.101	11.84	3.99	7.01
	Linear factor	0.626**	0.0001	1	0.185	21.63	3.99	7.01
	Quadratic factor	-0.044ns	0.1169	1	0.022	2.52	3.99	7.01
	Cubic factor	0.002ns	0.3201	1	0.009	1.00	3.99	7.01
10. 3.75%	Intercept	0.180ns	0.3196	1	0.009	1.00	3.99	7.01
	Linear factor	1.067**	0.0001	1	0.538	62.91	3.99	7.01
	Quadratic factor	-0.086**	0.0027	1	0.083	9.65	3.99	7.01
	Cubic factor	0.003ns	0.0872	1	0.026	3.01	3.99	7.01
11. 5.50%	Intercept	1.087**	0.0001	1	0.314	36.64	3.99	7.01
	Linear factor	0.535**	0.0002	1	0.135	15.81	3.99	7.01
	Quadratic factor	-0.007ns	0.7900	1	0.001	0.07	3.99	7.01
	Cubic factor	-0.000ns	0.8427	1	0.001	0.04	3.99	7.01
12. 10.00%	Intercept	1.872**	0.0001	1	0.930	108.65	3.99	7.01
	Linear factor	0.522**	0.0002	1	0.129	15.03	3.99	7.01
	Quadratic factor	-0.032ns	0.2508	1	0.011	1.34	3.99	7.01
	Cubic factor	0.002ns	0.3394	1	0.008	0.92	3.99	7.01

R^2 = 0.999420

APPENDIX 5.
Percent anthracnose severity on leaf area infected on cv. Rose coco-GLP-2 recorded in plots sown with seeds with varying levels of *Colletotrichum lindemuthianum* infection during the long rains at Kabete and Tigoni (April-July, 1992).

ANOVA TABLE

(1) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1.Replication	2	0.146	0.072	0.18 ns	3.47	5.78
2.Level of seed infection (S)	11	61.567	5.597	13.50 *	2.26	3.18
3.Error (a)	22	9.123	0.415			
4.Date of recording (D)	9	74.573	8.286	18.98 *	1.92	2.50
5.D x S	99	27.616	0.279	12.77 *	1.32	1.48
6.Error (b)	216	4.719	0.022			
Total	359	174.744				

cv. (a) = 48.52% se (a) = 0.0339399
cv. (b) = 11.14% se (b) = 0.0077900

(2) Tigoni.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1.Replication	2	0.678	0.339	0.80 ns	3.47	5.78
2.Level of seed infection (S)	11	40.204	3.655	8.64 *	2.26	3.18
3.Error (a)	22	9.308	0.423			
4.Date of recording (D)	9	83.128	9.236	18.27 *	1.92	2.50
5.D x S	99	20.239	0.204	3.99 *	1.32	1.48
6.Error (b)	216	11.067	0.051			
Total	359	164.622				

cv. (a) = 46.49% se (a) = 0.0342815
cv.(b) = 16.18% se (b) = 0.01193

APPENDIX 6A.

Regression analysis for anthracnose severity on leaves on cv. Rose coco-GLP-2 plants during the long rains (April-July 1992) season at Kabete.

Level of Seed Infection	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. PFS	Intercept	0.707**	0.0001	1	0.133	55.03	3.99	7.01
	Linear factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000ns	1.0000	1	0	0	3.99	7.01
2. CS	Intercept	0.707**	0.0001	1	0.133	55.03	3.99	7.01
	Linear factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000ns	1.0000	1	0	0	3.99	7.01
3. 0.00% (FS)	Intercept	0.877**	0.0001	1	0.204	84.62	3.99	7.01
	Linear factor	-0.170*	0.0197	1	0.014	5.69	3.99	7.01
	Quadratic factor	0.047**	0.0020	1	0.025	10.30	3.99	7.01
	Cubic factor	-0.002*	0.0474	1	0.010	4.07	3.99	7.01
4. 0.25%	Intercept	0.182**	0.0603	1	0.009	3.07	3.99	7.01
	Linear factor	0.603**	0.0001	1	0.172	71.26	3.99	7.01
	Quadratic factor	0.061**	0.0001	1	0.041	16.94	3.99	7.01
	Cubic factor	0.003**	0.0023	1	0.024	10.04	3.99	7.01
5. 0.50%	Intercept	0.864**	0.0001	1	0.198	82.25	3.99	7.01
	Linear factor	-0.198**	0.0071	1	0.018	7.67	3.99	7.01
	Quadratic factor	0.060**	0.0001	1	0.039	16.35	3.99	7.01
	Cubic factor	0.003**	0.0006	1	0.031	12.87	3.99	7.01
6. 0.75%	Intercept	0.913**	0.0001	1	0.221	91.75	3.99	7.01
	Linear factor	-0.289**	0.0001	1	0.040	16.39	3.99	7.01
	Quadratic factor	0.096**	0.0001	1	0.097	40.24	3.99	7.01
	Cubic factor	-0.005**	0.0001	1	0.091	37.70	3.99	7.01
7. 1.00%	Intercept	0.786**	0.0001	1	0.164	68.06	3.99	7.01
	Linear factor	-0.232**	0.0018	1	0.025	10.52	3.99	7.01
	Quadratic factor	0.137**	0.0001	1	0.209	86.75	3.99	7.01
	Cubic factor	-0.009**	0.0001	1	0.236	97.94	3.99	7.01
8. 2.00%	Intercept	0.697**	0.0001	1	0.129	53.41	3.99	7.01
	Linear factor	0.001ns	0.9863	1	0.001	0.01	3.99	7.01
	Quadratic factor	0.017ns	0.2457	1	0.003	1.37	3.99	7.01
	Cubic factor	-0.001ns	0.4644	1	0.001	0.54	3.99	7.01
9. 3.00%	Intercept	0.717**	0.0001	1	0.136	56.55	3.99	7.01
	Linear factor	-0.051ns	0.4762	1	0.001	0.51	3.99	7.01
	Quadratic factor	0.039*	0.0102	1	0.017	6.96	3.99	7.01
	Cubic factor	-0.002*	0.0252	1	0.013	5.22	3.99	7.01
10. 3.75%	Intercept	0.764**	0.0001	1	0.155	64.22	3.99	7.01
	Linear factor	-0.094ns	0.1906	1	0.004	1.75	3.99	7.01
	Quadratic factor	0.049**	0.0014	1	0.027	11.10	3.99	7.01
	Cubic factor	-0.002**	0.0069	1	0.019	7.75	3.99	7.01
11. 5.50%	Intercept	0.662**	0.0001	1	0.116	48.26	3.99	7.01
	Linear factor	0.012ns	0.8688	1	0.001	0.03	3.99	7.01
	Quadratic factor	0.013ns	0.3705	1	0.002	0.81	3.99	7.01
	Cubic factor	0.001ns	0.7998	1	0.001	0.06	3.99	7.01
12. 10.00%	Intercept	0.622**	0.0001	1	0.103	42.63	3.99	7.01
	Linear factor	0.065ns	0.3835	1	0.002	0.77	3.99	7.01
	Quadratic factor	0.028ns	0.0648	1	0.008	3.72	3.99	7.01
	Cubic factor	-0.002ns	0.0748	1	0.009	3.27	3.99	7.01

R^2 = 0.999347

APPENDIX 6B.
Regression analysis for anthracnose severity on leaves on cv. Rose coco-GLP-2 plants during the long rains (April-July 1992) season at Tigoni.

Level of Seed infection	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. PFS	Intercept	0.707**	0.0018	1	0.133	10.50	3.99	7.01
	Linear factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
2. CS	Intercept	0.778**	0.0006	1	0.161	12.72	3.99	7.01
	Linear factor	-0.100^{ns}	0.5410	1	0.005	0.38	3.99	7.01
	Quadratic factor	0.033^{ns}	0.3341	1	0.012	0.95	3.99	7.01
	Cubic factor	-0.002^{ns}	0.2990	1	0.014	1.09	3.99	7.01
3. 0.00% (FS)	Intercept	1.052**	0.0001	1	0.294	23.23	3.99	7.01
	Linear factor	-0.399*	0.0171	1	0.075	5.96	3.99	7.01
	Quadratic factor	0.112**	0.0015	1	0.138	10.92	3.99	7.01
	Cubic factor	-0.007**	0.0016	1	0.136	10.77	3.99	7.01
4. 0.25%	Intercept	1.284**	0.0001	1	0.438	34.62	3.99	7.01
	Linear factor	-0.605**	0.0004	1	0.173	13.69	3.99	7.01
	Quadratic factor	0.164**	0.0001	1	0.299	23.64	3.99	7.01
	Cubic factor	-0.010**	0.0001	1	0.281	22.27	3.99	7.01
5. 0.50%	Intercept	1.110**	0.0001	1	0.327	25.87	3.99	7.01
	Linear factor	-0.404*	0.0158	1	0.077	6.11	3.99	7.01
	Quadratic factor	0.113**	0.0013	1	0.141	11.18	3.99	7.01
	Cubic factor	-0.006**	0.0022	1	0.128	10.13	3.99	7.01
6. 0.75%	Intercept	0.596**	0.0079	1	0.094	7.47	3.99	7.01
	Linear factor	0.119^{ns}	0.4983	1	0.006	0.46	3.99	7.01
	Quadratic factor	0.042^{ns}	0.2219	1	0.019	1.52	3.99	7.01
	Cubic factor	-0.004^{ns}	0.0814	1	0.039	3.12	3.99	7.01
7. 1.00%	Intercept	1.256**	0.0001	1	0.419	33.12	3.99	7.01
	Linear factor	-0.507**	0.0028	1	0.121	9.60	3.99	7.01
	Quadratic factor	0.132**	0.0002	1	0.194	15.38	3.99	7.01
	Cubic factor	-0.007**	0.0008	1	0.156	12.38	3.99	7.01
8. 2.00%	Intercept	0.691**	0.0023	1	0.127	10.04	3.99	7.01
	Linear factor	0.079^{ns}	0.6325	1	0.003	0.23	3.99	7.01
	Quadratic factor	0.024^{ns}	0.4771	1	0.006	0.51	3.99	7.01
	Cubic factor	-0.002^{ns}	0.4588	1	0.007	0.55	3.99	7.01
9. 3.00%	Intercept	0.580**	0.0097	1	0.089	7.07	3.99	7.01
	Linear factor	-0.116^{ns}	0.4805	1	0.006	0.50	3.99	7.01
	Quadratic factor	0.032^{ns}	0.3540	1	0.011	0.87	3.99	7.01
	Cubic factor	-0.002^{ns}	0.2509	1	0.017	1.34	3.99	7.01
10. 3.75%	Intercept	0.827**	0.0003	1	0.182	14.37	3.99	7.01
	Linear factor	-0.097^{ns}	0.5546	1	0.004	0.35	3.99	7.01
	Quadratic factor	0.080*	0.0205	1	0.071	5.62	3.99	7.01
	Cubic factor	-0.006**	0.0067	1	0.098	7.79	3.99	7.01
11. 5.50%	Intercept	1.334**	0.0001	1	0.473	37.39	3.99	7.01
	Linear factor	-0.624**	0.0003	1	0.184	14.57	3.99	7.01
	Quadratic factor	0.174**	0.0001	1	0.335	26.52	3.99	7.01
	Cubic factor	-0.010**	0.0001	1	0.314	24.83	3.99	7.01
12. 10.00%	Intercept	1.138**	0.0001	1	0.344	27.18	3.99	7.01
	Linear factor	-0.482**	0.0044	1	0.110	8.67	3.99	7.01
	Quadratic factor	0.173**	0.0001	1	0.334	26.44	3.99	7.01
	Cubic factor	-0.011**	0.0001	1	0.390	30.85	3.99	7.01

R^2 = 0.996701

APPENDIX 7

Anthracnose severity on pods cv. Rose coco-GLP-2 recorded in plots sown with seeds with varying levels of *Colletotrichum lindemuthianum* infection during the long rains at Kabete and Tigoni (April-July, 1992).

ANOVA TABLE

(1) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1.Replication	2	0.002	0.008	0.12 ns	3.47	5.78
2.Level of seed infection (S)	11	2.199	0.200	30.14 **	2.26	3.18
3.Error (a)	22	0.146	0.007			
4.Date of recording (D)	4	2.070	0.516	160.55 **	2.46	3.51
5.D x S	44	0.925	0.021	6.52 **	1.51	1.79
6.Error (b)	96	0.309	0.003			
Total	359	5.652				

cv. (a) = 5.94% se (a) = 0.00429
cv. (b) = 4.14% se (b) = 0.00299

(2) Tigoni.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1.Replication	2	0.093	0.047	2.82 ns	3.47	5.78
2.Level of seed infection (S)	11	2.695	0.245	14.80 **	2.26	3.18
3.Error (a)	22	0.364	0.016			
4.Date of recording (D)	4	1.910	0.478	162.49 **	2.46	3.51
5.D x S	44	0.976	0.022	7.55 **	1.51	1.79
6.Error (b)	96	0.282	0.003			
Total	359	6.321				

cv. (a) = 9.21% se (a)= 0.00678
cv. (b) = 3.88% se (b)= 0.00286

APPENDIX 8A.

Regression analysis for anthracnose severity on pods on cv. Rose coco-GLP-2 plants during the long rains (April-July 1992) season at Kabete.

Level of Seed infection	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. PFS	Intercept	1.000**	0.0011	1	0.041	18.10	3.99	7.01
	Linear factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000ns	1.0000	1	0	0	3.99	7.01
2. CS	Intercept	1.000**	0.0011	1	0.041	18.10	3.99	7.01
	Linear factor	0.100ns	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000ns	1.0000	1	0	0	3.99	7.01
3. 0.00% (FS)	Intercept	0.886**	0.0027	1	0.032	14.21	3.99	7.01
	Linear factor	0.171ns	0.5887	1	0.001	0.31	3.99	7.01
	Quadratic factor	-0.072ns	0.5409	1	0.001	0.40	3.99	7.01
	Cubic factor	0.012ns	0.4065	1	0.002	0.74	3.99	7.01
4. 0.25%	Intercept	1.245**	0.0002	1	0.064	28.04	3.99	7.01
	Linear factor	-0.383ns	0.2361	1	0.004	1.56	3.99	7.01
	Quadratic factor	0.158ns	0.1915	1	0.004	1.92	3.99	7.01
	Cubic factor	-0.016ns	0.2403	1	0.003	1.53	3.99	7.01
5. 0.50%	Intercept	0.895**	0.0025	1	0.033	14.51	3.99	7.01
	Linear factor	0.185ns	0.5587	1	0.001	0.36	3.99	7.01
	Quadratic factor	-0.102ns	0.3870	1	0.002	0.81	3.99	7.01
	Cubic factor	0.019ns	0.1485	1	0.005	2.38	3.99	7.01
6. 0.75%	Intercept	1.098**	0.0005	1	0.050	21.82	3.99	7.01
	Linear factor	-0.221ns	0.4849	1	0.001	0.52	3.99	7.01
	Quadratic factor	0.143ns	0.2346	1	0.004	1.57	3.99	7.01
	Cubic factor	-0.125ns	0.3405	1	0.002	0.89	3.99	7.01
7. 1.00%	Intercept	0.692**	0.0123	1	0.020	8.67	3.99	7.01
	Linear factor	0.383ns	0.2361	1	0.004	1.56	3.99	7.01
	Quadratic factor	-0.097ns	0.4116	1	0.002	0.72	3.99	7.01
	Cubic factor	0.016ns	0.2175	1	0.004	1.69	3.99	7.01
8. 2.00%	Intercept	1.668**	0.0001	1	0.115	50.35	3.99	7.01
	Linear factor	-1.022**	0.0060	1	0.025	11.07	3.99	7.01
	Quadratic factor	0.604**	0.0002	1	0.064	28.06	3.99	7.01
	Cubic factor	-0.074ns	0.0001	1	0.078	34.17	3.99	7.01
9. 3.00%	Intercept	1.271**	0.0002	1	0.067	29.25	3.99	7.01
	Linear factor	-0.435ns	0.1823	1	0.005	2.00	3.99	7.01
	Quadratic factor	0.174ns	0.1527	1	0.005	2.33	3.99	7.01
	Cubic factor	-0.012ns	0.4065	1	0.002	0.74	3.99	7.01
10. 3.75%	Intercept	0.626*	0.0207	1	0.016	7.09	3.99	7.01
	Linear factor	0.481ns	0.1435	1	0.006	2.45	3.99	7.01
	Quadratic factor	-0.107ns	0.3650	1	0.002	0.89	3.99	7.01
	Cubic factor	0.015ns	0.2566	1	0.003	1.42	3.99	7.01
11. 5.50%	Intercept	1.439**	0.0001	1	0.086	37.46	3.99	7.01
	Linear factor	-0.429ns	0.1881	1	0.004	1.95	3.99	7.01
	Quadratic factor	0.200ns	0.1044	1	0.007	3.09	3.99	7.01
	Cubic factor	-0.012ns	0.4065	1	0.002	0.74	3.99	7.01
12. 10.00%	Intercept	1.735**	0.0001	1	0.124	54.50	3.99	7.01
	Linear factor	-1.050**	0.0051	1	0.027	11.67	3.99	7.01
	Quadratic factor	0.529**	0.0006	1	0.049	21.52	3.99	7.01
	Cubic factor	-0.058**	0.0006	1	0.048	21.05	3.99	7.01

R^2 = 0.999797

APPENDIX 88.
Regression analysis for anthracnose severity on pods on cv. Rose coco-GLP-2 plants during the long rains (April-July 1992) season at Tigoni.

Level of Seed Infection	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. PFS	Intercept	1.000*	0.0656	1	0.041	4.11	3.99	7.01
	Linear factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000ns	1.0000	1	0	0	3.99	7.01
2. CS	Intercept	1.000*	0.0656	1	0.041	4.11	3.99	7.01
	Linear factor	0.100ns	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000ns	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000ns	1.0000	1	0	0	3.99	7.01
3. 0.00% (FS)	Intercept	1.017*	0.0618	1	0.043	4.24	3.99	7.01
	Linear factor	-0.036ns	0.9567	1	0	0	3.99	7.01
	Quadratic factor	0.026ns	0.9140	1	0.001	0.01	3.99	7.01
	Cubic factor	-0.001ns	0.9672	1	0.001	0.01	3.99	7.01
4. 0.25%	Intercept	1.104*	0.0451	1	0.050	5.00	3.99	7.01
	Linear factor	-0.196ns	0.7659	1	0.001	0.09	3.99	7.01
	Quadratic factor	0.116ns	0.6352	1	0.002	0.24	3.99	7.01
	Cubic factor	-0.014ns	0.6160	1	0.003	0.27	3.99	7.01
5. 0.50%	Intercept	0.863ns	0.1058	1	0.031	3.06	3.99	7.01
	Linear factor	0.174ns	0.7917	1	0.001	0.07	3.99	7.01
	Quadratic factor	-0.033ns	0.8935	1	0.001	0.02	3.99	7.01
	Cubic factor	0.006ns	0.8131	1	0.001	0.06	3.99	7.01
6. 0.75%	Intercept	1.025*	0.0600	1	0.043	4.31	3.99	7.01
	Linear factor	0.023ns	0.9723	1	0	0	3.99	7.01
	Quadratic factor	0.048ns	0.8449	1	0.004	0.04	3.99	7.01
	Cubic factor	-0.005ns	0.8532	1	0.004	0.04	3.99	7.01
7. 1.00%	Intercept	1.181*	0.0340	1	0.058	5.72	3.99	7.01
	Linear factor	-0.164ns	0.8033	1	0.001	0.06	3.99	7.01
	Quadratic factor	0.092ns	0.7089	1	0.001	0.15	3.99	7.01
	Cubic factor	-0.008ns	0.7815	1	0.001	0.08	3.99	7.01
8. 2.00%	Intercept	0.872*	0.1027	1	0.031	3.12	3.99	7.01
	Linear factor	-0.037ns	0.9551	1	0	0	3.99	7.01
	Quadratic factor	0.222ns	0.3731	1	0.009	0.86	3.99	7.01
	Cubic factor	-0.028ns	0.3095	1	0.011	1.13	3.99	7.01
9. 3.00%	Intercept	1.449*	0.0125	1	0.087	8.62	3.99	7.01
	Linear factor	-0.355ns	0.5924	1	0.003	0.30	3.99	7.01
	Quadratic factor	0.235ns	0.3460	1	0.010	0.96	3.99	7.01
	Cubic factor	-0.024ns	0.3894	1	0.008	0.80	3.99	7.01
10. 3.75%	Intercept	1.372*	0.0167	1	0.078	7.73	3.99	7.01
	Linear factor	-0.069ns	0.9165	1	0.001	0.01	3.99	7.01
	Quadratic factor	0.068ns	0.7824	1	0.001	0.08	3.99	7.01
	Cubic factor	-0.000ns	1.0000	1	0	0	3.99	7.01
11. 5.50%	Intercept	1.475*	0.0113	1	0.090	8.94	3.99	7.01
	Linear factor	-0.486ns	0.4662	1	0.006	0.57	3.99	7.01
	Quadratic factor	0.224ns	0.3677	1	0.009	0.88	3.99	7.01
	Cubic factor	-0.014ns	0.6160	1	0.003	0.27	3.99	7.01
12. 10.00%	Intercept	1.735**	0.0043	1	0.124	12.36	3.99	7.01
	Linear factor	-1.050**	0.1296	1	0.027	2.65	3.99	7.01
	Quadratic factor	0.529*	0.0473	1	0.049	4.88	3.99	7.01
	Cubic factor	-0.058*	0.0494	1	0.048	4.78	3.99	7.01

R^2 = 0.999189

APPENDIX 9

Yield per Hectare recorded in plots sown with cv. Rose coco-GLP-2 seeds with varying levels of *Colletotrichum lindemuthianum* infection at Kabete and Tigoni during the long rains (April-July 1992)

ANOVA TABLE

(a) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	9464113.130	860373.921	55.466 **	2.26	3.18
2. Block	2	131003.656	65501.828	4.223 *	3.44	5.72
3. Error	22	341260.260	15511.830			
Total	35	44006377.016	Cv.= 5.22%	Se = 20.75775		

* Significant at 5% level

** Significant at 1% level

(b) Tigoni.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	1022214.243	92928.568	15.429**	2.26	3.18
2. Block	2	210069.154	105034.577	17.439**	3.44	5.72
3. Error	22	132505.228	6022.965			
Total	35	1364788.625				

Cv = 13.69% Se. = 12.934627

APPENDIX 10

Number of pods per plant recorded in plots sown with cv. Rose coco-GLP-2 seeds with varying levels of *Colletotrichum lindemuthianum* infection at Kabete and Tigoni during the long rains (April-July 1992)

ANOVA TABLE

(a) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1. Level of seed infection	11	102.055	9.278	26.158**	2.26	3.18
2. Block	2	4.933	2.467	6.955**	3.44	5.72
3. Error	22	7.803	0.355			
Total	35	114.791				

Cv. = 7.23%
Se = 0.0993031

(b) Tigoni.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1. Level of seed infection	11	33.677	2.890	10.942**	2.26	3.18
2. Block	2	1.885	0.942	3.568*	3.44	5.72
3. Error	22	5.811	0.264			
Total	35	39.488				

Cv. = 18.25% Se = 0.0856348

APPENDIX 11

Number of seeds per recorded in plots sown with cv. Rose coco-GLP-2 seeds with varying levels of Colletotrichum lindemuthianum infection at Kabete and Tigoni during the long rains (April-July 1992)

ANOVA TABLE

Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	2.078	0.189	1.789^{ns}	2.26	3.18
2. Block	2	0.158	0.079	0.748^{ns}	3.44	5.72
3. Error	22	2.323	0.106			
Total	35	4.559				

Cv. = 9.37% Se = 0.0542627

(b) Tigoni.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	5.185	0.471	5.633**	2.26	3.18
2. Block	2	1.504	0.752	8.985**	3.44	5.72
3. Error	22	1.841	0.084			
Total	35	8.530				

Cv = 12.55% Se = 0.0483045

APPENDIX 12

100 seed weight recorded in plots sown with cv. Rose coco-GLP-2 seeds with varying levels of Colletotrichum lindemuthianum infection at Kabete and Tigoni during the long rains (April-July 1992)

ANOVA TABLE

(a) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	338.039	35.276	12.245**	2.26	3.18
2. Block	2	4.197	2.097	0.728**	3.44	5.72
3. Error	15	63.381	2.881			
Total	35	455.617				

Cv = 3.19% Se = 0.2828918

(b) Tigoni.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	769.559	69.960	13.431**	2.26	3.18
2. Block	2	10.402	5.201	0.999^{NS}	3.44	5.72
3. Error	22	114.591	5.209			
Total	35	894.552				

Cv. = 4.40% Se. = 0.3803872

APPENDIX 13

Yield Reduction recorded in plots sown with cv. Rose coco-GLP-2 seeds with varying levels of *Colletotrichum lindemuthianum* infection at Kabete and Tigoni during the long rains (April-July 1992)

ANOVA TABLE

(a) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	10249293.019	931753.911	63.560**	2.26	3.18
2. Block	2	305727.681	152863.840	10.428**	3.44	5.72
3. Error	22	322509.486	14659.522			
Total	35	10877530.186				

Cv. = 12.67% Se. = 20.179419

(b) Tigoni

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	1022208.824	92928.075	15.426**	2.26	3.18
2. Block	2	3673448.532	183674.266	30.490**		
3. Error	22	132528.051	6024.002			
Total	35	1522085.408				

Cv. = 4.03% Se. = 12.935741

APPENDIX 14

AUDPC-Anthracnose incidence recorded in plots sown with cv. Rose coco-GLP-2 seeds with varying levels of Colletotrichum lindemuthianum infection at Kabete and Tigoni during the long rains (April-July 1992)

ANOVA TABLE

(a) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	70603.576	6418.507	11.289**	2.26	3.18
2. Block	2	1645.597	822.799	1.447ns	3.44	5.72
3. Error	22	12508.403	568.564			
Total	35	84757.576				

Cv. = 37.30% Se. = 3.9740967

(b) Tigoni

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	80111.083	7282.826	26.391**	2.26	3.18
2. Block	2	756.542	378.271	1.371ns	3.44	5.72
3. Error	22	6071.125	275.960			
Total	35	86938.750				

Cv. = 41.29% Se. = 2.768674

APPENDIX 15

AUDPC-Anthracnose severity recorded in plots sown with cv. Rose coco-GLP-2 seeds with varying levels of *Colletotrichum lindemuthianum* infection at Kabete and Tigoni during the long rains (April-July 1992)

ANOVA TABLE

(a) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	6239.233	567.203	14.007**	2.26	3.18
2. Block	2	21.211	10.605	0.262^{ns}	3.44	5.72
3. Error	22	890.893	40.495			
Total	35	7151.337				

Cv. = 38.33% Se. = 1.0605947

(b) Tigoni

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	3134.492	284.954	6.502**	2.26	3.18
2. Block	2	162.195	81.098	1.850^{ns}	3.44	5.72
3. Error	22	964.179	43.826			
Total	35	4260.867				

Cv. = 37.11% Se. = 0.4094357

APPENDIX 16

ACOPC-Anthracnose severity on pods recorded in plots sown with cv. Rose coco-GLP-2 seeds with varying levels of Colletotrichum lindemuthianum infection at Kabete and Tigoni during the long rains (April-July 1992)

ANOVA TABLE

(a) Kabete.

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	62.602	5.691	24.915**	2.26	3.18
2. Block	2	0.189	0.094	0.413ns	3.44	5.72
3. Error	22	5.025	0.228			
Total	35	67.816				

Cv. = 7.80% Se. = 0.0795822

(b) Tigoni

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Level of seed infection	11	90.283	8.208	14.50**	2.26	3.18
2. Block	2	3.032	1.516	2.678ns	3.44	5.72
3. Error	22	12.455	0.566			
Total	35	105.767				

Cv. = 11.48% Se. = 0.1253882

APPENDIX 17

Percent anthracnose incidence on cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

(a) Short rains (November 1991-February 1992)

ANOVA TABLE

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Block	3	182.103	60.701	1.28^{ns}	3.29	5.42
2. Time of inoculation (T)	5	203433.168	40686.633	857.25**	2.90	4.56
3. Error (a)	15	711.928	47.462			
4. Date of observation (D)	9	78734.858	8748.318	355.82**	1.94	2.53
5. T x D	45	111644.255	2480.983	100.91**	1.44	1.66
6. Error (b)	162	3982.941	24.586			
Total	239	398689.254				

cv. (a) = 26.17% se_a = 0.4446998

cv. (b) = 18.83% se_b = 0.3200637

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Block	3	10.803	3.601	0.30^{ns}	3.29	5.42
2. Time of inoculation (T)	5	188870.193	37774.038	3140.37**	2.90	4.56
3. Error (a)	15	180.428	12.028			
4. Date of observation (D)	9	131304.780	14589.420	1796.36**	1.94	2.53
5. T x D	45	146424.838	3253.855	400.64**	1.44	1.66
6. Error (b)	162	1315.706	8.122			
Total	239	468106.749				

cv. (a) = 11.25% se_a = 0.2238721

cv. (b) = 9.24% se_b = 0.1839565

APPENDIX 18

Table A 22a Environmental conditions during the long rains cropping season at Kabete

MONTH	APRIL 1992																													
DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
RAINFALL		2.8	50.7	2.4	0	2.3	5.1	40.5	37.4	16	38.3	0	0	0	0	0	0	0	16.8	0	17.8	14.5	0	0	1.7	0	60.5	12.8	45.2	8.2	30.7
TEMPERATURE	Max °C	26.9	25.6	24.7	25.6	25.9	25	26.2	23	23.4	23.7	22.1	23	23.1	23.9	23.7	24.5	25.8	25.8	24.2	24.2	23.2	23	23.7	24.6	25.5	24.8	23.8	23.1	24.1	23.4
	Min °C	15.8	13.6	14.5	15.8	15.8	14.4	15.2	14	13.6	14	14.8	13.2	12.4	14.6	15	15.3	15	15.6	15.3	14.8	16.2	14.8	14.7	15	13.8	13.5	16.5	14.1	14.6	14.7

MONTH	MAY 1992																														
DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
RAINFALL		27.8	33.4	8.8	0.8	0	0	0	0	0	1.1	0	0	8.3	4.4	18.5	3.5	0	0	0	1.9	0	0	0	0	0	0	0	0	6.5	1.3	
TEMPERATURE	Max °C	23.5	22.4	22.6	24.5	23.4	23.3	23.7	23.9	23.7	22.6	22.4	21.9	21.7	21	22.6	20.8	21.4	21.5	21	21.7	21.1	23.9	23.4	22.8	23.3	24.1	22.7	23.5	21.4	19.3	21
	Min °C	14.2	15.4	14	13.5	13.2	15.6	14.6	11.8	14.2	15	13.4	12.3	11.5	14.1	14.3	14.1	14.1	13.7	13.5	10.1	13.2	11.7	13.5	14.7	14.8	9.5	9.4	9	13.7	13.5	13

MONTH	JUNE 1992																														
DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
RAINFALL		0	0	0	2.9	2.5	0	0	0	0	0	0.8	1.8	2.9	4.8	0	0	0	0	0	2.2	0.8	0	0	0	0	0	0	0	0	0	
TEMPERATURE	Max °C	24.2	24.6	24.4	24.4	23	23	20.1	21.3	21.7	19.7	19.6	20.3	21.7	21	20.2	19.8	19.4	20.9	19.2	23.3	22.7	21.8	19.7	20.6	21.8	19.7	21.4	22.1	22.5	19.4	
	Min °C	10.5	8.4	9.6	9.3	13.8	10.6	13.5	13.2	12.4	11.8	13.2	13.5	13.3	14	13.2	13.2	13	11.2	12.7	12.8	13.2	13	12.2	13.8	12.2	14.4	13	12.2	13.4	11.4	

MONTH	JULY 1992																														
DAY		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
RAINFALL		2.4	14.1	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
TEMPERATURE	Max °C	20.2	20.2	20.3	18.8	19.4	17	19.8	20.1	20.2	21.1	19.7	18.8	19	17.2	17.9	20.5	17	17	18.7	17.2	23	20.8	21.4	18.9	23.4	21.3	21.2	20.2	21.2	24.8	20
	Min °C	12.8	12.9	13.9	12.3	11.4	11	11.1	12.4	11.7	12.3	12.7	12.7	9.8	9.2	11.5	11.2	11.2	10.7	10.1	8.8	12.5	12.9	12.2	9.9	12.2	10.2	11	7.8	11	11.6	11

APPENDIX 19A.

Regression analysis for anthracnose incidence on cv. Rose coco-GLP-2 plants during the short rains (November 1991-February 1992) season at Kabete.

Time of inoculation	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. Control	Intercept	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Linear factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
2. 2 weeks	Intercept	-75.633^{**}	0.0004	1	1518.691	15.55	3.99	7.01
	Linear factor	70.480^{**}	0.0001	1	2347.370	24.04	3.99	7.01
	Quadratic factor	-8.993^{**}	0.0045	1	898.326	9.20	3.99	7.01
	Cubic factor	0.369^{*}	0.0452	1	420.580	4.31	3.99	7.01
3. 4 weeks	Intercept	30.583^{ns}	0.1195	1	248.320	2.54	3.99	7.01
	Linear factor	-41.054^{**}	0.0071	1	796.428	8.16	3.99	7.01
	Quadratic factor	12.718^{**}	0.0001	1	1796.425	18.40	3.99	7.01
	Cubic factor	-0.798^{**}	0.0001	1	1968.824	20.16	3.99	7.01
4. 6 weeks	Intercept	10.554^{ns}	0.5855	1	29.573	0.30	3.99	7.01
	Linear factor	-7.801^{ns}	0.5907	1	28.755	0.29	3.99	7.01
	Quadratic factor	0.674^{ns}	0.8214	1	5.051	0.05	3.99	7.01
	Cubic factor	0.087^{ns}	0.6282	1	23.301	0.24	3.99	7.01
5. Pod filling stage	Intercept	-0.058^{ns}	0.9976	1	0.001	0	3.99	7.01
	Linear factor	1.397^{ns}	0.9231	1	0.923	0.01	3.99	7.01
	Quadratic factor	-0.880^{ns}	0.7683	1	8.606	0.09	3.99	7.01
	Cubic factor	0.112^{ns}	0.5309	1	39.106	0.40	3.99	7.01
6. Maturity	Intercept	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Linear factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01

$R^2 = 0.974896$

PENDIX 19B. Regression analysis for anthracnose incidence on cv. Rose coco-GLP-2 plants during the long rains (April-July 1992) season at Kabete.

me of noculation	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
Control	Intercept	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Linear factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Cubic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
2 weeks	Intercept	-73.575^{**}	0.0078	1	1437.154	7.95	4.11	7.39
	Linear factor	68.816^{**}	0.0012	1	2237.908	12.38	4.11	7.39
	Quadratic factor	-8.705^{*}	0.0377	1	841.566	4.66	4.11	7.39
	Cubic factor	0.355^{ns}	0.1512	1	388.770	2.15	4.11	7.39
4 weeks	Intercept	23.583^{**}	0.3721	1	147.657	0.82	4.11	7.39
	Linear factor	-35.971^{ns}	0.0742	1	611.438	3.38	4.11	7.39
	Quadratic factor	12.235^{**}	0.0045	1	1662.534	9.20	4.11	7.39
	Cubic factor	-0.796^{**}	0.0022	1	1957.894	10.83	4.11	7.39
6 weeks	Intercept	17.829^{ns}	0.4988	1	84.393	0.47	4.11	7.39
	Linear factor	-14.465^{ns}	0.4644	1	98.870	0.55	4.11	7.39
	Quadratic factor	1.956^{ns}	0.6308	1	42.488	0.24	4.11	7.39
	Cubic factor	0.044^{ns}	0.8577	1	5.894	0.03	4.11	7.39
Pod filling stage	Intercept	11.446^{ns}	0.6635	1	34.781	0.19	3.99	7.01
	Linear factor	-8.057^{ns}	0.6280	1	30.675	0.17	3.99	7.01
	Quadratic factor	0.441^{ns}	0.9136	1	2.156	0.01	3.99	7.01
	Cubic factor	0.136^{ns}	0.5780	1	59.967	0.32	3.99	7.01
Maturity	Intercept	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Linear factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01
	Cubic factor	0.000^{ns}	1.0000	1	0	0	3.99	7.01

$R^2 = 0.962535$

APPENDIX 20

Percent anthracnose severity on leaves on cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

(a) Short rains (November 1991-February 1992)

ANOVA TABLE

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Block	3	9.735	3.245	0.40^{ns}	3.29	5.42
2. Time of inoculation (T)	5	15855.703	3171.141	389.97**	2.90	4.56
3. Error (a)	15	121.976	8.132			
4. Date of observation (D)	9	2853.248	317.032	157.55**	1.94	2.53
5. T x D	45	7097.394	157.720	78.38**	1.44	1.66
6. Error (b)	162	325.981	2.012			
Total	239	26264.075				

cv. (a) = 52.59% se_a = 0.1840709

cv. (b) = 26.16% se_b = 0.0915657

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Block	3	50.126	16.708	0.61^{ns}	3.29	5.42
2. Time of inoculation (T)	5	38387.650	7677.530	280.83**	2.90	4.56
3. Error (a)	15	410.078	27.338			
4. Date of observation (D)	9	6687.940	743.104	139.77**	1.94	2.53
5. T x D	45	16778.904	372.864	70.13**	1.44	1.66
6. Error (b)	162	861.305	5.317			
Total	239	63176.002				

cv. (a) = 63.33% se_a = 0.2136755

cv. (b) = 27.93% se_b = 0.1488385

APPENDIX 21A

Regression analysis for anthracnose severity on leaves on cv. Rose coco-GLP-2 plants during the short rains (November 1991-February 1992) season at Kabete.

Time of inoculation	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. Control	Intercept	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Linear factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Cubic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
2. 2 weeks	Intercept	-17.826**	0.0002	1	84.360	16.74	4.11	7.39
	Linear factor	14.402**	0.0001	1	98.012	19.45	4.11	7.39
	Quadratic factor	-0.954^{ns}	0.1652	1	10.111	2.01	4.11	7.39
	Cubic factor	-0.007^{ns}	0.8615	1	0.156	0.03	4.11	7.39
3. 4 weeks	Intercept	8.213^{ns}	0.0675	1	17.908	3.55	4.11	7.39
	Linear factor	-8.390*	0.0145	1	33.266	6.60	4.11	7.39
	Quadratic factor	1.943**	0.0066	1	41.926	8.32	4.11	7.39
	Cubic factor	-0.095*	0.0237	1	28.126	5.58	4.11	7.39
4. 6 weeks	Intercept	-0.370^{ns}	0.9329	1	0.036	0.01	4.11	7.39
	Linear factor	0.614^{ns}	0.8520	1	0.178	0.04	4.11	7.39
	Quadratic factor	-0.246^{ns}	0.7166	1	0.675	0.13	4.11	7.39
	Cubic factor	0.026^{ns}	0.5235	1	2.091	0.41	4.11	7.39
5. Pod filling stage	Intercept	-1.194^{ns}	0.7855	1	0.379	0.08	4.11	7.39
	Linear factor	1.343^{ns}	0.6833	1	0.852	0.17	4.11	7.39
	Quadratic factor	-0.379^{ns}	0.5769	1	1.597	0.32	4.11	7.39
	Cubic factor	0.030^{ns}	0.4639	1	2.761	0.55	4.11	7.39
6. Maturity	Intercept	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Linear factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Cubic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39

R^2 = 0.977923

APPENDIX 21B. Regression analysis for anthracnose severity on leaves on cv. Rose coco-GLP-2 plants during the long rains (April-July 1992) season at Kabete.

Time of inoculation	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. Control	Intercept	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Linear factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Cubic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
2. 2 weeks	Intercept	-28.803**	0.0001	1	220.252	18.49	4.11	7.39
	Linear factor	23.643**	0.0001	1	264.153	22.18	4.11	7.39
	Quadratic factor	-1.894^{ns}	0.0758	1	39.827	3.34	4.11	7.39
	Cubic factor	0.022^{ns}	0.7283	1	1.460	0.12	4.11	7.39
3. 4 weeks	Intercept	10.179^{ns}	0.1373	1	27.507	2.31	4.11	7.39
	Linear factor	-10.222^{ns}	0.0492	1	49.376	4.15	3.99	7.39
	Quadratic factor	2.279^{ns}	0.0342	1	57.708	4.84	4.11	7.39
	Cubic factor	-0.098^{ns}	0.1237	1	29.604	2.49	4.11	7.39
4. 6 weeks	Intercept	0.336^{ns}	0.9603	1	0.030	0	4.11	7.39
	Linear factor	-0.186^{ns}	0.9706	1	0.016	0	4.11	7.39
	Quadratic factor	-0.033^{ns}	0.9744	1	0.012	0	4.11	7.39
	Cubic factor	0.012^{ns}	0.8448	1	0.463	0.04	4.11	7.39
5. Pod filling stage	Intercept	-1.011^{ns}	0.8808	1	0.271	0.02	4.11	7.39
	Linear factor	1.191^{ns}	0.8138	1	0.671	0.06	4.11	7.39
	Quadratic factor	-0.355^{ns}	0.7340	1	1.397	0.12	4.11	7.39
	Cubic factor	0.029^{ns}	0.6384	1	2.676	0.22	4.11	7.39
6. Maturity	Intercept	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Linear factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39
	Cubic factor	0.000^{ns}	1.0000	1	0	0	4.11	7.39

R^2 = 0.999189

APPENDIX 22

Anthracnose severity on pods on cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

(a) Short rains (November 1991-February 1992)

ANOVA TABLE

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Block	3	0.213	0.070	0.39^{ns}	3.29	5.42
2. Time of inoculation (T)	5	22.378	4.476	24.41**	2.90	4.56
3. Error (a)	15	2.750	0.183			
4. Date of observation (D)	4	8.642	2.161	106.48**	2.50	3.60
5. T x D	20	7.928	0.396	19.54**	1.67	2.07
6. Error (b)	72	1.461	0.020			
Total	119	40.994				

cv. (a) = 30.13% se_a = 0.0390885

cv. (b) = 10.02% se_b = 0.0130037

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Block	3	0.146	0.048	0.80^{ns}	3.29	5.42
2. Time of inoculation (T)	5	71.955	14.391	238.09**	2.90	4.56
3. Error (a)	15	0.907	0.060			
4. Date of observation (D)	4	51.404	12.851	312.03**	2.50	3.60
5. T x D	20	29.656	1.483	36.00**	1.67	2.07
6. Error (b)	72	2.965	0.042			
Total	119	157.033				

cv. (a) = 12.55% se_a = 0.0224431

cv. (b) = 10.36% se_b = 0.0185258

APPENDIX 23a.

Regression analysis for anthracnose severity on pods on cv. Rose coco-GLP-2 plants during the short (November 1991-February) season at Kabete.

Time of inoculation	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.(
1. Control	Intercept	1.000^{ns}	0.3682	1	0.041	0.95	5.99	13.7
	Linear factor	0.000^{ns}	1.0000	1	0	0	5.99	13.7
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	5.99	13.7
	Cubic factor	0.000^{ns}	1.0000	1	0	0	5.99	13.7
2. 2 weeks	Intercept	0.418^{ns}	0.6984	1	0.007	0.17	5.99	13.7
	Linear factor	0.732^{ns}	0.6055	1	0.123	0.30	5.99	13.7
	Quadratic factor	0.020^{ns}	0.9689	1	0	0	5.99	13.7
	Cubic factor	-0.014^{ns}	0.8028	1	0	0	5.99	13.7
3. 4 weeks	Intercept	0.756^{ns}	0.4901	1	0.024	0.54	5.99	13.74
	Linear factor	0.226^{ns}	0.8716	1	0.001	0.03	5.99	13.74
	Quadratic factor	0.045^{ns}	0.9319	1	0	0.01	5.99	13.74
	Cubic factor	-0.007^{ns}	0.9018	1	0.001	0.02	5.99	13.74
4. 6 weeks	Intercept	1.138^{ns}	0.3104	1	0.054	1.23	5.99	13.74
	Linear factor	-0.250^{ns}	0.8586	1	0.002	0.03	5.99	13.74
	Quadratic factor	0.123^{ns}	0.8128	1	0.003	0.06	5.99	13.74
	Cubic factor	-0.014^{ns}	0.8056	1	0.003	0.07	5.99	13.74
5. Pod filling stage	Intercept	1.630^{ns}	0.1639	1	0.110	2.51	5.99	13.74
	Linear factor	-1.294^{ns}	0.3727	1	0.040	0.93	5.99	13.74
	Quadratic factor	0.707^{ns}	0.2062	1	0.088	2.01	5.99	13.74
	Cubic factor	-0.088^{ns}	0.1666	1	0.108	2.48	5.99	13.74
6. Maturity	Intercept	1.000^{ns}	0.3682	1	0.041	0.95	5.99	13.74
	Linear factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74
	Cubic factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74

R^2 = 0.996275

APPENDIX 23b.
Regression analysis for anthracnose severity on pods on cv. Rose coco-GLP-2 plants during the long rains (April-July 1992) season at Kabete.

Time of inoculation	Regression parameter estimates		P≥0	Degree of Freedom	Mean Square	Computed F	Tabular F 0.05	0.01
1. Control	Intercept	1.000^{ns}	0.2457	1	0.041	1.61	5.99	13.74
	Linear factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74
	Cubic factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74
2. 2 weeks	Intercept	1.574^{ns}	0.0894	1	0.102	4.10	5.99	13.74
	Linear factor	-0.819^{ns}	0.4511	1	0.016	0.65	5.99	13.74
	Quadratic factor	0.765^{ns}	0.0890	1	0.103	4.11	5.99	13.74
	Cubic factor	-0.097*	0.0593	1	0.135	5.39	5.99	13.74
3. 4 weeks	Intercept	0.574^{ns}	0.4877	1	0.014	0.55	5.99	13.74
	Linear factor	0.540^{ns}	0.6144	1	0.007	0.28	5.99	13.74
	Quadratic factor	0.078^{ns}	0.8427	1	0.001	0.04	5.99	13.74
	Cubic factor	-0.014^{ns}	0.7489	1	0.003	0.11	5.99	13.74
4. 6 weeks	Intercept	2.522*	0.0176	1	0.263	10.53	5.99	13.74
	Linear factor	-2.452*	0.0524	1	0.145	5.82	5.99	13.74
	Quadratic factor	1.086*	0.0280	1	0.207	8.30	5.99	13.74
	Cubic factor	-0.114*	0.0332	1	0.189	7.57	5.99	13.74
5. Pod filling stage	Intercept	3.715**	0.0065	1	0.417	16.69	5.99	13.74
	Linear factor	-3.612**	0.0120	1	0.316	12.64	5.99	13.74
	Quadratic factor	1.614**	0.0052	1	0.458	18.33	5.99	13.74
	Cubic factor	-0.176**	0.0056	1	0.444	17.66	5.99	13.74
6. Maturity	Intercept	1.000^{ns}	0.2457	1	0.041	1.66	5.99	13.74
	Linear factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74
	Quadratic factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74
	Cubic factor	0.000^{ns}	1.0000	1	0	0	5.99	13.74

R^2 = 0.999024

APPENDIX 24

Yield per Hectare of cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	4221237.089	844247.418	13.964**	2.90	4.56
2. Block	3	512311.757	170770.586	2.824ns	3.29	5.42
3. Error	15	906910.028	60460.669			
Total	23	5640458.874				

cv. = 15.89% Se. = 50.191578

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	6123046.958	1224609.392	15.298**	2.90	4.56
2. Block	3	934022.755	311340.918	3.889*	3.29	5.42
3. Error	15	1200772.464	80051.498			
Total	23	8257842.177				

cv. = 18.14% Se. = 57.753607

APPENDIX 25

Number of pods per plant of cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	216.271	43.254	102.341**	2.90	4.56
2. Block	3	4.982	1.661	3.929*	3.29	5.42
3. Error	15	6.340	0.423			
Total	23	227.593				

cv. = 7.97% Se = 0.1327591

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	219.880	43.976	35.008**	2.90	4.56
2. Block	3	3.040	1.013	0.853^{ns}	3.29	5.42
3. Error	15	58.674	3.912			
Total	23	240.744				

cv. = 24.66% Se = 0.4037325

APPENDIX 26

Number of seeds per pod of cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	0.513	0.103	2.181^{ns}	2.90	4.56
2. Block	3	1.076	0.359	7.617^{**}	3.29	5.42
3. Error	15	0.706	0.047			
Total	23	2.295				

cv. = 7.32% Se. = 0.044253

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	1.402	0.280	2.630^{ns}	2.90	4.56
2. Block	3	1.076	0.359	3.365^{*}	3.29	5.42
3. Error	15	1.599	0.110			
Total	23	4.077				

cv. = 11.47% se = 0.0677003

APPENDIX 27

100 seed weight of cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	338.135	67.627	30.270**	2.90	4.56
2. Block	3	7.664	2.555	1.142ns	3.29	5.42
3. Error	15	33.511	2.234			
Total	23	379.310				

Cv. = 3.58% Se. = 0.0622773

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	704.991	140.998	14.051	2.90	4.56
2. Block	3	27.365	9.122	0.909	3.29	5.42
3. Error	15	150.524	10.035			
Total	23	882.880				

Cv. = 6.43% Se. = 0.6466258

APPENDIX 28

Yield Reduction per Hectare of cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	338.135	67.627	30.270**	2.90	4.56
2. Block	3	7.664	2.555	1.142ns	3.29	5.42
3. Error	15	33.511	2.234			
Total	23	379.310				

Cv = 3.58% Se. = 0.0622773

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	704.991	140.998	14.051**	2.90	4.56
2. Block	3	27.365	9.122	0.909ns	3.29	5.42
3. Error	15	150.524	10.035			
Total	23	882.880				

Cv. = 6.43% Se. = 0.6466258

APPENDIX 29

ANOVA-Anthracnose incidence recorded on cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	1800334.208	360066.842	1123.716**	2.90	4.56
2. Block	3	1715.250	576.750	1.784^{ns}	3.29	5.42
3. Error	15	4806.375	320.425			
	23	1806855.833				

Cv. = 29.92% Se. = 2.9834032

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	Tabular F 1%
1. Time of inoculation.	5	1655496.647	331099.329	2780.955**	2.90	4.56
2. Block	3	123.425	41.142	0.346^{ns}	3.29	5.42
3. Error	15	1785.894	119.060			
	23	1657405.955				

Cv. = 21.43% Se. = 1.81577

APPENDIX 30

AUDPC-Anthracnose severity on leaves recorded on cv. Rose coco-GLP-3 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1. Time of inoculation.	5	141451.427	28290.295	407.641**	2.90	4.56
2. Block	3	77.166	25.922	0.371ns	3.29	5.42
3. Error	15	1041.001	69.400			
	23	142569.595				

Cv. = 16.86% Se. = 1.3884444

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1. Time of inoculation.	5	337866.681	67573.336	274.590**	2.90	4.56
2. Block	3	381.795	127.265	0.517ns	3.29	5.42
3. Error	15	3692.663	246.178			
	23	3411941.139				

Cv. = 20.83% Se. = 3.2027202

APPENDIX 31

AUDPC-Anthracnose severity on pods recorded on cv. Rose coco-GLP-2 plants recorded in in plots sprayed with sterile distilled water and inoculated with Colletotrichum lindemuthianum at various growth stages during the short rains (November 1991-February 1992) and long rains (April-July 1992) seasons at Kabete.

ANOVA TABLE

(a) Short rains (November 1991-February 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1. Time of inoculation.	5	74.932	14.986	26.963**	2.90	4.56
2. Block	3	1.216	0.405	0.729ns	3.29	5.42
3. Error	15	8.337	0.556			
	23	86.754				

Cv. = 11.98% Se. = 0.152206

(b) Long rains (April-July 1992)

Source of variation	Degree of Freedom	Sum of Square	Mean Square	Computed F	Tabular F 5%	1%
1. Time of inoculation.	5	245.085	49.107	214.353**	2.90	4.56
2. Block	3	0.684	0.228	0.996ns	3.29	5.42
3. Error	15	3.430	0.229			
	23	249.198				

Cv. = 5.74% Se. = 0.0976614