BREEDING FOR RESISTANCE TO BEAN COMMON MOSAIC VIRUS, HALO BLIGHT, *Pseudomonas phaseolicola* AND ANTHRACNOSE, *Colletotrichum lidemuthianum* IN COMMON BEAN *Phaseolus vulgaris* L.

BY

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DECLARATION

I hereby declare that this thesis is my original work and has not been submitted for a degree in any other University.

Signed _____ Date 2/9/92

J.K. KAMAU

This thesis has been submitted for examination with my approval as University Supervisor.

Signed _____ Date 2/9/92

Dr. P.M. KIMANI

(Supervisor)

DEDICATION

Dedicated to all those citizens of our Nation who have worked hard for the development and enhancement of plant breeding and who have been to me, a source of aspiration.

ABSTRACT

Five popular bean cultivars susceptible to bean common mosaic virus, halo blight *Pseudomonas phaseolicola* and anthracnose *Colletotrichum lindemuthianum* were crossed in a diallel with two other cultivars resistant to these pathogens. Progenies were evaluated at the National Horticultural Research Centre - Thika and the University of Nairobi - Kabete. Lines combining resistance to two or more of the diseases were selected. Mode of inheritance of resistance to BCMV in cultivar L226-10 (52) and that of resistance to *Pseudomonas phaseolicola* and *Colletotrichum lindemunthianum* in NB-123 were studied.

Out of 1800 pollinations of the diallel crossing to seven bean cultivars, 1400 were successful, giving an overall 78.3% of successful crosses with each pod containing 3-7 seeds. L226-10 (52) was rated resistant to BCMV isolate 510 both in the green house and in the field. The F_1, F_2 and F_3 progenies of the crosses GLP-2 x GLP-24, GLP-2 x M535, GLP-288 x GLP-24, GLP-24 x GLP-2, GLP-24 x M535, GLP-x.92 x M535, M535 x GLP-2, M535 x GLP-2, M535 x GLP-288, M535 x GLP-24 and M535 x GLP-x.92 were highly tolerant to the virus isolate both in the green house and in the field. NB-123 was rated resistant to *Pseudomonas phaseolicola* both in the green house and in the field. The F_1, F_2 and F_3 progenies with NB-123 and M535 as one of the parents were resistant to the pathogen both in the green house and in the field. NB-123 was rated resistant to *Colletotrichum lindemuthianum* both in the green house

and in the field. The F_1, F_2 and F_3 progenies with M535 and NB-123 as one of the parents had a high degree of resistance to the pathogen both in the green house and in the field.

Segregation of the F_2 progenies for resistance to BCMV of the crosses GLP-2 x L226-10 (52), GLP-x.92 x L226-10 (52) and their reciprocals did not differ from the expected ratio 3:1 (resistant:susceptible). Segregation of the F_3 progenies for resistance to BCMV of the same crosses and their reciprocals also did not differ from the expected ratio 2:1 (segregating:non-segregating). It was therefore concluded that resistance to BCMV in L226-10 (52) is governed by a single dominant gene.

The segregation of the F_2 progenies for resistance to *Pseudomonas phaseolicola* of the crosses GLP-2 x NB-123, GLP- x.92 x NB-123 and their reciprocals differed from the expected ratio 3:1 (resistant:susceptible). Segregation of the F_3 progenies for resistant to *Pseudomonas phaseolicola* of the same crosses and their reciprocals differed from the expected ratio 2:1 (segregating:non-segregating).It was therefore concluded that resistance to *Pseudomonas phaseolicola* in NB-123 is not governed by a single dominant gene.

The segregation of the F_2 progenies for resistance to *Colletotrichum lindemuthianum* of the crosses GLP-2 x NB-123, GLP-x.92 x NB-123 and their reciprocals did not differ from the expected ratio 3:1 (resistant:susceptible). Segregation of the F_3 progenies for resistance to *Colletotrichum lindemuthianum* for the

same crosses and their reciprocals also did not differ from the expected ratio 2:1 (segregating:non-segregating) and it was therefore concluded that resistance to *Colletotrichum lindemuthianum* in NB-123 is governed by a single dominant gene.

When compared with the control, plants inoculated with BCMV, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum* showed 0 to 84% reduction in branching, podding, seeding abilities, 100 seed weight and dry matter weight.

On the basis of high yield, disease resistance and tolerance, good adaptability and seed acceptability, the F_2 and F_3 progenies of the crosses GLP-2 x GLP-24, GLP-2 x GLP-x.92, GLP-2 x M535, GLP-24 x GLP-x.92, M535 x GLP-2 and M535 x GLP-24 were selected for further improvement.

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1.0 INTRODUCTION

Common bean, *Phaseolus vulgaris* L. is an important food crop in Kenya. They are staple food for the majority of the population serving as a major source of relatively cheap protein. The crop is cultivated in monocultures or mixtures with other crops such as maize, cotton and bananas. Beans are widely grown by small scale farmers in the country. Together with other pulses, beans are the second important group of crops in Kenya after maize (Mukunya and Keya, 1975). The total area devoted to legume production is about 480,000 hectares annually. Of this area, about 320,000 hectares are under beans alone. Although beans are grown in almost all provinces in Kenya, the leading producers are: Eastern 40.6%, Central 32.2% and Nyanza 12.4% (Eijnatten, 1975).

The common bean is exposed to a large number of varied constraints. Diseases and pests among these factors contribute to the large gap between actual and potential yields. Yield of beans in Kenya is about 500 kg ha^{-1} but a potential of 1500 kg ha^{-1} has been suggested (Mukunya and Keya, 1975). In the United States, monoculture yields of nearly 1400 kg ha^{-1} have been reported (Schwartz and Galvez, 1980).

The major diseases affecting beans in Kenya include: bean common mosaic virus, halo blight, *Pseudomonas phaseolicola*; common blight, *Xanthomonas phaseoli*; anthracnose, *Colletotrichum lindemuthianum*; angular leaf spot, *Isariopsis griseola* and rust, *Uromyces phaseoli*. The major insect pests include: Bean fly, *Ophiomya phaseoli*;

ollworm, *Heliothis armigera*; aphids, *Aphis fabae* and other storage bruchids, *canthoscelides absentus* (Omunyin, 1984).

The importance of a plant pathogen or pest is determined by the economic loss causes. The magnitude of this loss depends on the frequency of the pathogens ccurrence and the severity of the damage caused during the crop life- cycle (Shwartz nd Galvez, 1980).

In Kenya , bean common mosaic virus was reported to reduce the bean height,pod umber,seed weight and weight of whole plant dry matter by 55.3%,55.9%,63.0% and 7.2% respectively in the three commonly cultivated varieties i.e. 'Rose Coco', 'Mwezi oja', and 'Canadian Wonder' (Omunyin, 1984).

Studies conducted by Mukunya and Keya (1978) showed that plots planted with eeds infected with anthracnose were more diseased and correspondingly had more sses than those planted with hand sorted clean seeds.

Halo blight has been reported to cause yield losses ranging between 23-40% in perimental fields (Saettler and Potter,1970).In Kenya the average loss due to the sease amounts to 42% (Mukunya and Keya, 1975).

The objectives of this study were:-

(1) To hybridize some popular bean cultivars susceptible to bean common mosaic virus, anthracnose, *Colletotrichum lindemuthianum* and halo blight, *Pseudomonas phaseolicola* with local or exotic lines resistant to these diseases.

(2) Select lines with combined resistance to two or more of these diseases.

(3) Determine the nature of inheritance of resistance to the above three diseases.

(4) Assess the effect of these diseases on agronomic performance of parental material and their progenies.

LITERATURE REVIEW

2.0

2.1 Classification and biological description of *Phaseolus vulgaris* L.

Taxonomically, the common bean belongs to the genus *Phaseolus* and species *Vulgaris* assigned by Linneaus in 1953. It belongs to the tribe *Phaseoleae* sub-family *Papilionoideae*, family *Leguminosae*, order *Rosales*. According to Purseglove 1968), the genus *Phaseolus* L. has about 150 species of annuals and perennials hroughout the warm regions of both hemispheres. Some species have tuberous roots. The standard is reflexed; wings same length or longer than standard; keel spirally coiled, which is the distinctive mark of the genus; stamens 10, diadelphous with free vexillary stamens of equal length, anthers are uniform, style is filiform, twisted, bearded on inner curve.

The most important and widely cultivated species of *Phaseolus* are *Phaseolus vulgaris* and *lunatus*. *P. aureus* and *P. mungo* are important pulse crops n India. *P. aconitifolius, P. acutifolius, P. angularis* and *P. calcaratus* are pulse crops of minor importance. *Phaseolus coccineus* is an important summer vegetable in Europe, but can only be grown at higher altitudes in the tropics. A number of species are grown as green manure and cover crops and also for fodder. These include *Phaseolus aconitifolius, Phaseolus aureus, Phaseolus calcaratus, Phaseolus metcalfci* and *Phaseolus mungo.*

Phaseolus vulgaris L. (2n = 22, X = n = 11) is the best known and mostly ultivated species of *Phaseolus*. They are grown for their immature edible pods and for

ne dry ripe seeds and to a lesser extent for green shelled beans. The leaves are used ıs a pot-herb in some parts of the tropics. In Latin America and parts of tropical Africa hey furnish a large part of the protein food of the inhabitants, being grown mainly for ıe dried pulse. They are little grown in India where the people prefer their own, better nown pulses. In Europe, the United States and other temperate countries, they are rown mainly for the green immature pods which are eaten as a vegetable and are also anned and frozen. The whole dried beans are also cooked with tomato sauce and anned and are usually known as baked beans. The straw is used for forage Purseglove, 1968).

In *Phaseolus vulgaris* L. the flowers are hermaphrodite and the pollination is 98% utogamous (Roemer and Rudolf, 1962). The flower biology is illustrated in Figure 1.

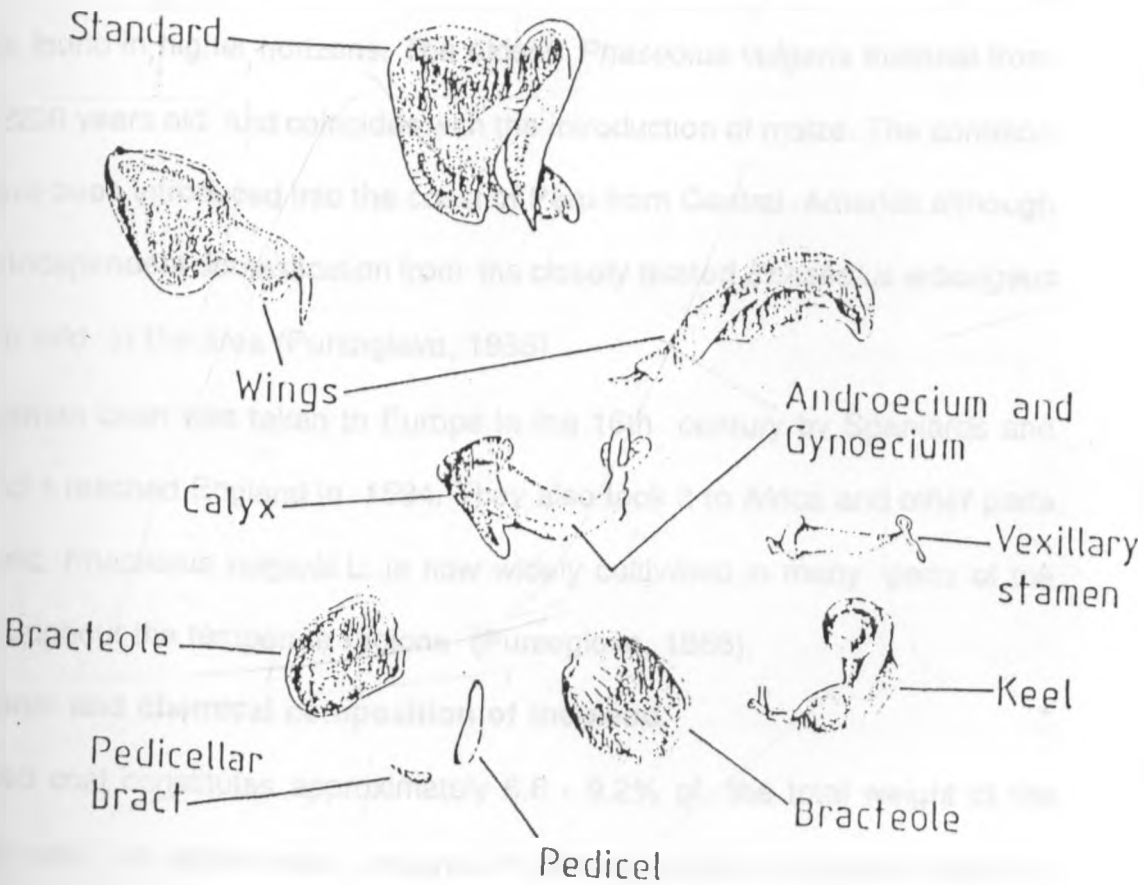


Figure 1: Parts of the bean *Phaseolus vulgaris* L. flower. (Daniel Deboreck, A.I.GX; Rigoberto Hidalgo, H.; M.S. CIAT; 1986).

2.2 Origin and distribution of *Phaseolus vulgaris* L.,

Phasaeolus vulgaris L. is of New world origin. The earliest remains of the common ean that are clearly domesticated is an uncharred pod value with a carbon^{14} date 4975 .C. ± 200 from the Cox Catlan cave in the Tehuacan valley in Mexico and is ontemporary with maize. The evidence for domestication is the breadth of the pod and ıe absence of the well developed parchment layer and dehiscence mechanism, being milar to those found in higher horizons. The oldest *Phaseolus vulgaris* material from eru is about 2200 years old and coincides with the introduction of maize. The common ean could have been introduced into the coast of Peru from Central America although may have an independent domestication from the closely related *Phaseolus arborigeus* ıich occurs in wild in the area (Purseglove, 1968).

The common bean was taken to Europe in the 16th century by Spaniards and ırtuguese and it reached England in 1594. They also took it to Africa and other parts the old world. *Phaseolus vulgaris* L. is now widely cultivated in many parts of the pics and throughout the temperate regions (Purseglove, 1968).

Nutritional and chemical composition of the seed.

The seed coat constitutes approximately 6.6 - 9.2% of the total weight of the mmon bean seed. An approximate analysis of the dry matter of common bean is: isture 11.0%, protein 22.0%, carbohydrates 57.8%, fibre 4%, ash 3.6% , calcium 137 /100 g, iron 6.7 mg/100 g, vitamin A 30 µm/100 g, thiamin 0.54 mg/100g, riboflavin 3 mg/100 g, niacin 2.1 mg/100 g and ascorbic acid 3.0 mg/100 g (Kay, 1979).

2.4 Bean common mosaic virus.

Common mosaic of bean was first recognized by Iwanoski in Russia as early as 899, and by Chinton in Connecticut, U.S.A. in 1908. Symptoms of mosaic have been bserved in young seedlings of bean from 22 different countries. The disease has been ported in 42 of the 51 states of the U.S.A.

Bean common mosaic virus has been widely regarded as one of the most iquitous and generally destructive virus-induced disease of beans. Plants from infected ed comprise the primary inoculum source from which common bean mosaic virus is nsmitted by aphids to other plants. Moderate and severe bean mosaic cause 50% and % reduction in the number of pods per plant respectively and 53% and 68% reduction eed yield (Hamton, 1975). The estimated yield losses obtained from bean pathogens l insect pests under experimental conditions are shown in appendix 6 (FAO,1979).

In Kenya, bean common mosaic virus was reported to reduce the bean height, pod ber, seed weight and weight of whole plant dry matter by 55.3%, 55.9%, 63% and ?% respectively in the three commonly cultivated varieties i.e 'Rose Coco', 'Mwezi a' and 'Canadian Wonder' (Omunyin, 1984). There has been a rapidly growing reness of the impact of resistant bean cultivars as a tool for effective control of IV. Plant resistance to the virus has been available since resistance was discovered ltivar Robust (Schwartz and Galvez, 1980). The resistance to robust was conferred single recessive gene which originated from pea bean (Ali, 1950). Known strains MV in Kenya and East Africa in general include E.A.-BCMV (Kulkerni, 1972), the

T-BCMV (Gathuru, 1975) and K-BCMV (Buruchara, 1979). In addition to these strains, various isolates of BCMV have been reported to occur in Kenya (Mukunya and Karue, 1979).

The particles of BCMV are long pod like structures measuring 750 um in length similar to other viruses of the potato virus Y group.

The bean common mosaic virus is inactivated by alcohol at strength between 25 to 50%. The thermal inactivation point is between 56° and 58°C for 10 minutes exposures. The dilution end point is about 1:1000 and the longevity in vitro lies between 24 and 32 hours at room temperature (Omunyin, 1984).

2.4.1 Mode of transmission of bean common mosaic virus.

Bean common mosaic virus could be transmitted through seed, aphid and mechanical injury. Seed transmission of bean common mosaic virus and New York virus (NY 15) through either pollen or ovules of infected plants was obtained in high percentage by crossing diseased and healthy plants(Medina and Grogan, 1961). The F_1 progeny resulting from pollination of resistant plants with infected pollen from susceptible plants contained a large number of infected plants when resistance was recessive, and no infected plants when resistance was dominant. A portion of seed of some resistant varieties transmitted the virus when fertilized with pollen from infected plants but less transmission occured when infected susceptible females received pollen from the same resistant varieties. Low percentage of seed transmission of the virus resulted if infection occured after blooming period and plants infected during early vegetative growth

oduced more infected seed than plants infected at later stages. Therefore, any effect the environment on the percentage of seed transmission probably would be pressed only if applied prior to the flowering stage (Medina and Grogan, 1961).

Crowly (1955) studied the effect of temperature on the percentage of seed nsmission of bean common mosaic virus and reported that no seed transmission curred when the temperature was maintained below 68°F before the flowering period edina and Grogan, 1961).

Settler and Wilkinson (1966) reported that the aphid species, *Myzus persicae* ade two kinds of probing behaviours during the transmission of common bean mosaic us and therefore grouped the two probing behaviours into single probe aphids (SPA) d multiple-probe aphids (MPA). The single probe aphids were those that made only gle initial probe within a given access period. The multiple probe aphids were those it made several terminations within the same given access period. The major ference in transmission between single-probe aphids and multiple-probe aphids curred when the duration of terminal probes was between 11 and 20 seconds. Their estigations showed that 30 of 37 (81%) MPA making terminal probes of 11 to 20 conds transmitted BCMV, whereas only 79 of 167 (47%) SPA making probes of 11 to seconds transmitted the virus. No appreciable difference in the rate of transmission s noted, however, between MPA making terminal probes of 212 to 100 seconds and A making similar probes: 10 of 22 MPA (46%) transmitted BCMV compared to 49 of SPA (49%). Nor was any appreciable

difference noted between MPA and SPA probing for 6 to 10 seconds: 3 of 11 MPA (27%) transmitted BCMV compared to 11 of 38 SPA (29%).

It would appear from the above information that the terminal probe is the one that largely determines virus transmission but that the probability of transmission by a probe of a given duration is influenced by whether or not the aphid has probed previously. The data also indicated that an aphid that acquires BCMV during a short probe can lose it by making a long subsequent probe on the virus source. Conversely, it appeared that an insect making, one or more 'feeding probes' on the virus source still become a good transmitter by making a 'transmission' probe just before being transferred to a test plant.

According to Ali (1950), bean common mosaic virus was transmismitted from an infected susceptible variety of *Phaseolus vulgaris* L. (Stringless Green Refugee) to varieties of the same species (Stringless Green Refugee x M.5 No.5 Refugee, Stringless Green Refugee x Idaho Refugee and Stringless Green Refugee x Robust) through rub-inoculation technique which is a form of mechanical transmission. This situation implies that common bean mosaic virus can also be transmitted through weeding tools from infected plants to uninfected ones.

2.4.2 Genetics of resistance to bean common mosaic virus.

Resistance to bean common mosaic virus could be classified into two categories:-

1. Dominant resistance, present in the cultivars derived from Corbett Refugee.

Recessive resistance, present in the varieties Robust and Michelite also from the U.S.A. and which probably originated from pea bean (Ali, 1950).

A number of recessive genes have been reported as conferring resistance to CMV. One recessive gene bc-μ is strain non-specific and is complimentary to a series f strain specific genes, some of which occupy different loci. Thus bc-1 and bc-1^2 are lelic, as are bc-2 and bc-2^2 while only one allele bc-3 has been found at a third locus. c-2 is on gene 'a' found originally in the cultivar Robust (Drijfhout, 1978).

There are corresponding pathogenicity (P) factors for each of the four rain-specific resistance genes bc-1, bc-1^2, bc-2 and bc-2^2. For a fifth resistance gene c-3, a corresponding pathogenicity gene has not yet been found. NL4 strain of BCMV as the pathogenicity genes P1, P1^2 and P2^2 and in conjuncture with bc-μ. Only bc-2 nd bc-3 confer resistance to NL4. Resistance to the strain NL3 can be achieved only y plant homologous for bc-μ, bc-2^2 or bc-μ, bc-3. The pathogenicity genes P2 and P2^2 ay be allelic (Drijfhout, 1978).

The cultivar L226-10 (52) which was developed and released co-operatively by RS-USDA and the Agricultural Experiment station of Michigan State University and the niversity of Puerto Rico may have one or more of the above resistance genes to BCMV nce it has high resistance to this disease (Kimani et al, 1990).

5 Halo blight, *Pseudomonas phaseolicola.*

Halo blight has been reported to cause yield losses ranging between 23-40% in perimental fields (Saettler and Potter,1970).In Kenya the average loss due to the

disease amounts to 42% (Mukunya and Keya, 1975).

Patel and Walker (1965) distinguished race 1 and race 2 of the pathogen. Young trifoliate leaves of the dry bean cultivar Red Mexican U.1.3. developed lesions with race 1 at temperatures between 21 and 24°C, occasionally reaching 34°C and water soaked lesions with race 2. They observed the same difference in reaction with the other dry bean cultivars - 'Red Mexican', 'Great Northern' and 'Pinto'. Also on this basis Epton and Deverall (1965), Guthrie and Fenwick (1967) in the U.S.A., Rudolf (1967) in Germany and Wallen (1968) in Canada identified race 1 and race 2.

Schroth, et. al., (1971) concluded that there is an infinite number of races within *Pseudomonas P.- glycinea-P-* non group. Moreover they stated that neither *Pseudomonas phaseolicola* race 1 nor race 2 is homozygous with regard to virulence when tested on a number of bean cultivars. The distinction of race 1 and race 2, however, does not exclude a quantitative variation in host reaction between strains of each race.

Johnson (1969) described 'halo-less' halo blight of French bean in Queensland. Greasy spots in the leaves of susceptible cultivars soon became necrotic. Often leaf malformation resulted from bacterial infection in particular due to necrosis along leaf margins. After inoculation of ten day seedlings near the stem, leaves exhibited premature withering but no chlorosis. Hubbeling (1961) also reported a strain that did not produce toxins which induce chlorosis in the leaves. This isolate was defined as a wild strain of race 1.

1.5.1 Mode of transmission of *Pseudomonas phaseolicola.*

Halo blight is caused by a seedborne bacterium *Pseudomonas phaseolicola* Hill, et. al., 1972). Field experiments conducted at Kabete in Faculty of Agriculture, Field Station in 1976 and 1977 and in small scale farmers' fields in Murang'a District in 1979 showed an average crop loss amounting to 42% due to using infected seed. *Pseudomonas phaseolicola* can also be transmitted through contact by workers while weeding and spraying the crops (Mukunya and Keya, 1978).

1.5.2 Genetics of resistance to *Pseudomonas phaseolicola.*

Patel and Walker (1966) studied the inheritance of tolerance to race ô and race of *Pseudomonas phaseolicola.* They found out that the local necrotic reaction of 'Red Mexican U.1.3' to race 1 was governed by the dominant gene Ppr, while tolerance to race 2 of 'P.1 250414' was based on one recessive gene 'ppt'. Hill, et. al., (1972) found three different genes, each separately controlling the expression of the halo blight reaction in inoculated pods and leaves, and the systemic chlorosis reaction of leaves with respect to race 1. These genes were dominant and also in respect to race 2 when a low concentration of bacteria in the inoculum was used. However, in F_1 hybrids of cultivars tolerant to race 1 and 2 (Great Northern Nebraska 1, selection 27 and P.1. 150414 with the susceptible cultivar 'Gallatio 50') Some susceptible plants occurred when inoculation with a high concentration of bacteria of race 2, was done.

1.6 Bean anthracnose *Colletotrichum lindemuthianum.*

Anthracnose caused by, *Colletotrichum lindemuthianum* is one of the most

that encourages inoculum production and dissemination (Boyd, 1942; Mukunya and Keya, 1975). The pathogen is seed borne and hence remains in the seed from one season to another (Mukunya and Keya, 1978; Chaves, 1980) and the majority of farmers in East Africa use their own seed from previous seasons (Leakey and Simbwa-Bunnya, 1972; Schonherr and Mbugua, 1976). Diseased seeds are planted in nutrient deficient soils with poor cultural practices thus aggravating the problem (Mutitu and Musyimi, 1980). Losses of nearly 100% occur in areas of high humidity when diseased seeds are planted (Chaves, 1980).

Studies conducted by Mukunya and Keya (1978) showed that plots planted with diseased seeds had more disease and correspondingly more losses than those planted with hand sorted clear seeds. Intercropping of beans with maize has been found to reduce disease levels (Rheenen,et al. 1981). Fungicides have been used to control the disease, but resistant varieties are viewed as the cheapest and most practical (Yerkes, 1958; Kinyua, 1976/77a).

Mwangi (1986) tested 41 Kenyan beans lines for resistance to bean anthracnose through inoculation in the greenhouse with one isolate of 'alpha' two of 'beta', two of 'gamma', two of 'lambda', and two of 'epsilon'. He found that the NB 123, a small seeded black bean of indeterminate growth habit, originally collected from Kirinyaga District, was immune to all the nine isolates and could be a potential source of resistance to anthracnose.

Many physiological races of *Colletotrichum lindemuthianum* are known from *Phaseolus* bean grown in various parts of the world. Since Barrus (1911, 1918) distinguished the races 'alpha' and 'beta', Greek letters were used for differentiation of races. Burkhulder (1923) described race 'gamma', Andrus and Wade (1942) race 'delta' and Blondet (1962) defined race 'epsilon'. The identification of races was based on reactions of some American bean cultivars used as differential hosts.

Hubbeling (1974) isolated a deviating mutant 'alpha' race, which one, later called 'lambda'. Resistance to 'lambda' included resistance to the races 'alpha', 'beta', 'gamma', 'delta' and 'epsilon' (Kruger, et. al., 1976).

2.6.1. Mode of transmission of *Colletotrichum lindemuthianum.*

Bean anthracnose caused by *Colletotrichum lindemuthianum* is seedborne and is a major disease of beans in East Africa (Leakey, 1972). Field experiments conducted at Kabete in Faculty of Agriculture Field Station in 1976 and 1977 and in small scale farms in Murang'a District in 1979 showed and average crop loss amounting to 42% due to using infected seed. *Colletotrichum lindemuthianum* can also be transmitted through contact by workers while weeding and spraying the crops (Mukunya, and Keya, 1978).

2.6.2 Genetics of resistance to *Colletotrichum lindemuthianum*

Mastenbroek (1960) found one dominant 'Are' gene in the black seeded dry-shell bean Cornell 49-242 which included resistance to all the races: 'alpha', 'beta', 'gamma', 'delta' and 'epsilon'. Hoffmann et al (1974, 1975) described a new race 'Ebnet' which broke down the resistance derived from the 'Are' gene. During the past years, the

monogenic dominant resistance of 'Cornell 49-242' and other cultivars carrying the same 'Are' gene had been considered of a 'uniform' or 'horizontal' type because this gene was active against many races of the fungus. However, the break-down of this gene by the 'Kappa' race of *Colletotrichum lindemuthianum* raises a surmise that this gene only gave a 'vertical', race specific resistance (Kruger, et. al., 1976).

NB-123 is a black and small seeded bean indigenous in Kenya and has proved resistant to all common races of bean anthracnose (Mwangi, 1986) and other common diseases of beans like halo blight and rust in Kenya (Mukunya and Keya, 1978). The cultivar 535 (M9) is also a possible source of resistance to *Colletotrichum lindemuthianum* (Kimani, personal communication). The above two varieties could therefore serve as good parental materials in breeding for resistance to *Colletotrichum lindemuthianum.*

3.0 MATERIALS AND METHODS

3.1 The plant material

Seven bean cultivars; GLP-2, GLP-288, GLP-24, GLP-x.92, M535, L226-10(52) and NB-123 were used in this study. GLP-2, GLP-24 and GLP-x.92 are from an extensive testing programme (Grain Legume Project) of dry bean cultivars at the National Horticultural Research station, Thika. They have been released to the farmers after extensive testing and have proved very acceptable (Van Rheenen et al., 1984).

GLP-288 was also developed by the Grain Legume Project of Horticultural Research station (NHRS) at Thika but has not been released to the farmers due to the lack of data to support its distinctiveness, uniformity, stability, superiority in yield and disease resistance (Van Rheenen et al., 1984).

M535 is one of the advanced generation (M_9) lines derived from radiation treated bean cultivar Canadian Wonder. Earlier generations have been evaluated for resistance to common bean diseases like anthracnose *Colletotrichum lindemuthianum,* angular leaf spots *Isariopsis griseola* Sacc. and rust *Uromyces appendiculatus* in Kenya and upto 11% increase in grain yield in M5 and M6 generations has been reported (Kimani, 1988).

L226-10(52) is a white and small seeded cultivar which is one of the two breeding lines of navy beans *Phaseolus vulgaris* L.. It was developed and released co-operatively by ARS-USDA and the Agricultural Experiment station of Michigan State University and the University of Puerto Rico. It has an upright architecture and combines high level of

disease resistance to rust, bean common mosaic virus, and several root rot diseases and a high yield potential. It is resistant to angular leaf spot, *Isariopsis griseola* Sacc. and bean rust *Uromyces phaseoli* under field conditions at Kabete (Buruchara, 1987; personal communication).

NB-123 is a small-seeded black bean indigenous in Kenya and is resistant to all common races of bean anthracnose (Mwangi, 1986), halo blight and rust in Kenya (Mukunya and Keya, 1978). Due to its small size and black colour, it is not acceptable to consumers and hence can not be released as such.

Table 1 indicates the growth habits, days to 50% flowering, grain yield (kg ha^{-1}), 100 seed weight and the average number of seeds per pod of the seven cultivars used in this study.

The seeds, flowers and growth habits of the seven cultivars are shown in plates, 1, 2, 3. 4, 5, 6, 7 and 8. Figures 2, 3, 4 and 5 show the growth habits types I, II, III and IV respectively as described by CIAT bean researchers Daniel Debouck and Rigoberto Hidalgo (1986).

The F_1 progenies were derived from a complete diallel cross with all the seven bean cultivars. The 28 F_2 and F_3 progenies used in this study were selected from among the 42 F_1 progenies with the best general and specific combining abilities in respect to some agronomic traits tested by Tumwesigye (1988).

Table 1: Some characteristics of the seven bean cultivars.

Cultivars	Characteristics					
	Growth habit 'type'	Days to 50% flowering	Days to 50% maturity	Grain yield (kg ha^{-1})	100-seed Weight (g)	Seeds/ pod
GLP 2	I	49	91	1828	52	5
GLP-288	I	47	96	1201	43	4
GLP-24	II	52	100	1662	34	5
GLP-x.92	III	48	92	1472	39	4
M535	II	54	98	1732	49	6
L226-10(52)	I	56	104	1907	18	7
NB-123	IV	52	97	1722	20	6

Source: (Tumwesigye, 1988)

1: Flowers and seeds of the seven parental bean cultivars: 1 = M535;

LP.X.92; 3 = GLP-2; 4 = GLP-288; 5 = L226-10(52); 6 = GLP-24;

3-123.

Plate 2: A GLP-2 plant showing type I growth habit. Plants with this type of growth habit have the following characteristics.

1. The main stem and lateral branches end in well developed inflorescences. When an inflorescence is formed, the growth of the main stem generally ceases.

2. Flowering lasts for only a short time and the pod mature almost simultaneously.

Plate 3: A GLP-288 plant showing type I growth habit. It has growth characteristics similar to those of GLP-2 shown on plate 2.

Plate 4: A GLP-24 plant showing type II growth habit. Plants with this type of growth habit have the following characteristics:-

1. The number of nodes on the main stem is greater than in type I plants.
2. The plant continue growing vegetatively even during flowering thus developing longer main stems and branches than type I plants.
3. It has more side branches than type I plants which are generally short with respect to the main stem.

Plate 5: A GLP-X.92 plant showing type III growth habit.

Plants with this type of growth habit have the following characteristics:-

1. The number of nodes on the main stem and branches are greater than those of type I and II.
2. The main stem is longer than those of type I and II plants.

Plate 6: A M535 plant showing type II growth habit.

It has growth characteristics similar to those of GLP-24 shown on plate 4.

Plate 7: A L226-10(52) plant showing type I growth habit.

It has growth characteristics similar to those of GLP-2 shown in plate 2.

Plate 8: A NB-123 plant showing type IV growth habit.

Plants with this type of growth habit have the following characteristics:-

1. The main stem can attain a height of over 2 m. meters with support.
2. Has poorly developed branching due to the strong apical dominance.
3. The flowering period is much longer than that of growth habit I, II and III.

Figure 2: Diagram of a plant with determinate bush growth habit (Type I) Daniel Debouck, A.I. GX: Rigoberto Hidalgo, H., M.S. CIAT, 1986).

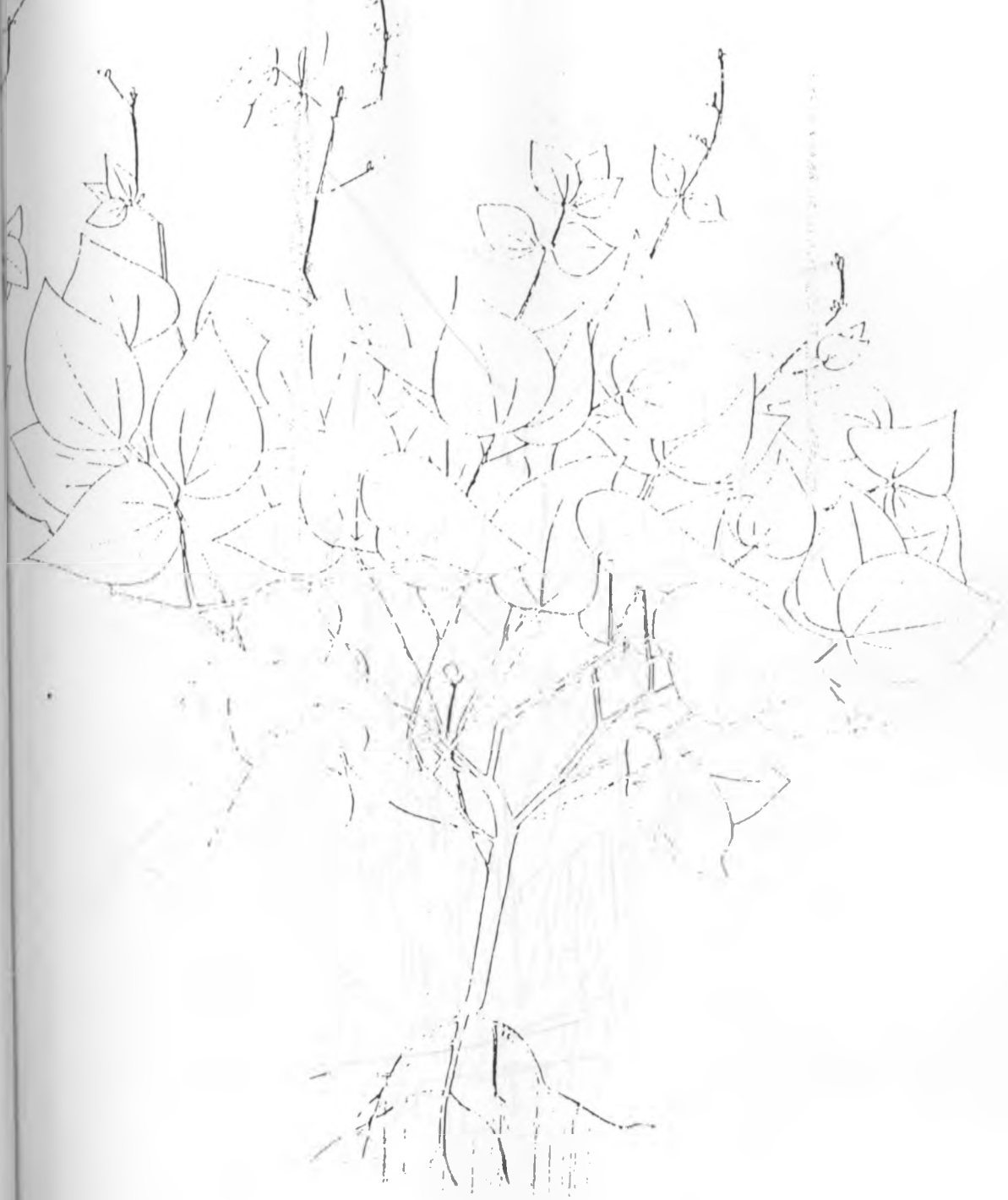


Figure 3: Diagram of a plant with indeterminate bush growth habit (TypeII) (Daniel Debouck, A.I., GX; Rigoberto Hidalgo,H.M.S.;CIAT,1986).

igure 4: Diagram of a plant with indeterminate prostrate growth habit (Type III)

(Daniel Debouck, A.I., GX; Rigoberto Hidalgo, H. M.S., CIAT, 1986).

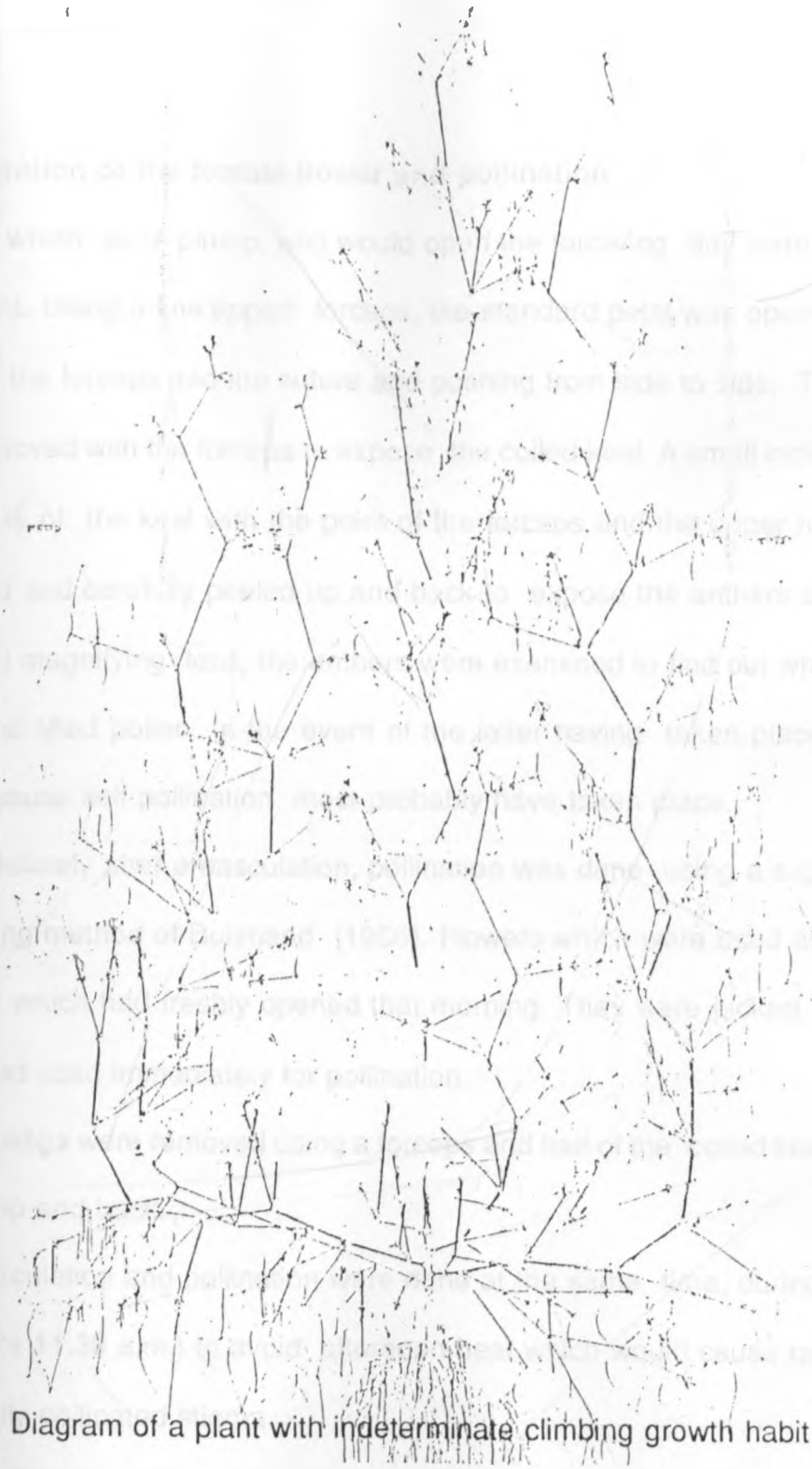


Figure 5: Diagram of a plant with indeterminate climbing growth habit (Type IV) (Daniel Debouck, A.I., GX; Rigoberto IV. Hidalgo H. M.S. CIAT,1986).

3.2 Preparation of the female flower and pollination.

Buds which were plump, and would open the following day were chosen as the female parent. Using a fine tipped forceps, the standard petal was opened by inserting the point of the forceps into the suture and pushing from side to side. The wings were carefully removed with the forceps to expose the coiled keel. A small incision was made near the base of the keel with the point of the forceps and the upper half of the keel was grasped and carefully peeled up and back to expose the anthers and the stigma. Using a x 10 magnifying lens, the anthers were examined to find out whether they had dehisced and shed pollen. In the event of the latter having taken place, the bud was rejected because self pollination most probably have taken place.

Immediately after emasculation, pollination was done using a slight modification of the hooking method of Buishand (1956). Flowers which were used as pollen source were those which had freshly opened that morning. They were picked, placed on the petri-dish and used immediately for pollination.

The wings were removed using a forceps and half of the coiled keel was removed by peeling up and back.

Emasculation and pollination were done at the same time, during early morning hours (before 11.30 a.m.) to avoid afternoon heat which would cause rapid desiccation of the freshly pollinated stigma.

All subsequent flowers and selfed pods were removed regularly to avoid competition between crossed and selfed pods Crossing was done in all possible

combinations to obtain a complete set of 42 F_1s. At least five crosses were made per plant.

After pollination, a tag labelled with the pedigree of the cross was tied loosely on the flower stalk. At maturity, the pods were harvested, together with their identification tags into separate bags. They were further sun-dried and hand threshed. The dry seeds were kept in separate envelopes which were stapled and labelled. Plate 9 shows part of the crossing procedure.

3.3 Soil preparation and plant management in the greenhouse.

Crossing was carried out under greenhouse conditions at the field station, Faculty of Agriculture, Kabete for a period of four months (October-January, 1988/89). Plastic pots of 8" diameter were filled with unsterilized soil mixture made from top forest soil, sand and farmyard manure in the ratio of 2:1:1 by volume, respectively. Diammonium phosphate (18% N, 21-23% P) fertilizer was added at the rate of 20 g per debe (20 litre tins) of soil mixture (Okiror, 1981). One week before planting, the greenhouse was thoroughly washed with pressurized water and fumigated with Dithane M 45 (50 g in 20 litres of water) and Rogor L 40 (50 litres of water) to kill any floating fungal spores, mites and whiteflies, respectively. Seeds were dressed with Aldrin (40% WP) at the rate of 10 g/kg seed before planting for protection against beanfly. Three seeds were planted per pot and later thinned to two plants per pot. Watering was regularly done to avoid moisture stress which is detrimental to bean growth. Water splashing on the plants and benches during watering was avoided to reduce spread of the pathogens.

Plate 9: Crossing procedure with the seven bean cultivars

Spraying of the plants with a mixture of Rogor L 40 and Dithane M 45 30 cc in 20 l water and 30 g in 20 l water respectively at 2-week intervals kept mite population low. All the plants were staked for support owing to the greenhouse conditions which enhanced viny growth even for non-climbers. In addition, the greenhouse floor was thoroughly wetted to keep humidity high throughout the crossing period. High relative humidity reduces the desiccation of flowers after emasculation and is conducive to good seed set.

3.4 Experimental design.

In the greenhouse at the Faculty of Agriculture, Field Station, Kabete and in the field both at Kabete and at the National Horticutural Research Centre-Thika, the parental material F_2 and F_3 were arranged in a split plot design with four replications in March 1989. The disease treatments were in the main plots while the cultivars and the crosses were in the sub-plots. In the greenhouse, there were two plants per pot. In the field, the parental material was planted in $10m^2$ plots while the F_2 and F_3 were planted on 8 m^2 plots.

Due to the limiting amount of F_1 seeds (averaging 130 seeds/cross) the F_1s were planted on double rows of 3 m per cross both at Kabete and Thika.

The spacing of the parental material, F_1, F_2 and F_3 in the field was 50 cm between the rows and 10 cm within rows. DAP fertilizer was applied at the rate of 10 g per plant.

3.5 Pathogen preparation, inoculation and disease assessment.

3.5.1 Bean Common Mosaic Virus.

A virus isolate 510 was obtained from the National Horticultural Research Centre (NHRC) Thika. The virus is very virulent because it has reduced the shoot dry weight of the varieties; 'Rose Coco', 'Mwezi Moja' and Canadian Wonder by 25.31, 25.33 and 30.34% respectively (Omunyin, 1984). Inoculum was prepared by macerating 22 day old diseased plants in 0.01 m potassium-phosphate buffer pH 7.3 at the ratio of 1:1 (tissue-buffer) and the crude extract diluted with distilled water at the ratio 1:10 (crude extract: water) (Buruchara, 1979; Morales, 1979)

Mechanical inoculations were performed on 10 day-old plants. Plants to be inoculated were dusted with 500 or 600 mesh caborundum powder and rubbed with the fore finger after dipping it into the inoculum. All the plants used for testing were raised in the greenhouse at the field station of Faculty of Agriculture, Kabete, where greenhouse temperatures were maintained at 25 ± 5%. The temperatures were regulated in extreme cases using the mist system installed inside the greenhouse. The inoculation with bean common mosaic virus is illustrated in plate 10.

In the visual disease assessment of bean common mosaic, a 1 to 5 disease assessment scale was not used but instead, the symbols (R) and (S) standing for 'Resistant' and 'Susceptible' respectively were used. This was in accordance with Vijfhout's (1978), system of BCMV disease evaluation. The term tolerance (T) was used in describing the situation whereby the plants expressed the disease

symptoms but the symptoms did not have a significant effect on the quantative trait of the host plants (Van der plank, 1968).

In order to determine the effect of bean common mosaic virus on the parental material, F_2 and F_3 in the greenhouse, data on number of primary branches per plant, number of pods per plant, number of seeds per plant, the 100 seed weight and weight of dry matter per plant was recorded on 4 randomly selected plants for both inoculated and control plants. In order to determine the mode of inheritance of resistance to BCMV in the cultivar L226-10 (52), the ratios between the resistant and susceptible plants in the F_1 and F_2 progenies of the crosses:- L226-10(52) x GLP-2, L226-10(52) x GLP-X.92 and their reciprocal was investigated.

Plate 10: Rub-inoculation with bean common mosaic virus.

3.5.2 *Pseudomonas phaseolicola*

Inoculum suspensions were prepared in distilled water from 48 hr old cultures grown on yeast dextrose calcium carbonate agar (YDCA) medium; (Yeast extract (Difco), 10 g, dextrose (Difco), 20 g, $CaC0_3$ 3.5 g; bacto - agar (Difco), 20 g distilled water, 100 ml.). The suspensions were then adjusted turbidimetrically using a spectronic 20 spectrophotometer (Bausen and Lomb Co.) at 600 nm to a concentration of about 5 x 10^7 colony forming units (CFU) per ml of water.

The primary and the first tri-foliate leaves of 12 day old plants were inoculated using the watersoaking method as described by Schuster (1953). The abaxial surface of the leaf was sprayed with the bacterial suspension using a De Vilbiss No. 15 atomizer attached to a compressed airline at 15 p.s.i. (1.05 kg of force/cm^2) until water soaking appeared. Distilled water was also infiltrated on some plants used as controls. Inoculated plants were kept in the cooler part of the greenhouse where temperatures averaged 22°C. The inoculation procedure is illustrated in plate 11.

A five class disease severity assessment scale was used to score the degree of infection with *Pseudomonas phaseolicola*. This was done ten days from inoculation.

The scale was follows:-

1.= Healthy (no symptoms)- 0% of leaf area covered with lesions.

2. = A few isolated small lesions; < 2% of the leaf area covered with lesions.

3. = Many small lesions; 3-10% of the leaf area covered with lesions.

Plate 11: Inoculation of 10 day old bean plants with *Pseoudomonas phaseolicola* using the watersoaking method.

Plate 12: Symptoms of halo blight *Pseudomonas phaseolicola* as expressed on the primary leaves of a thirteen day old GLP-2 plant.

3.5.3 *Colletotrichum lindemuthianum.*

Infected leaves and stems were thoroughly washed in sterile water and dried between two sterile filter papers. The parts with lesions were cut with a scaple blade into pieces and imersed into 10% bleach (sodium hypochlorite) for 5-10 minutes. They were then gently pressed between sterile filter papers to drain off excess bleach and transferred into potato dextrose agar (PDA) plates in sterile water and small pieces cut from infected parts and treated like leaves and stems.

In order to have pure cultures of the isolates and to ensure uniformity for each isolate used for inoculation, single spores were used to propagate stocks for inoculation. After sporulation, spores were scraped off with a microscope slide and placed in a beaker with sterile water. Serial dilutions were then made from the initial suspension. To establish the appropriate dilution, samples were observed under a compound microscope and the one showing one to two spores in X 100 objective was selected.

One ml of the selected dilution was poured into plain PDA plate and spread evenly, excess water was drained off by tilting the plate. Using a dissecting microscope, a small rectangular piece of the medium with a spore was cut off using a hair size end of a glass rod. The spore mounted on the piece of medium was then transferred into a bean pod enriched nutrient agar plate and incubated at 20°C for 5-7 days. When the colony was established, sporulating small pieces were cut and each placed in fresh plate of PDA and nutrient agar enriched with green bean pod extract.

From the plates, spores were wetted with 0.2 ml phosphate buffer (0.01 m) at pH 7.2. Using a microscope slide, the spores were dislodged from the media and placed into 250 ml beakers containing 200 ml of sterile water. The suspension that was filtered through cheese cloth was adjusted to a concentration of 1.0×10^6 spores per ml using a hemocytometer. These suspensions were translucent when poured into universal bottles ready for inoculation.

Plate 13 shows a culture of *Colletotrichum lindemuthianum* grown on PDA and nutrient agar enriched with green bean pod extract medium.

The seedlings were considered ready for inoculation 12 days after germination when the primary leaves spread. The beans were sprayed outside the greenhouse so as to prevent the spread of the pathogen throughout the greenhouse. The beans were then covered with moistured polythene plastic bags and transferred into the greenhouse. A household atomizer (Bayer East Africa Ltd. household products) was used for inoculation. Control plants were sprayed with sterile water and covered. All test plants remained covered for 48 hours after inoculation in the greenhouse where temperatures rarely exceeded 25°C.

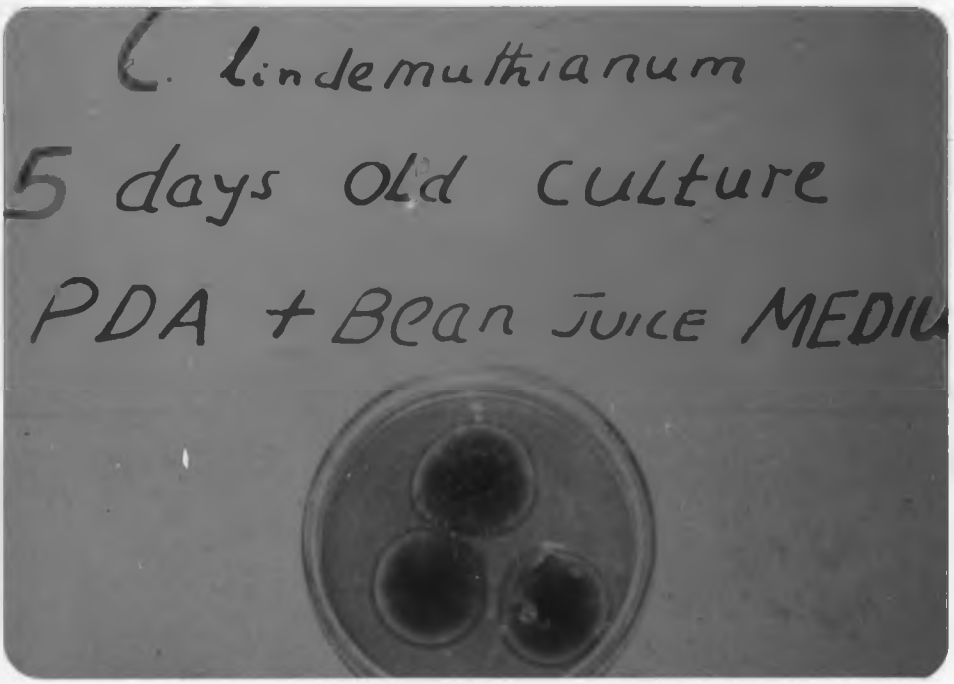


Plate 13: A culture of *Colletotrichum lindemuthianum* grown on PDA and nutrient agar enriched with green pod extract medium.

The inoculation procedure and the covering method are shown in plates 14 and 15, respectively.

A five class disease severity assessment scale, described in section 3.5.2 was used to score the degree of infection with *Colletotrichum lindemuthianum*. This was done ten days after inoculation.

Plate 16 shows the five class severity assessment scale in respect to anthracnose. In order to determine the effect of *Colletotrichum lindemuthianum* on the parental material, F_2 and F_3 in the greenhouse, the data were recorded on number of primary branches per plant, number of pods per plant, number of seeds per plant, 100 seed weight and the weight of dry matter per plant for both inoculated and control plants.

In order to determine the mode of inheritance for resistance to *Colletotrichum lindemuthianum* in the cultivar NB-123, the number of resistant and susceptible plants in the F_1 and F_2 progenies of the crosses NB-123XGLP-2, NB-123 x GLP- X.92 and their reciprocals were counted. Plants with disease ratings 1 and 2 were considered resistant while those with ratings 3, 4 and 5 were considered susceptible.

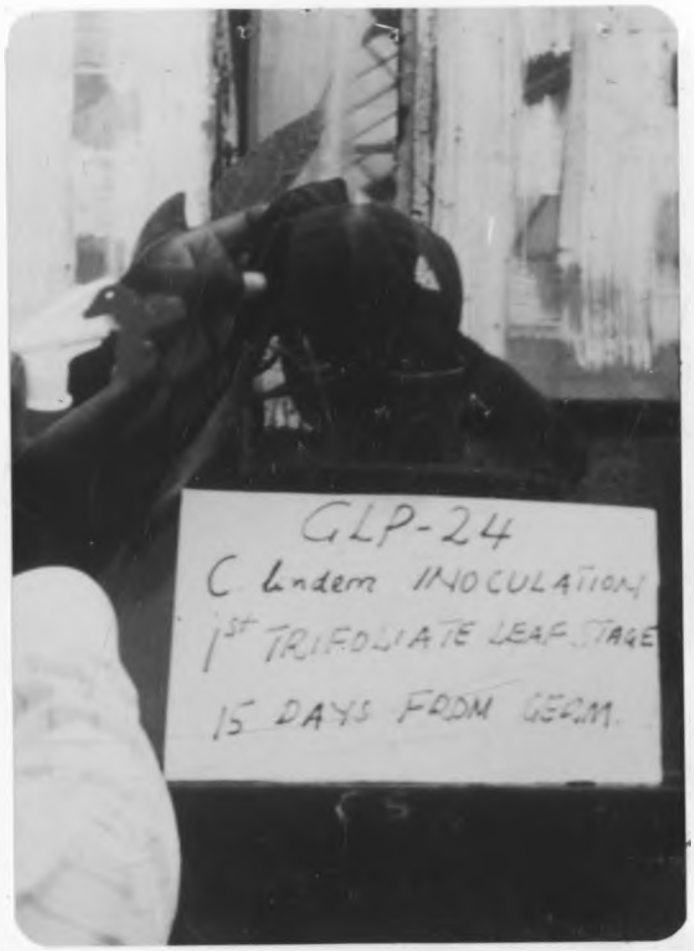


Plate 14: Inoculation of 15 day old plants with *Colletotrichum lindemuthianum*.

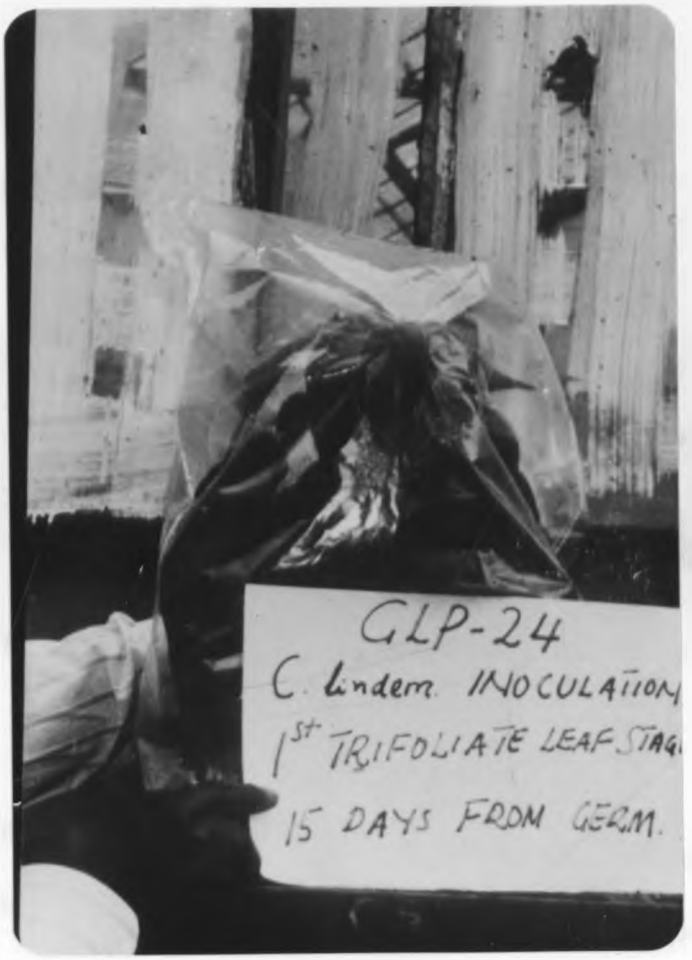
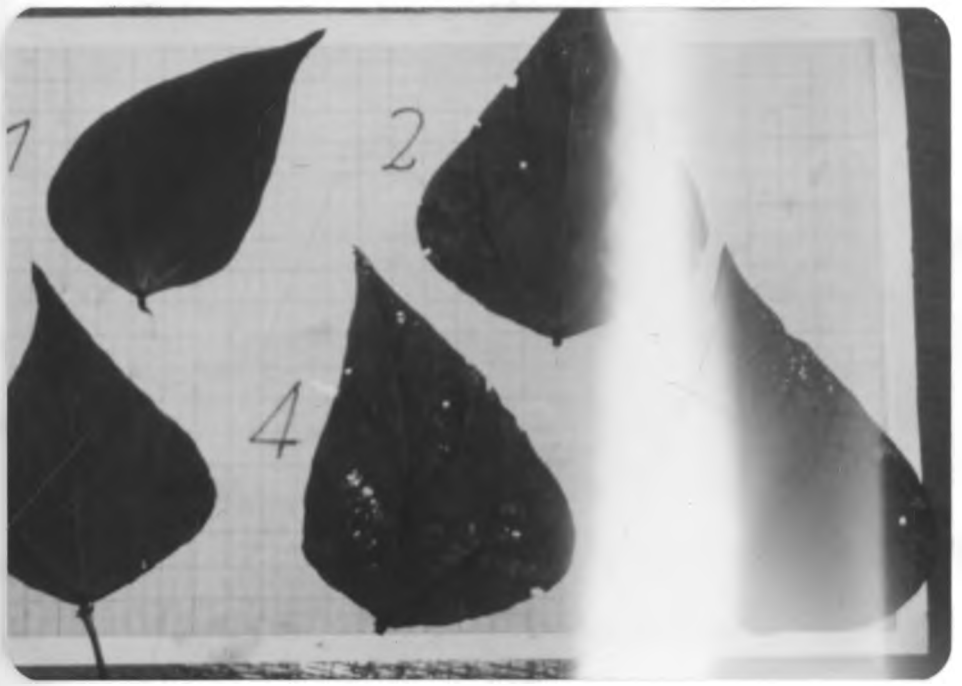


Plate 15: The covering of beans inoculated with *Colletotrichum lindemuthianum*.



e 16: Mid-points of the five classes used in the assessment of severity of anthracnose *Colletotrichum lindemuthianum* based on the percentage of the leaf area covered with lesions.

1 = 0%, 2 = < 2%, 3 = 3-10%; 4=11-25% 5 = > 26%.

3.6 Statistical analysis.

A chi-square test for a fixed ratio hypothesis was used to predict whether the observed ratios (resistant: susceptible) were consistent with the theoretical expected ratios (Steel and Torrie, 1960).

In all cases, the formula employed was as follows:-

$$\text{Chi-square} = \sum (O-E)^2/E$$

Where: O = Observed numbers

E = Expected numbers

The calculated chi-square value was then compared to the tabulated chi-square values based on the chi-square distribution with k-1 degrees of freedom where k is the number of pairs of comparisons.

Data on agronomic traits; number of primary branches per plant, number of pods per plant, number of seeds per plant, 100 seed weight and weight of dry stem and roots of the parental bean material, F_2 and F_3 was subjected to the analysis of variance.

The model used was;-

$$X_{ijk} = \mu + \rho_i + \alpha_j + \delta_{ij} + \beta_k + (\alpha\beta)_{jk} + E_{ijk}$$

Where; X_{ijk} = Observation in the i^{th} block on the j^{th} pathogen and the k^{th} cultivar.

μ = mean

pi = effect of the i^{th} block

α_j = effect of the j^{th} disease treatment

δ_{ij} = Interaction effect of the blocks and the disease treatment

β_k = Effect of the k^{th} genotype

$(\alpha\beta)_{jk}$ = Interaction effect of the j^{th} disease treatment and the k^{th} genotype

E_{ijk} = Error term (the random effect associated with the ith block on the jth disease treatment and the k^{th} genotype).

RESULTS

.1 Diallel Crossing.

A total of 1800 pollination were made out of the complete diallel with the seven arental bean cultivars. Of these, 1400 were successful, giving an overall 78.3% of uccessful crosses. The crosses GLP-2 x GLP-X.92, GLP-2 x M535, GLP-288 x GLP-2, LP-24 x GLP-2, GLP-24x NB-123, GLP- X.92 x GLP-2, GLP-X.92 x GLP-24, M535 x LP-2, M535 x GLP-288, M535 x GLP-X.92, NB-123 x GLP-2, NB-123 x GLP-288, B-123 x GLP-24, NB-123 x GLP.X.92, NB-123 x M535, NB-123 x L226-10(52) and 226-10(52) x NB-123 had the higher success rates among the 42 crosses performed ppendix 4).

.2 Disease development in the greenhouse and in the field.

.2.1 Bean Common Mosaic Virus

Table 2 shows the reaction of the parental material, F_1, F_2 and F_3 to bean ommon mosaic virus in the greenhouse and in the field. The GLP-2, GLP-288, LP-X.92 and NB-123 were very susceptible to the virus isolate 510 both in the reenhouse at Kabete and in the field at Kabete and Thika. GLP-24 and M535 were lerant to the virus isolate in the greenhouse and in the field at both locations. 226-10(52) showed a high degree of resistance to the virus isolate both in the eenhouse and in the field. Some F_1, F_2 and F_3 progenies with L226-10(52) as one of parents showed a high degree of resistance to the virus in the greenhouse and in field. Most of the F_1, F_2 and F_3 progenies of the crosses; GLP-288 x GLP-X.92,

Table 2: Reactions of parents, F_1, F_2 and F_3 progenies to BCMV isolate 510 in the greenhouse and in the field.

	Disease reaction							
	F1		F2				F3	
	Field		Green house	Field		Green house	Field	
Cross*	Kabete	Thika	Kabete	Kabete	Thika	Kabete	Kabete	Thika
GLP-2 x GLP-288	T	T	T	T	T	T	T	T
GLP-2 x GLP-24	T	T	T	T	T	T	T	T
GLP-2 x GLP-X.92	T	T	T	T	T	S	T	T
GLP-2 x M535	T	T	T	T	T	T	T	T
GLP-2 x L226-10(52)	R	R	R	364R;131S	350R;140S	T	420R;220S	350R;220S
GLP-2 x NB-123	T	T	T	S	T	T	T	T
GLP-288 x GLP-2	T	T	T	T	T	S	T	T
GLP-288 x GLP-24	T	T	T	T	T	T	T	T
GLP-288 x GLP-X.92	S	S	S	S	S	S	S	S
GLP-288 x M535	T	T	T	T	T	S	T	T
GLP-24 x GLP-2	T	T	T	T	T	T	T	T
GLP-24 x GLP-288	T	T	T	T	T	S	T	T
GLP-24 x GLP-X.92	T	T	T	T	T	S	S	T
GLP-24 x M535	T	T	T	T	T	T	T	T
GLP-X.92x GLP-2	T	T	T	T	T	T	T	T
GLP-X.92x GLP-288	T	T	T	T	T	S	T	T
GLP-X.92x M535	T	T	T	T	T	T	T	T
GLP-X.92x GLP-24	S	T	T	S	T	T	S	T
GLP-X.92x L226-10(52)	R	T	T	370R128S	360R;135S	R	410R;185S	280R;210S
GLP-X.92x NB-123	S	T	T	S	T	S	S	T
M535 x GLP-2	T	T	T	T	T	T	T	T
M535 x GLP-288	T	T	T	T	T	T	T	S
M535 x GLP-24	T	T	T	T	T	T	T	T
M535 x GLP-24	T	T	T	T	T	T	T	T
M535 x GLP-X.92	T	T	T	T	T	T	T	T
L226-10(52) x GLP-2	R	R	R	372R;120S	280R;122S	R	395R;180S	210R;150S
L226-10(52) x GLP-X.92	R	R	T	378R;128S	365R;120S	T	420R;145S	310R;148S
NB-123 x GLP-2	S	T	S	S	T	S	S	T
NB-123 x GLP-X.92	S	T	S	S	T	S	S	T

Description of notations:

Reaction of parents: R - Resistant — L226-10(52) - Resistant
T - Tolerant — GLP-24; M535 - Tolerant
S - Susceptible — GLP-2;GLP 288; GLP-X.92;NB-123 - Susceptible

R = Segregating

S = Non Segregating

GLP-X.92 x GLP-24, GLP-X.92 x NB-123, NB- 123 x GLP-2 and NB-123 x GLP-X.92 were very susceptible to the virus isolate. Most of the F_1, F_2 and F_3 progenies of the crosses; GLP-2 x GLP-24, GLP-2 x M535, GLP-288 x GLP-24, GLP- 24 x GLP-2, GLP-24 x M535, GLP-X.92 xM535, M535x GLP-2, M535 x GLP-288, M5353 x GLP-24 and M535 x GLP-X.92 showed a high degree of tolerance to virus isolate 510 both in the greenhouse and in the field.

4.2.2 Halo blight, *Pseudomonas phaseolicola.*

Table 3 shows the mean disease ratings of the parental material, F_1, F_2 and F_3 to *Pseudomonas phaseolicola* in the greenhouse and in the field. The cultivars GLP-2, GLP-288, GLP-24, GLP-X.92, M535 and L226-10(52) showed a high degree of tolerance to *Pseudomonas phaseolicola* both in the greenhouse and in the field. NB-123 showed a high degree of resistance to the pathogen both in the greenhouse and in the field. All F_1, F_2 and F_3 progenies with NB-123 and M535 as one of the parents showed a high degree of resistance to *Pseudomonas phaseolicola* both in the greenhouse and in the field. All other F_1, F_2 and F_3 progenies showed a high degree of tolerance to the pathogen both in the greenhouse and in the field.

4.2.3 Anthracnose , *Colletotrichum lindemuthianum*

Table 4 shows the mean disease ratings of the parental material, F_1, F_2 and F_3 due to infection by *Colletotrichum lindemuthianum* in the greenhouse and in the field. GLP-2, GLP- 288, GLP-X.92, M535 and L226-10(52) showed a high degree of tolerance to the pathogen under both conditions. GLP-24 was relatively more susceptible to the

Table 3: Reactions of parents, F_1, F_2 and F_3 progenies to halo blight (*Pseudomonas phaseolicola*) in the greenhouse and in the field.

	Mean disease ratings							
	F1		F2			F3		
	Field		Green house	Field		Green house	Field	
Cross*	Kabete	Thika	Kabete	Kabete	Thika	Kabete	Kabete	Thika
-2 x GLP-288	2.3	1.9	2.3	2.2	2.0	2.2	2.1	2.3
-2 x GLP-24	2.2	1.5	2.0	2.0	2.3	2.2	2.2	1.8
-2 x GLP-X.92	2.0	2.0	2.3	3.0	1.6	2.4	2.3	3.0
-2 x M535	1.8	1.3	1.5	2.8	1.3	1.6	1.4	1.8
-2 x L226-10(52)	1.8	1.3	1.3	2.3	1.3	2.3	1.5	1.3
-2 x NB-123	1.0	1.4	1.0	1.2	1.3	1.4	1.2	2.8
-288 x GLP-2	2.3	2.5	2.2	2.2	2.3	2.2	2.0	2.5
-288 x GLP-24	2.4	2.4	2.0	2.3	2.3	2.3	2.2	2.4
-288 x GLP-X.92	3.2	1.9	2.3	2.5	2.0	2.7	2.3	1.9
-288 x M535	1.8	1.5	2.8	2.0	1.3	2.7	1.4	1.5
-24 x GLP-2	2.3	1.2	2.2	2.2	2.0	2.0	2.8	2.2
-24 x GLP-288	2.5	2.4	2.0	2.4	1.9	2.2	2.7	2.4
24 x GLP.X-92	2.2	1.7	2.2	2.5	1.6	2.3	3.0	1.7
24 x M535	1.3	1.3	1.2	2.3	1.5	2.3	1.9	1.3
X.92x GLP-2	2.8	2.3	2.0	2.5	2.0	3.0	2.0	2.3
X.92x GLP-288	2.1	1.8	2.8	2.5	1.8	2.3	2.2	1.8
X.92x M535	1.9	1.6	1.6	2.4	1.6	2.2	2.2	1.6
X.92x GLP-24	1.3	2.0	1.5	2.3	1.9	2.0	2.1	2.0
X.92 x L226-10(52)	2.1	1.7	1.4	1.3	1.5	1.8	1.8	1.7
X.92 x NB-123	1.0	1.4	1.5	1.3	1.2	1.3	2.3	1.5
x GLP-2	2.2	2.0	2.0	2.3	1.5	2.4	2.4	1.7
x GLP-288	2.3	1.5	2.4	2.4	1.9	2.5	2.8	1.5
x CLP-24	1.3	1.4	2.5	1.5	1.3	1.8	1.7	1.5
x GLP-X.92	1.6	1.2	2.8	2.3	1.3	2.0	1.8	1.3
10(52) x GLP-2	2.2	1.7	2.7	2.5	1.9	2.0	2.2	1.6
10(52) x GLP.X.92	2.1	1.9	2.6	2.4	1.5	2.8	2.7	1.5
3 x GLP-X.92	1.0	1.0	1.8	1.4	1.3	2.0	1.3	1.4
3 x GLLP-X.92	1.0	1.0	2.3	1.3	1.2	1.8	1.8	1.5

*disease ratings of the parents: GLP-2 = 2.3; GLP-288, =2.7; GLP-24 = 2.4; GLP-X.92, =2.3; M535 =2.1; L226-10(52), = 2.0; NB-123, =1.

Table 4: Reactions of parents, F_1, F_2 and F_3 progenies to anthracnose (*Colletotrichum lindemuthianum*) in the greenhouse and in the field.

	Mean disease ratings							
	F1		F2			F3		
	Field		Green house	Field		Green house	Field	
Cross	Kabete	Thika	Kabete	Kabete	Thika	Kabete	Kabete	Thika
GLP-2 x GLP-288	2.1	2.1	2.2	2.3	2.0	2.2	2.6	1.8
GLP-2 x GLP-24	1.3	1.8	2.8	1.8	2.2	2.8	1.9	2.5
GLP-2 x GLP-X.92	1.1	2.0	2.6	1.6	2.1	2.0	2.0	1.9
GLP-2 x M535	1.0	1.3	1.4	1.4	1.8	2.2	1.9	1.8
GLP-2 x L226-10(52)	1.2	1.2	2.4	1.7	1.6	2.2	2.0	1.4
GLP-2 x NB-123	1.0	1.0	1.2	1.2	1.2	2.3	1.7	1.6
GLP-288 x GLP-2	2.3	2.3	2.3	2.1	2.0	2.7	2.3	2.1
GLP-288 x GLP-24	1.8	2.0	2.5	2.0	2.2	3.0	2.2	2.2
GLP-288 x GLP-X.92	2.0	1.8	1.5	2.3	2.0	2.2	2.3	1.6
GLP-288 x M535	1.3	1.3	1.4	1.8	1.6	2.3	1.7	1.7
GLP-24 x GLP-2	2.0	2.0	2.3	2.3	2.4	2.5	2.4	2.2
GLP-24 x GLP-288	1.7	1.5	2.8	1.9	1.8	2.4	2.0	2.4
GLP-24 x GLP-X.92	1.5	1.2	2.5	1.3	1.4	2.0	2.0	1.8
GLP-24 x M535	1.1	1.6	1.5	1.2	1.8	1.2	1.9	1.5
GLP-X.92x GLP-2	2.3	2.5	2.3	2.0	2.0	2.8	1.8	2.3
GLP-X.92x GLP-288	2.2	2.0	2.4	2.2	2.2	2.7	1.8	2.0
GLP-X.92x M535	1.8	1.8	1.5	1.4	2.0	2.0	1.7	1.9
GLP-X.92x GLP-24	1.6	1.9	2.1	1.9	1.8	2.2	1.6	1.8
GLP-X.92x L226-10(52)	1.5	1.3	2.2	2.0	1.7	2.3	1.5	1.5
GLP-X.92x NB-123	1.0	1.0	1.0	1.3	1.3	1.2	1.2	1.2
M535 x GLP-2	1.8	2.0	2.5	2.0	2.5	3.1	1.6	2.0
M535 x GLP-288	1.7	2.3	2.2	1.9	2.1	2.2	2.0	2.3
M535 x GLP-24	1.1	2.0	2.0	1.4	2.1	1.3	1.5	1.5
M535 x GLP-X.92	1.3	1.8	2.2	1.5	1.8	2.3	1.8	1.8
L226-10(52) x GLP-2	1.4	1.8	2.3	1.9	1.3	2.2	2.0	1.4
L226-10(52)x GLP-X.92	1.3	1.7	2.2	2.0	1.2	2.4	1.8	1.5
NB-123 x GLP-2	1.4	1.0	2.2	1.2	1.3	1.5	1.2	1.2
NB-123 x GLP-X.92	1.0	1.0	1.3	1.3	1.2	2.7	1.4	1.5

Mean disease ratings of the parents: GLP-2, = 2.5; GLP-288, = 2.3; GLP-24, =3.0

GLP-X.92, = 2.2; M535, =2.0; L226-10(52), =2.0
NB-123 = 1

pathogen under the two conditions. NB-123 showed a high degree of resistance to the pathogen under both conditions. Most of the F_1, F_2 and F_3 progenies involving M535 and NB-123 as one of the parents showed a high degree of resistance to the pathogen under both conditions. All other F_1, F_2 and F_3 progenies showed a high degree of tolerance to the pathogen under both conditions.

4.3 Inheritance of resistance to bean common mosaic virus.

All the L226-10(52) plants showed a high degree of resistance to isolate 510 of BCMV. All the F_1 progeny of crosses involving L226-10(52) as one of the parents also showed a high degree of resistance to the pathogen. Table 5 shows the segregation ratios of the F_2 progenies of the crosses GLP-2 x L226-10(52), GLP-X.92 x L226-10(52) and their reciprocals. The segregation of the F_2 progenies of the above crosses did not differ from the expected ratio of 3:1 (resistant:susceptible). Segregation of the F_3 progenies for resistance to the above pathogen of the same crosses and their reciprocals was 1.90:1, 2.19:1, 2.21 and 2.09:1 respectively as shown in table 6 and therefore did not differ from the expected ratio of 2:1 (segregating:non-segregating). The data indicated that resistance to BCMV in L226-10(52) is governed by a single dominant gene.

4.4 Inheritance of resistance to halo blight *Pseudomonas phaseolicola* in NB-123.

All the NB-123 plants showed a high degree of resistance (rating=1) to halo blight *Pseudomonas phaseolicola* forty days after inoculation. All the F_1 crosses involving

Table 5: Segregation ratios for resistance to BCMV in F_2 populations of *Phaseolus vulgaris*.

Cross	Observed			Expected ratio		X^2	Probability
	Total No. of plants	Resistant plants	Susceptible plants	Resistant:Susceptible (R) (S)	Ratio calculated (R:S)		
BLP-2xL226-10(52)	495	364	131	3:1	2.78:1	0.56NS	0.05
L226-10(52)x BLP-2.	492	372	120	3:1	3.10:1	0.09NS	0.05
BLP-X.92x L226-10(52)	498	370	128	3:1	2.89:1	0.13NS	0.05
L226-10(52) BLP-X.92	496	378	128	3:1	2.95:1	0.07NS	0.05

Description of notations:

R - Resistant

S - Susceptible

NS - Not significant

Table 6: Segregation ratios for resistance to BCMV in F_2 populations of *Phaseolus vulgaris* (L.)

Crosses	Observed			Expected ratio			
	Total No. of lines	Seg. lines	Non -seg. lines	Seg.:non-seg.	Seg.:non-seg. (calc)	X^2	Prob.
GLP-2XL226-10(52)	640	420	220	2:1	1.90:1.00	0.30N	0.05
L226-10(52)XGLP-2	57	395	180	2:1	2.19:1.00	0.96NS	0.05
GLP-x.92XL226-10(52)	595	410	18	2:1	2.21:1.00	0.92NS	0.05
L226-10(52)XGLP-x.92	458	310	148	2:1	2.09:1.00	0.20NS	0.05

Description of Notations:

seg.= Segregating; non-seg.= Non-segregating; X^2 = Chi-square;

NS= Not Significant; calc. = calculated; Prob. = probability

Table 7: Segregation ratios for resistance to halo blight *Pseudomonas phaseolicola* in F_2 populations of *Phaseolus vulgaris*.

Cross	Observed		Expected ratio			χ^2	Probability
	Total No. of plants	Resistant plants	Susceptible plants	Resistant:Susceptible (R)	(S)	Ratio calculated (R:S)		
GLP-2xNB-123	304	283	21	3:1		13.5:1	53.1**	0.05
NB-123xGLP-2	345	340	5	3:1		68:1	105.86**	0.05
GLP-X.92xNB-123	305	290	15	3:1		19.3:1	65.6**	0.05
NB-123 x GLP-X.92	319	310	9	3:1		34.4:1	83.68**	0.05

Description of notations:- R - Resistant (disease ratings 1 and 2)

S - Susceptible (disease ratings 3, 4 and 5)

** - Significant at the 1% level.

8: Segregation ratios for resistance to halo blight *Pseudomonas phaseolicola* in F_2 populations of *Phaseolus vulgaris*.

	Total No. of plants	Observed: Seg. lines	Observed: Non-seg. lines	Expected ratio: seg.:non-seg.	seg. :non-seg.	X^2	Probability
-123	430	220	210	2:1	1.05:1	46.55**	0.05
LP-2	390	350	40	2:1	8.75:1	93.36**	0.05
:NB-123	370	320	50	2:1	6.40:1	65.36**	0.05
LP-x.92	410	384	26	2:1	14.77:1	134.42**	0.05

tion of notations:

seg.= Segregating; non-seg.= Non-segregating; X^2 = Chi-square; calc. = calculated;

** - Significant at the 1% level

B-123 as one of the parents were rated resistant to the pathogen. Table 7 shows the egregation ratios of the F_2 progenies of the crosses GLP-2 x NB-123 and GLP-X.92 x B-123 and their reciprocals. The F_2 populations segregated significantly different from e expected ratio of 3:1 (resistant:susceptible). Segregation of the F_3 progenies for sistance to the above pathogen of the same crosses and their reciprocals was 1.05:1, 75:1, 6.40:1 and 14.77:1 respectively as shown in table 8 and therefore segregated gnificantly different from the expected ratio of 2:1 (Segregating:non-segregating). The ata therefore did not agree with the null hypothesis of NB-123 carrying a single ominant gene for resistance to *Pseudomonas phaseolicola*.

5 Inheritance of resistance to anthracnose *Colletotrichum indemuthianum* in NB-123.

All the NB-123 plants showed a high degree of resistance to anthracnose *olletotrichum lindemuthianum*. All the F_1 crosses with NB-123 as one of the parents lso showed a high degree of resistance to the pathogen (Table 4). Table 9 show the egregation ratios of the F_2 progenies of the crosses: GLP- 2xNB-123, GLP-X.92 x B-123 and their reciprocals. The F_2 population of the above crosses did not segregate gnificantly different from the expected ratio of 3:1 (segregating:non-segregating). The ata indicated that resistance to *Colletotrichum lindemuthianum* in NB-123 is governed y a single dominant gene. Segregation of the F_3 progenies for resistance to the above athogen of the same crosses and their reciprocals was 2.19:1, 2.27:1, 1.85:1 and

B-123 as one of the parents were rated resistant to the pathogen. Table 7 shows the egregation ratios of the F_2 progenies of the crosses GLP-2 x NB-123 and GLP-X.92 x B-123 and their reciprocals. The F_2 populations segregated significantly different from e expected ratio of 3:1 (resistant:susceptible). Segregation of the F_3 progenies for sistance to the above pathogen of the same crosses and their reciprocals was 1.05:1, 75:1, 6.40:1 and 14.77:1 respectively as shown in table 8 and therefore segregated gnificantly different from the expected ratio of 2:1 (Segregating:non-segregating). The ata therefore did not agree with the null hypothesis of NB-123 carrying a single minant gene for resistance to *Pseudomonas phaseolicola*.

5 Inheritance of resistance to anthracnose *Colletotrichum indemuthianum* in NB-123.

All the NB-123 plants showed a high degree of resistance to anthracnose *olletotrichum lindemuthianum*. All the F_1 crosses with NB-123 as one of the parents lso showed a high degree of resistance to the pathogen (Table 4). Table 9 show the egregation ratios of the F_2 progenies of the crosses: GLP- 2xNB-123, GLP-X.92 x B-123 and their reciprocals. The F_2 population of the above crosses did not segregate gnificantly different from the expected ratio of 3:1 (segregating:non-segregating). The ata indicated that resistance to *Colletotrichum lindemuthianum* in NB-123 is governed y a single dominant gene. Segregation of the F_3 progenies for resistance to the above athogen of the same crosses and their reciprocals was 2.19:1, 2.27:1, 1.85:1 and

Table 9: Segregation ratios for resistance to anthracnose *Colletotrichum lindemuthianum* in F_2 populations of *Phaseolus vulgaris*.

Cross	Observed			Expected ratio			X^2	Probability
	Total No. of plants	Resistant plants	Susceptible plants	Resistant plants(R)	: Susceptible plant(s)	Ratio calculated (R:S)		
P-2xNB-123	380	280	100	3:1		2.8:1	0.35 NS	0.05
-123xGLP-2	420	310	110	3:1		2.8:1	0.32 NS	0.05
P-X.92xNB-123	440	323	118	3:1		2.7:1	0.77 NS	0.05
-123xGLP-X.92	400	308	92	3:1		3.3:1	0.85 NS	0.05

escription of notations:

R - Resistant (disease ratings 1 and 2)

S - Susceptible (disease ratings 3, 4 and 5).

NS - Not significant.

101 Segregation ratios for resistance to anthracnose *Colletotrichum lindemuthianum* in F2 populations of *Phaseolus vulgaris*.

Cross	Total No. of lines	Observed Seg. lines	Observed Non-seg. lines	Expected ratio seg.:non-seg.	Observed seg.:non-seg. (calc)	X^2	Prob.
-123	450	309	141	2:1	2.19:1	0.81NS	0.05
LP-2	490	340	150	2:1	2.27:1	1.62NS	0.05
MB-123	520	338	182	2:1	1.82:1	0.94NS	0.05
LP-x.92	480	310	170	2:1	1.82:1	0.94NS	0.05

Description of Notations:

seg.= Segregating; non-seg.= Non-segregating; X^2 = Chi-square;

NS= Not Significant; calc. = calculated; Prob. = probability

1 82:1 respectively as shown in table 10 and therefore did not differ from the expected ratio of 2:1 (segregating:non-segregating). The data therefore indicated that resistance to *Colletotrichum lindemuthianum* in NB-123 is governed by a single dominant gene.

4.6 Effects of pathogens on agronomic traits

4.6.1 Number of primary branches per plant.

The effects of inoculation with BCMV, *Pseudomonas phaseolicol*a and *Colletotrichum lindemuthianum* on the number of primary branches of the parental material are given in Table 11. Compared with the control, the three pathogens reduced the branching ability of the cultivars by 5, 15.8 and 0% respectively.The three pathogens did not show a significant difference on the effect of the branching ability of the seven cultivars. The branching ability of the seven cultivars was also not significantly different.

The effects of inoculation with the above three pathogens on the number of primary branches of the F_2 progenies are shown in Table 12. Compared with the control, BCMV, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum* reduced the branching ability of the progenies by 28, 20 and 24%, respectively. Differences amongst the pathogen were highly significant. However the effects of the genotypes were not significant. Interaction between inoculations and genotypes were highly significant.

The effects of inoculation with the three pathogens on the number of primary branches of the F_3 progenies are shown in Table 13. Compared with the control, the pathogen reduced the branching ability of the progenies by 35.8, 28.3 and 28.3%

11: Number of primary branches per plant of the seven bean cultivars inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum*.

Cultivar	Number of primary branches			
	Non-inoculated (Control)	Inoculated		
		BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
KP-2	3.5	3.3	3.0	3.9
KP-288	3.5	3.8	3.0	4.3
KP-24	3.8	3.5	3.3	3.5
KP-X.92	4.3	4.5	3.3	4.3
435	4.0	3.3	3.5	3.5
226-10(52)	3.8	3.8	2.8	3.5
0-123	3.5	3.3	3.8	3.5
Means	3.8	3.6	3.2	3.8

.05 = 1.0

= 9.7

Table 12: Number of primary branches per plant of the F_2 progenies inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum*.

Cross	Number of primary branches			
	Non-inoculated control	Inoculated		
		BCMV	*Pseudomonas phaseolicola*	*Colletotrichus Lindemuthianum*
GLP-2 x GLP-288	4.8	3.0	5.0	3.3
GLP-2 x GLP-24	5.3	2.3	3.3	2.8
GLP-2 x GLP-X.92	4.3	3.3	3.8	4.8
GLP-2 x M535	5.0	2.3	3.8	3.3
GLP-2 x L226-10(52)	4.5	2.3	3.8	3.0
GLP-2 x NB-123	4.0	2.5	4.3	4.6
GLP-288 x GLP-2	4.5	3.3	4.0	3.8
GLP-288 x GLP-24	3.8	4.0	4.0	3.8
GLP-288 x GLP-X.92	4.8	2.8	3.8	3.8
GLP-288 x M535	4.3	5.0	3.8	2.3
GLP-24 x GLP-2	4.8	2.0	2.3	4.3
GLP-24 x GLP-288	4.8	3.0	3.5	4.3
GLP-24 x GLP-X.92	4.5	2.8	2.5	3.0
GLP-24 x M535	5.0	4.8	3.8	3.5
GLP-X.92 x GLP-2	4.5	3.3	4.0	2.3
GLP-X.92 x GLP-288	6.0	3.3	3.0	3.3
GLP-X.92 x M535	3.5	2.5	3.3	3.8
GLP-X.92 x GLP-24	4.0	4.5	2.5	3.8
GLP-X.92 x L226-10(52)	3.5	2.5	3.5	3.5
GLP-X.92 x NB-123	4.3	2.3	3.0	3.3
535 x GLP-2	4.5	3.8	3.3	3.5
535 x GLP-288	4.5	4.8	3.0	3.3
535 x GLP-24	5.3	3.8	3.3	3.3
535 x GLP-X.92	4.8	4.0	4.3	3.3
226-10(52) x GLP-2	4.5	3.0	4.3	3.5
226-10(52) x GLP-X.92	4.8	2.8	3.3	3.5
B-123 x GLP-2	4.8	2.5	4.8	3.5
B-123 x GLP-X.92	4.5	2.5	2.3	2.5
Means	4.5	3.2	3.6	3.4

$LSD_{0.05}$ = 2.9
CV% = 7.6

Table 13: Number of primary branches per plant of the F_3 progenies inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum*.

Cross	Number of primary branches			
	Non-inoculated	Inoculated		
	(Control)	BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2 x GLP-288	5.3	2.8	5.0	4.3
GLP-2 x GLP-24	5.5	2.8	4.3	4.0
GLP-2 x GLP-X.92	4.3	3.0	5.0	4.0
GLP-2 x M535	5.3	3.3	4.8	3.5
GLP-2 x L226-10(52)	5.0	3.5	4.5	3.8
GLP-2 x NB-123	5.3	3.3	5.3	4.0
GLP-288 x GLP-2	5.8	3.5	3.3	3.3
GLP-288 x GLP-24	5.3	3.5	3.5	3.0
GLP-288 x GLP-X.92	5.3	3.8	3.3	3.3
GLP-288 x M535	6.3	4.0	3.0	3.0
GLP-24 x GLP-2	4.8	2.5	3.3	5.0
GLP-24 x GLP-288	4.5	3.3	3.0	4.8
GLP-24 x GLP-X.92	4.8	2.8	3.5	4.5
GLP-24 x M535	5.0	4.0	3.5	4.8
GLP-X.92x GLP-2	4.5	3.0	4.3	2.5
GLP-X.92x GLP-288	6.0	3.0	4.0	3.0
GLP-X.92x M535	5.3	3.5	4.0	3.3
GLP-X.92 x GLP-24	6.0	3.3	4.5	3.5
GLP-X.92 x L226-10(52)	5.3	2.5	4.0	3.3
GLP-X.92 x NB-123	6.0	2.8	3.5	3.5
M535 x GLP-2	5.0	5.0	2.5	4.0
M535 x GLP-288	5.5	4.8	2.8	3.8
M535 x GLP-24	5.5	4.8	2.8	3.5
M535 x GLP-X.92	5.5	5.5	2.5	3.8
L226-10(52) x GLP-2	4.5	4.5	4.8	3.5
L226-10(52) x GLP-X.92	5.0	3.8	5.3	3.5
NB-123 x GLP-2	6.3	2.0	4.3	4.3
NB-123 x GLP-X.92	6.0	2.0	3.0	4.3
Mean	5.3	3.4	3.8	3.8

$SD_{0.05}$ = 1.1

CV% = 3.8

respectively. The effects of pathogens were highly significant. However genotypic effects and the interaction were not significant. The coefficient of variation for the pathogens was 3.8% (Appendix 3).

4.6.2 Number of pods per plant

The effects of inoculation with BCMV, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum* on the number of pods of the parental material are given in Table 14. Compared with the control, the three pathogens reduced the podding ability of the cultivars by 74.6, 33.8 and 33.8%, respectively. L226-10(52) was the least susceptible to BCMV with an average pod reduction of 13.4%. GLP-2 and GLP-288 were the most susceptible to BCMV with a reduction in podding ability of 74.5% for both cultivars. The effects of the pathogens, cultivars and the interaction were highly significant. The coefficient of variation for the pathogens was 4.6% (Appendix 1).

The effects of inoculation with the three pathogens on the number of pods of the F_2 progenies are shown in Table 15. Compared with the control, the three pathogens reduced the podding ability of the progenies by 77.2, 31.7 and 0% respectively. The effects of the pathogens, progenies and the interaction were highly significant.

The effects of inoculation with the three pathogens on the number of pods of the F_3 progenies are shown in Table 16. Compared with the control, the three pathogens reduced the podding ability of the progenies by 82.6%, 54.9 and 5 2..0% respectively. The effects of the pathogens, progenies and the interaction were highly significant.

ble 14: Number of pods per plant of the seven bean cultivars inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum*.

ultivars	Number of pods			
	Non-inoculated (Control)	Inoculated		
		BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
p-2	11.0	2.8	5.0	5.5
p-288	11.0	2.8	7.5	4.8
p-24	13.5	5.3	8.0	8.5
p-X.92	10.5	1.5	7.0	5.8
35	15.0	3.8	10.5	10.5
26-10(52)	10.8	6.8	8.5	11.3
-123	19.3	2.0	13.5	14.0
ans	13.0	3.3	8.6	8.6

$D_{0.05}$ = 3.4

% = 4.6

Table 15: Number of pods per plant of the F_2 progenies inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum*.

Cross	Number of pods			
	Non-inoculated (control)	Inoculated		
		BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2 x GLP-288	13.3	3.0	5.0	5.5
GLP-2 x GLP-24	12.3	4.0	5.0	6.0
GLP-2 x GLP-X.92	12.5	2.8	6.8	5.0
GLP-2 x M535	12.5	3.3	5.0	7.0
GLP-2 x L226-10(52)	12.3	3.8	5.5	7.8
GLP-2 x NB-123	12.3	2.5	5.8	6.3
GLP-288 x GLP-2	12.0	2.5	8.0	5.8
GLP-288 x GLP-24	12.8	3.5	7.5	5.3
GLP-288 x GLP-X.92	14.5	3.3	8.3	6.3
GLP-288 x M535	13.0	3.5	8.3	6.5
GLP-24 x GLP-2	14.8	3.8	9.5	8.5
GLP-24 x GLP-288	15.5	4.0	9.8	9.3
GLP-24 x GLP-X.92	15.5	2.0	9.5	7.8
GLP-24 x M535	15.6	3.8	10.0	9.8
GLP-X.92x GLP-2	11.8	2.0	7.5	7.0
GLP-X.92x GLP-288	12.3	2.0	8.5	8.3
GLP-X.92x 535	12.5	2.5	8.5	9.5
GLP-X.92 x GLP-24	13.3	2.3	9.0	10.0
GLP-X.92 x L226-10(52)	13.3	2.3	9.8	10.5
GLP-X.92 x NB-123	14.0	2.3	8.0	10.8
M535 x GLP-2	16.8	2.3	10.5	11.5
M535 x GLP-288	14.3	3.8	12.3	11.3
M535 x GLP-24	17.3	2.5	12.0	12.8
M535 x GLP-X.92	16.8	3.0	13.3	13.5
L226-10(52) x GLP-2	14.3	7.0	10.8	14.3
L226-10(52) x GLP-X.92	11.0	6.8	11.8	11.0
NB-123 x GLP-2	21.0	5.0	14.5	21.0
NB-123 x GLP-X.92	21.0	5.8	9.3	21.0
Means	14.5	3.3	9.9	9.6

$LSD_{0.05}$ = 2.9

CV% = 3.9

Table 16: Number of pods per plant of the F_3 progenies inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum*.

Cross	Number of pods			
	Non-inoculated (control)	Inoculated		
		BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2 x GLP-288	14.0	3.3	5.8	6.0
GLP-2 x GLP-24	11.8	4.5	5.3	6.0
GLP-2 x GLP-X.92	13.8	2.5	3.8	6.3
GLP-2 x M535	12.0	3.5	6.3	6.8
GLP-2 x L226-10(52)	12.5	4.3	5.3	7.0
GLP-2 x NB-123	16.5	3.3	6.5	7.0
GLP-288 x GLP-2	13.3	2.5	8.0	5.8
GLP-288 x GLP-24	13.8	3.0	7.3	5.5
GLP-288 x GLP-X.92	14.0	3.0	9.0	7.5
GLP-288 x M535	13.5	3.5	8.0	7.0
GLP-24 x GLP-2	13.8	3.5	9.8	9.3
GLP-24 x GLP-288	15.3	3.3	11.0	9.5
GLP-24 x GLP-X.92	16.3	3.3	10.3	10.5
GLP-24 x M535	16.0	3.5	10.3	9.8
GLP-X.92x GLP-2	12.0	2.3	8.0	9.0
GLP-X.92x GLP-288	12.3	2.3	8.5	7.0
GLP-X.92x M535	11.0	2.8	10.0	10.0
GLP-X.92 x GLP-24	13.8	2.0	9.8	10.5
GLP-X.92 x L226-10(52)	16.0	2.5	9.5	10.5
GLP-X.92 x NB-123	16.5	3.0	9.8	10.5
M535 x GLP-2	16.0	3.3	10.5	11.5
M535 x GLP-288	17.3	3.0	10.3	12.5
M535 x GLP-24	17.0	3.0	11.3	14.0
M535 x GLP-X.92	17.0	3.3	12.8	12.5
L226-10(52) x GLP-2	14.3	8.8	9.3	13.8
L226-10(52) x GLP-X.92	13.3	8.0	12.5	14.8
NB-123 x GLP-2	20.8	4.5	14.0	15.0
NB-123 x GLP-X.92	20.0	2.8	12.3	16.0
Means	20.2	3.5	9.1	9.7

$LSD_{0.05}$ = 1.7

CV% = 1.9

4.6.3 Number of seeds per plant.

The effects of inoculation with BCMV, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum* on the number of seeds of the parental material are given in Table 17. Compared with the control, the three pathogens reduced the seed bearing ability of the cultivars by 81.9, 54.1 and 51.0% respectively. The effects of the pathogens, cultivars and the interaction were highly significant.

The effects of inoculation with the three pathogens on the number of seeds of the F_2 progenies are shown in Table 18. Compared with the control, the three pathogens reduced the seeding ability of the progenies by 84.9, 54.0 and 53.2% respectively. The effects of the pathogens, progenies and interaction were highly significant.

The effects of inoculation with the three pathogens on the number of seeds of the F_3 progenies are shown in Table 19. Compared with the control, the three pathogens reduced the seeding ability of the progenies by 84.2, 54.1 and 45.0% respectively. The effects of the pathogens, progenies and interaction were highly significant.

Table 17: Number of seeds per plant of the seven bean cultiv
inoculated with bean common mosaic virus *Pseudomo*
phaseolicola and *Colletotrichum lindemuthianum*.

	Number of seeds			
	Non-inoculated	Inoculated		
Cultivars	(control)	BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2	43.3	6.0	15.0	16.0
GLP-288	45.8	7.3	21.0	20.0
GLP-24	60.5	15.5	22.5	23.3
GLP-x.92	44.5	3.3	21.6	22.8
M535	77.0	10.8	37.0	40.8
L226-10(52)	60.0	27.0	28.0	32.8
NB-123	83.5	5.3	45.5	47.8
Means	59.2	10.7	27.2	29.0

$LSD_{0.05} = 1.9$

CV% = 3.1

Table 18: Number of seeds per plant of F_2 progenies inoculated wi bean common mosaic virus, *Pseudomonas phaseolicola* a *Colletotrichum lindemuthianum*.

Cross	Number of seeds			
	Non-inoculated	Inoculated		
	(Control)	BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2 x GLP-288	49.3	4.8	12.8	14.8
GLP-2 x GLP-24	48.8	10.0	11.5	16.5
GLP-2 x GLP-X.92	47.0	8.3	10.0	17.5
GLP-2 x M535	49.8	8.0	12.0	19.0
GLP-2 x L226-10(52)	42.3	8.3	14.0	25.5
GLP-2 x NB-123	62.0	5.8	13.3	16.3
GLP-288 x GLP-2	51.3	6.8	20.3	18.3
GLP-288 x GLP-24	53.5	9.8	18.5	11.5
GLP-288 x GLP-X.92	57.8	5.0	20.3	18.3
GLP-288 x M535	48.0	8.5	24.8	18.8
GLP-24 x GLP-2	68.5	11.0	26.5	23.3
GLP-24 x GLP-288	71.3	8.0	27.8	25.3
GLP-24 x GLP-X.92	60.0	4.8	30.8	27.5
GLP-24 x M535	59.5	9.5	32.5	29.5
GLP-X.92 x GLP-2	50.0	5.0	18.5	23.0
GLP-X.92 x GLP-288	45.8	4.3	18.8	20.3
GLP-X.92 x M535	47.5	5.5	23.0	23.8
GLP-X.92 x GLP-24	52.5	6.0	21.8	27.5
GLP-X.92 x L226-10(52)	35.8	5.8	24.5	26.3
GLP-X.92 x NB-123	45.8	5.8	21.8	29.3
M535 x GLP-2	84.5	8.0	39.5	35.0
M535 x GLP-288	75.5	9.0	52.0	28.5
M535 x GLP-24	70.5	5.5	46.0	42.3
M535 x GLP-X.92	70.8	7.8	47.3	34.8
L226-10(52) x GLP-2	56.8	26.5	32.8	44.0
L226-10(52) x GLP-X.92	56.3	25.0	32.3	42.3
NB-123 x GLP-2	79.0	10.3	48.0	56.0
NB-123 x GLP-X.92	89.3	11.3	50.0	47.8
Means	58.2	8.8	26.8	27.2

$LSD = _{0.05} = 11.6$

CV% = 6.8

Table 19: Number of seeds per plant of the F_3 progenies inoculat
with bean common mosaic virus, *Pseudomonas phaseolicol*
and *Colletotrichum lindemuthianum*.

Cross	Number of seeds			
	Non-inoculated	Inoculated		
	(Control)	BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2 x GLP-288	63.0	8.3	17.0	18.3
GLP-2 x GLP-24	47.3	8.8	13.3	17.0
GLP-2 x M535	50.8	8.3	16.8	18.5
GLP-2 x L226-10(52)	52.8	15.0	17.0	18.5
GLP-2 x NB-123	65.5	10.3	18.3	19.0
GLP-288 x GLP-2	46.5	7.8	21.5	21.5
GLP-288 x GLP-24	61.0	8.5	17.8	18.0
GLP-288 x GLP-X.92	63.5	6.8	27.3	30.0
GLP-288 x M535	63.5	7.9	23.5	26.3
GLP-24 x GLP-2	81.5	12.0	31.8	25.3
GLP-24 x GLP-288	67.3	7.3	35.8	29.3
GLP-24 x GLP-X.92	56.5	5.0	35.5	28.3
GLP-24 x M535	72.0	8.5	35.0	34.0
GLP-X.92 x GLP-2	45.3	4.8	19.8	33.5
GLP-X.92 x GLP-288	46.3	5.8	28.0	26.0
GLP-X.92 x M535	47.0	8.0	25.3	35.0
GLP-X.92 x GLP-24	51.3	6.8	24.3	37.3
GLP-X.92 x L226-10(52)	60.5	10.0	23.5	34.3
GLP-X.92 x NB-123	57.8	5.8	29.8	36.8
M535 x GLP-2	72.25	7.8	41.3	37.5
M535 x GLP-288	86.8	5.0	38.3	52.8
M535 x GLP-24	80.75	7.0	28.5	55.8
M535 x GLP-X.92	80.5	7.3	47.8	61.0
L226-10(52) x GLP-2	60.8	28.8	27.3	42.0
L226-10(52) x GLP-X.92	56.8	30.0	37.5	36.5
NB-123 x GLP-2	47.8	8.8	49.5	56.3
NB-123 x GLP-X.92	94.0	12.0	33.8	59.5
Means	60.6	9.6	27.8	33.3

$LSD_{0.05}$ = 11.4

CV% = 3.1

4.6.4 100-seed weight

The effects of inoculation with BCMV, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum* on the 100-seed weight of the parental material are given in Table 20. Compared with the control, the three pathogens reduced the 100-seed weight of the cultivars by 58.1, 10.4 and 18.9% respectively. The effects of the pathogens, cultivars and interaction were highly significant. The coefficient of variation for the pathogens was 2.2% (Appendix 1).

The effects of inoculation with the three pathogens on the 100-seed weight of the F_2 progenies is shown in Table 21. Compared with the control, the three pathogens reduced the 100-seed weight of the progenies by 59.1, 17.9 and 20.8%, respectively. The effects of the pathogens, progenies and interaction were highly significant. The coefficient of variation for the pathogens was 26.9% (Appendix 2).

The effects of inoculation with the three pathogens on the 100-seed weight of the F_3 progenies are shown in Table 22. Compared with the control, the three pathogens reduced the 100-seed weight of the progenies by 59.1, 17.1 and 21.7%, respectively. The effects of the pathogens, progenies and interaction were highly significant. The coefficient of variation for the pathogens was 25.1% (Appendix 3).

able 20: 100-seed weight (g) of the seven bean cultivars inoculate. with bean common mosaic virus *Pseudomonas phaseolicola* an *Colletotrichum lindemuthianum*.

ultivars	100 seed weight (g)			
	Non-inoculated (control)	Inoculated		
		BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
LP-2	68.2	34.9	59.4	50.7
LP-288	58.1	20.4	53.0	38.4
LP-24	62.4	19.6	50.6	48.9
LP-X.92	57.1	18.5	46.4	44.7
535	66.8	24.2	60.2	61.8
226-10(52)	24.2	21.7	21.1	21.2
B-123	31.9	15.4	31.9	33.1
Means	52.7	22.1	47.2	42.7

$SD_{0.05}$ = 1.2

V% = 2.2

Table 21: 100-seed weight (g) of the F_2 progenies inoculated with bea common mosaic virus *Pseudomonas phaseolicola* an *Colletotrichum lindemuthianum*.

Cross	100-seed weight (gm)			
	Non-inoculated	Inoculated		
	(Control)	BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2 x GLP-288	68.4	31.0	51.9	68.4
GLP-2 x GLP-24	67.7	23.7	54.7	67.7
GLP-2 x GLP-X.92	63.8	23.8	44.8	63.8
GLP-2 x M535	67.7	22.1	56.2	67.7
GLP-2 x L226-10(52)	32.4	24.6	26.9	32.4
GLP-2 x NB-123	42.9	20.2	34.8	42.9
GLP-288 x GLP-2	64.4	19.4	51.2	64.4
GLP-288 x GLP-24	61.6	26.8	51.2	61.6
GLP-288 x GLP-X.92	62.3	23.0	45.5	62.3
GLP-288 x M535	67.8	19.7	56.3	67.8
GLP-24 x GLP-2	68.0	23.6	56.4	68.0
GLP-24 x GLP-288	57.6	29.2	52.1	57.6
GLP-24 x GLP-X.92	61.6	20.7	45.9	61.6
GLP-24 x M535	70.2	24.8	57.9	70.2
GLP-X.92 x GLP-2	63.8	24.7	46.7	63.8
GLP-X.92 x GLP-288	58.4	17.4	59.5	58.4
GLP-X.92 x M535	62.1	20.7	53.7	62.1
GLP-X.92 x GLP-24	62.2	21.7	54.8	65.2
GLP-X.92 x L226-10(52)	30.9	21.8	26.8	30.9
GLP-X.92 x NB-123	35.5	16.5	36.8	35.5
M535 x GLP-2	66.5	28.0	60.7	66.5
M535 x GLP-288	62.1	21.7	53.6	62.1
M535 x GLP-24	68.8	21.7	47.3	68.8
M535 x GLP-X.92	63.1	21.9	50.4	63.1
L226-10(52) x GLP-2	29.7	26.9	24.0	29.7
L226-10(52) x GLP-X.92	32.9	20.7	31.6	32.9
NB-123 x GLP-2	35.5	21.2	30.8	36.4
NB-123 x GLP-X.92	39.9	23.4	28.6	33.7
Means	55.8	22.8	45.8	44.2

$LSD_{0.05}$ = 1.2

CV% = 26.9

Table 22: 100-seed weight (gms) of the F$_2$ populations inoculated with Bean Common Mosaic Virus (BCMV), *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum*.

Crosses	100-seed weight (gms)			
	Non-Inoculated (control)	Inoculated		
		BCMV	*P. phaseolicola*	*C. lindemuthianum*
GLP-2XGLP-288	68.5	30.7	51.3	46.6
GLP-2XGLP-24	67.9	27.7	55.6	51.5
GLP-2XGLP-x.92	62.1	24.3	46.4	47.2
GLP-2XM535	71.8	21.7	57.6	61.6
GLP-2XL226-10(52)	31.0	24.6	27.8	21.2
GLP-2XNB-123	41.6	20.7	37.2	31.7
GLP-288XGLP-2	63.9	20.1	51.1	45.4
GLP-288XGLP-24	62.7	24.9	52.3	48.9
GLP-288XGLP-x.92	61.4	22.9	47.2	42.5
GLP-288XM535	68.3	20.4	24.8	52.6
GLP-24XGLP-2	68.2	24.0	59.2	47.2
GLP-24XGLP-288	60.2	30.1	52.1	41.8
GLP-24XGLP-x.92	61.1	20.9	47.1	45.9
GLP-24XM535	70.5	24.8	57.2	52.9
GLP-x.92XGLP-2	62.7	25.3	47.1	46.0
GLP-x.92XGLP-288	60.0	18.0	49.9	43.9
GLP-x.92XM535	61.7	20.3	53.7	46.1
GLP-x.92XGLP-24	64.7	20.6	54.8	54.8
GLP-x.92XL226-10(52)	31.6	22.4	27.9	24.5
GLP-x.92XNB-123	38.8	18.1	37.4	33.0
M535XGLP-2	67.6	28.2	61.1	54.9
M535XGLP-288	63.3	21.5	53.7	44.4
M535XGLP-24	69.1	20.3	46.5	52.8
M535XGLP-x.92	63.3	22.3	50.4	54.1
L226-10(52)XGLP-2	29.3	24.8	24.5	32.9
L226-10(52)XGLP-x.92	31.9	21.2	31.1	31.3
NB-123XGLP-2	34.9	21.7	31.4	37.3
NB-123XGLP-x.92	30.0	20.8	31.8	32.6
Means	56.0	22.9	46.4	43.7

$LSD_{0.05}$ = 1.2

CV (%) = 4.7

6.5 Weight of dry matter.

The effects of BCMV, *Pseudomonas phaseolicola* and *Colletotrichum demuthianum* on the weight of dry matter of the parental material are given in Table 1. Compared with the control the three pathogens reduced the weight of dry matter of the cultivars by 44.9, 32.7 and 22.4%, respectively. The effects of the pathogens, cultivars and interaction were highly significant. The coefficient of variation for the pathogens was 3.4% (Appendix 1).

The effects of inoculation with the three pathogens on the weight of dry matter of the F_2 progenies are given in Table 24. Compared with the control, the three pathogens reduced the weight of dry matter of the progenies by 59.4, 26.9 and 35.5% respectively. The effects of the pathogens, progenies and interaction were highly significant. The coefficient of variation for the pathogens was 2.0% (Appendix 2).

The effects of inoculation with the three pathogens on the weight of dry matter of the F_3 progenies are given in Table 25. Compared with the control, the three pathogens reduced the weight of dry matter of the progenies by 63.0, 29.3 and 33.7% respectively. The effects of the pathogens, progenies and interaction were highly significant. The coefficient of variation for the pathogens was 6.4% (Appendix 3).

able 23: Weight of dry matter (g) per plant of the seven bean cultivars inoculated with bean common mosaic virus *Pseudomonas phaseolicola* and *Colletotrichum.*

	Weight of dry matter (g)			
	Non-inoculated (control)	Inoculated		
ultivars		BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
LP-2	5.1	2.5	3.8	3.4
LP-288	4.9	3.2	3.7	3.3
LP-24	5.4	2.1	4.3	4.4
LP-X.92	4.2	3.1	4.2	4.3
535	5.6	2.6	4.1	4.9
226-10(52)	4.0	3.6	3.1	3.2
B-123	4.0	2.0	3.1	3.2
Means	4.9	2.7	3.3	3.8

LSD $_{0.05}$ = 0.5

CV% = 3.4

Table 24: Weight of dry matter (g) per plant of the F_2 progenies inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum*.

Cross	Weight of dry matter (gms)			
	Non-inoculated	Inoculated		
	(Control)	BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2 x GLP-288	8.2	3.3	3.5	5.5
GLP-2 x GLP-24	6.8	2.9	6.4	4.2
GLP-2 x GLP-X.92	6.8	3.1	5.8	5.7
GLP-2 x M535	8.4	4.6	6.1	4.9
GLP-2 x L226-10(52)	8.1	4.2	5.0	5.9
GLP-2 x NB-123	9.4	3.4	8.6	8.4
GLP-288 x GLP-2	8.9	4.7	4.9	6.6
GLP-288 x GLP-24	9.8	2.3	7.7	7.7
GLP-288 x GLP-X.92	8.9	2.1	6.9	5.2
GLP-288 x M535	9.6	4.1	7.9	5.0
GLP-24 x GLP-2	10.7	3.1	6.5	5.1
GLP-24 x GLP-288	11.3	3.4	7.1	6.1
GLP-24 x GLP-X.92	9.4	3.1	4.2	4.4
GLP-24 x M535	9.1	4.9	10.2	6.3
GLP-X.92 x GLP-2	10.4	3.9	5.0	5.3
GLP-X.92 x GLP-288	9.8	2.9	4.5	6.1
GLP-X.92 x M535	11.4	2.5	5.3	7.0
GLP-X.92 x GLP-24	9.6	1.6	7.2	5.7
GLP-X.92 x L226-10(52)	8.1	5.1	5.5	5.1
GLP-X.92 x NB-123	7.8	1.2	4.2	7.2
M535 x GLP-2	8.8	2.8	7.9	7.9
M535 x GLP-288	8.9	4.4	9.8	7.7
M535 x GLP-X.92	10.7	2.6	8.0	9.1
L226-10(52) x GLP-2	9.9	6.0	7.7	4.9
L226-10(52) x GLP-X.92	9.7	7.0	6.8	5.2
NB-123 x GLP-2	9.7	2.0	5.9	8.3
NB-123 x GLP-X.92	7.9	1.8	5.2	5.2
Means	9.3	3.6	6.8	6.0

$LSD_{0.05}$ = 0.8

CV% = 2.0

Table 25: Weight of dry matter (g) per plant of the F_3 progen inoculated with bean common mosaic virus, *Pseudomo phaseolicola* and *Colletotrichum lindemuthianum*.

	Weight of dry matter (g)			
	Non-inoculated	Inoculated		
Cross	(Control)	BCMV	*Pseudomonas phaseolicola*	*Colletotrichum lindemuthianum*
GLP-2 x GLP-288	8.6	3.6	3.5	5.6
GLP-2 x GLP-24	6.6	3.2	6.9	4.1
GLP-2 x GLP-X.92	6.9	3.1	5.8	5.5
GLP-2 x M535	8.4	4.3	6.8	4.9
GLP-2 x L226-10(52)	8.3	4.3	5.3	6.1
GLP-2 x NB-123	9.7	3.5	8.5	8.6
GLP-288 x GLP-2	9.3	5.2	5.6	6.8
GLP-288 x GLP-24	9.8	2.6	8.8	7.7
GLP-288 x GLP-X.92	9.4	2.4	7.1	5.4
GLP-288 x M535	9.7	4.2	8.1	5.4
GLP-24 x GLP-2	10.8	3.1	6.6	5.6
GLP-24 x GLP-288	9.7	3.9	7.9	6.1
GLP-24 x GLP-X.92	9.5	3.2	3.8	4.4
GLP-24 x M535	10.4	4.9	9.5	6.3
GLP-X.92 x GLP-2	9.6	4.0	5.8	5.6
GLP-X.92 x GLP-288	9.9	3.1	4.8	6.2
GLP-X.92 x M535	10.0	2.8	5.6	6.2
GLP-X.92 x GLP-24	10.4	1.7	7.7	6.2
GLP-X.92 x L226-10(52)	8.9	5.2	5.7	4.7
GLP-X.92 x NB-123	7.9	1.9	4.7	7.0
M535 x GLP-2	9.3	2.9	8.2	6.4
M535 x GLP-288	9.3	4.9	9.9	7.6
535 x GLP-24	10.6	3.6	8.2	6.4
535 x GLP-X.92	10.8	2.9	8.4	5.4
L226-10(52) x GLP-2	9.9	6.0	8.2	5.3
L226-10(52) x GLP-X.92	9.9	5.9	6.7	5.5
NB-123 x GLP-2	8.9	2.0	6.1	4.5
NB-123 x GLP-X.92	8.8	2.4	4.5	5.8
Means	9.2	3.4	6.5	6.1

$LSD_{0.05}$ = 0.6

CV% = 6.4

4.7. Performance of the parental bean material, F_1 F_2 and F_3 in the field.

Table 26 shows the yield of the parental bean material in the field at Kabete and Thika. The cultivars NB-123, M535, GLP-24 and GLP-2 had the higher yields at both locations. The F_1 progenies of the crosses, GLP-2 x GLP-24, GLP-2X GLP-X.92, GLP-2 x M535, GLP-2 X NB-123, GLP-288 x M535, M535 x GLP-24 and GLP-24 x GLP-288 had higher yields at both locations. The F_2 progenies of the crosses, GLP-2 x GLP-24, GLP-2 x M535, GLP-288 x GLP-2, GLP-288 x M535, GLP-24 x GLP-2, GLP-24 x GLP-288, GLP-24 x M535 and M535 x GLP-X.92 were the higher yielders at Kabete. At Thika, the F_2 progenies of the crosses, GLP-2 x CLP-24, GLP-2 x M535, GLP-288 x GLP-2, GLP-24 x GLP-288, GLP-24 x M535, GLP-X.92 x GLP-2, M535 x GLP-24 and M535 x GLP-X.92 had the higher yields. At both Kabete and Thika, the F_3 progenies of the crosses, GLP-2 x GLP-24, GLP-2 x GLP-X.92, GLP-2 x M535, GLP-24 x GLP-X.92, M535 x GLP-2 and M535 x GLP-24 were the higher yielders. On the basis of general disease resistance and tolerance, yield, general adaptability and seed acceptability, F_3 progenies of the above six crosses were selected for further improvement. The reaction of the parental bean material, F_1, F_2 and F_3 to common blight *Xanthomonas phaseoli*, angular leaf spots, *Isariopsis griseola* and rust, *Uromyces phaseoli* is shown in Appendices 7 and 8.

Table 26: Yields ($kgha^{-1}$) of the seven bean cultivars at Kabete and Thika.

Cultivar	Yield ($kg\ ha^{-1}$)		
	Kabete	Thika	Mean
GLP-2	1493	1320	1406.5
GLP-288	821	900	860.5
GLP-24	1629	1560	1594.5
GLP-X.92	1261	1160	1210.5
M535	1795	1730	1762.5
L226-10(52)	1301	1407	1354
NB-123	2343	2030	2186.5

Table 27: Yields of the F_1, F_2 and F_3 progenies at Kabete and Thika

Cross	Yield (kg/ha^{-1})					
	F_1		F_2		F_3	
	Kabete	Thika	Kabete	Thika	Kabete	Thika
GLP-2 x GLP-288	2095	1630	1537	1450	1650	1590
GLP-2 x GLP-24	2380	2292	2035	1950	2370	2240
GLP-2 x GLP-X.92	2590	2395	1226	1350	2546	2450
GLP-2 x M535	2605	2670	2075	2130	2540	2630
GLP-2 x L226-10(52)	2190	2110	1045	1005	2178	2080
GLP-2 x NB-123	2290	2350	1674	1510	2252	2310
GLP-288 x GLP-2	2185	2195	2140	2050	1671	1550
GLP-288 x GLP-24	1805	1710	1759	1639	1003	1100
GLP-288 x GLP-X.92	1710	1650	1637	1530	1647	1490
GLP-288 x M535	2250	2250	2028	1835	2124	2210
GLP-24 x GLP-2	2350	2205	2465	2195	1428	1395
GLP-24 x GLP-288	2305	2265	2295	2205	1609	1590
GLP-24 x GLP-X.92	2285	2215	1484	1400	2260	2195
GLP-24 x M535	2395	2020	2067	2170	1445	1350
GLP-X.92 x GLP-2	2150	2120	2149	2040	1511	1414
GLP-X.92 x GLP-288	2395	2325	1302	1210	2491	2320
GLP-X.92 x M535	2250	2225	1719	1650	1959	2010
GLP-X.92 x GLP-24	2010	2155	1579	1600	1959	2005
GLP-X.92 x L226-10(52)	1985	1950	1870	1790	1735	1630
GLP-X.92 x NB-123	2190	2050	1566	1450	2016	1980
M535 x GLP-2	1950	1805	1804	1785	1850	1730
M535 x GLP-288	1805	1565	1064	1105	1556	1405
M535 x GLP-24	2330	2310	1672	2120	2234	2195
M535 x GLP-X.92	2265	2205	2126	2070	1612	1950
L226-10(52) x GLP-2	1190	2190	1060	1105	1150	1020
L226-10(52) x GLP-X.92	1895	2020	1714	1850	1523	1390
NB-123 x GLP-2	2235	2150	1917	1805	1965	1720
NB-123 x GLP-X.92	2010	1405	1746	1340	1156	1090

5.0 DISCUSSION

5.1 Disease development in the greenhouse and in the field.

The cultivars GLP-2, GLP-288, GLP-X.92 and NB-123 showed a high degree of susceptibility to BCMV isolate 510. This is an indication that the virus isolate was very virulent and the cultivars lacked genes for resistance. On the other hand the cultivars GLP-24 and M535 showed a high degree of tolerance to the BCMV isolate. This shows that these cultivars possibly carry a number of minor genes for resistance to the virus. Such minor genes allow the expression of the disease symptoms in the host plant but minimizes the effects of the disease symptoms on the quantitative traits of the host plant (Van der Plank, 1968). The high degree of resistance to the BCMV isolate 510 by the cultivar L226-10(52) expressed in the form of a hypersensitive reaction is an indication of the presence of a dominant gene for resistance. According to Ali (1950) such resistance is due to the presence of the dominant I gene derived from the cultivar Corbett Refugee which was originally identified in the U.S.A. All the F_1 and some F_2 and F_3 progenies with L226-10(52) as one of the parents showed a high degree of resistance to the BCMV isolate. This was an indication that the dominant 'I' gene for resistance to BCMV was passed on from L226-10(52) to the F_1, F_2 and F_3 progenies. The high degree of tolerance to the virus isolate showed by the F_2 and F_3 progenies of the crosses GLP-2 x GLP-24, GLP-2 x M535, GLP-288, GLP-24, GLP-24 x GLP-2, GLP-24X M535, GLP-X.92 x M535, M535 x GLP-2, 535X GLP-288, M535 x GLP-24 and M535 x

GLP-X.92 suggests that the progenies posses some minor genes for resistance to the virus isolate.

The high degree of resistance to *Pseudomonas phaseolicola* expressed by NB-123 both in the field and in the greenhouse was an indication of the presence of horizontal non-race specific genes for resistance to the pathogen. The high degree of tolerance to *Pseudomonas phaseolicola* expressed by the cultivars GLP-2, GLP-288, GLP-24, GLP-X.92, M535 and L226-10(52) shows that these cultivars posses some minor genes for resistance to the virus. The F_1, F_2 and F_3 progenies with M535 and NB-123 as one of the parents showed a high degree tolerance to *Pseudomonas phaseolicola* both in the greenhouse and in the field. This is an indication that genes for resistance were passed from the above cultivars to their progenies.

NB-123 showed a high degree of resistance to *Colletotrichum lindemuthianum* both in the greenhouse and in the field. The cultivar also showed a hypersensitive reaction to the pathogen in form of systemic necrosis in the greenhouse. This was an indication that the cultivar posses a major gene for resistance to the pathogen. The cultivars GLP- 2, GLP-288, GLP-X.92. M535 and L226-10(52) showed a high degree of tolerance to the pathogen in the greenhouse and the field. This shows that the above cultivars posses some minor genes for resistance to the pathogen. The fact that GLP-24 was relatively more susceptible to *C. lindemuthianum* than the other cultivars suggests that it carries low resistance genes to the pathogen.

5.2 Inheritance of Resistance to Bean Common Mosaic Virus in L226-10(52).

The high degree of resistance to BCMV shown by L226- 10(52) could be due to the presence of a dominant resistant gene. The fact that all F_1 crosses involving L226-10(52) showed a high degree of resistance to the pathogen was an indication that the resistance was governed by a dominant gene. The segregation of the F_2 and F_3 progenies of the crosses GLP-2 x L226-10(52), GLP-X.92 x L226-10(52) and their reciprocals did not differ from the expected ratio 3:1 (resistant:susceptible) and 2:1 Segregating:non-segregating) respectively and therefore further confirmed that resistance to BCMV in L226-10(52) is governed by a single dominant gene.

5.3 Inheritance of resistance to halo blight *Pseudomonas phaseolicola* in NB-123.

All the NB-123 plants showed a high degree of resistance to halo blight *Pseudomonas phaseolicola* but there was no hypersensitive reaction in form of system necrosis observed. There is therefore a high chance that the resistance to *Pseudomonas phaseolicola* in NB-123 is determined by minor genes. All the F_1 crosses involving NB-123 as one of the parents were rated resistant to the pathogen but the average disease ratings were lower than that of NB-123. This could have been due to the less effect of the minor genes in heterozygous state to the pathogen. The segregation of the F_2 and F_3 progenies of the crosses GLP-2 x NB-123, GLP-x.92 x NB-123 and their reciprocals differed from the expected ratios of 3:1 (resistant:susceptible) and 2:1 (segregating:non-segregating) respectively and therefore

urther suggested that resistance to *Pseudomonas phaseolicola* in NB-123 is not overned by a single dominant gene.

4.4 Inheritance of Resistance of Anthracnose *Colletotrichum lindemuthianum* in NB-123.

All the NB-123 plants showed a high degree of resistance to *Colletotrichum indemuthianum* with most plants showing a hypersensitive reaction in form of systemic ecrosis. This kind of reaction suggests the presence of one or more major genes for esistance to *Colletotrichum lindemuthianum* in NB-123. The fact that the F_2 and F_3 opulations of the crosses GLP-2 x NB-123, GLP-X.92 x NB-123 and their reciprocals id not segregate significantly different from the expected ratios of 3:1 esistant:susceptible) and 2:1 (segregating:non-segregating) respectively was therefore a further indication that resistance to *Colletotrichum lindemuthianum* in NB-123 is overned by a major dominant gene. This gene could be the 'Are' gene described by Mastenbroek (1960).

4.5 Effects of pathogens on agronomic traits.

Compared with the control, BCMV, *Pseudomonas phaseolicola* and *Colletrotrichum lindemuthianum* reduced the branching ability of the parental bean material by 5.0, 15.8 and 0% respectively. It was also established that the three pathogens did not significantly affect the branching ability of the cultivars. This small eduction in branching ability indicates that the pathogens had little effect on the ormation of the branches but instead reduced the growth vigour of the branches formed.

The three pathogens reduced the branching ability of the F_2 progenies by 28.0, 20.0 and 24.0%, respectively. The branching ability of the F_3 progenies was reduced by the three pathogens by 35.8, 28.3 and 28.3%, respectively.

The three pathogens reduced podding ability of the parental cultivars by 74.6, 33.8 and 33.8% respectively. They also reduced the podding ability of F_2 progenies by 77.2, 31.7 and 0%, respectively. Podding ability of the F_3 was reduced by 82.6, 54.9 and 52.0%, respectively. In both the cultivars, F_2 and F_3, BCMV caused the highest reduction in podding ability. According to Medina and Grogan (1961), BCMV inhibits the germination of pollen grains of virus infected plants whereby the normal functioning of micro and megaspores is interfered with. The three pathogens reduced the number of seeds of the parental bean material by 81.9, 54.1 and 51.0%, respectively. The number of seeds of the F_2 progenies was reduced by 84.9, 54.0 and 53.2%, respectively. That of the F_3 progenies was reduced by 84.2, 54.1 and 45.0%, respectively. The high reduction in seeding ability of BCMV in both the parental material, F_2 and F_3 was an indication that the virus isolate was very virulent and may have interfered with the normal seed formation as indicated above by Medina and Grogan (1961).

The three pathogens reduced the 100-seed weight (gms) of the parental cultivars by 58.1, 10.4 and 18.9% respectively. That of the F_2 progenies was reduced by the three pathogens by 59.1, 17.9 and 20.8%,respectively. The three pathogen reduced the 100-seed weight of the F_3 progenies by 59.1, 17.1 and 21.7%, respectively. The above figures indicate that BCMV caused the highest reduction in 100-seed weight (g) of the

parental material, F_2 and F_3 progenies. This was a further indication that BCMV interferes most with the physiological activities of the bean plant as compared to the other two pathogens.

The three pathogens reduced the dry matter weight (g) of the parental bean material by 44.9, 32.7 and 22.7% respectively. The three pathogens also reduced the dry matter weight (g) of the F_2 progenies by 59.4, 26.9 and 35.5% respectively. The three pathogens reduced the dry matter weight (g) of the F_3 progenies by 63.0, 29.3 and 33.7% respectively. The above figures is a further confirmation that BCMV was the most destructive among the three pathogens.

5.6 Performance of the Parental Bean Material (P), F_1, F_2 and F_3 in the field.

The cultivars NB-123, M535, GLP-24 and GLP-2 had the highest yields at both Kabete and Thika. This indicated that the cultivars had a potential for yield and were adapted to both locations. The F_1 progenies of the crosses GLP-2 x GLP- 24, GLP-2 x GLP-X.92, GLP-2 x M535 , GLP-2 x NB-123, GLP- 288 x M535,M535 GLP-24 and GLP-24 x GLP-288 had the highest yields at both locations. This suggests a good compatibility of the crosses, high degree of heterosis and good adaptation of the progenies to both locations. The F_2 and F_3 progenies of the crosses; GLP-2 x GLP-24, GLP-2 x GLP-X.92, GLP-2 x M353, GLP-24 x GLP-X.92, M535 x GLP-2 and M535 x GLP-24 were selected for further improvement on the basis of high yield, disease tolerance, general adaptability and seed acceptability.

6.0 CONCLUSIONS

Out of 1800 pollination of a diallel cross involving seven bean cultivars, 1400 were successful, giving an overall success rate of 78.3% with each pod containing 3-7 seeds. L226-10(52) was rated resistant to the virus isolate 510 both in the greenhouse and in the field. GLP-24 and M535 were tolerant to the virus isolate both in the greenhouse and in the field. GLP-2, GLP-288, GLP-X.92 and NB-123 were very susceptible to the virus isolate both in the greenhouse and in the field. The F_1, F_2 and F_3 progenies of the crosses GLP-288 x GLP-X.92, GLP-X.92 x GLP-24, GLP-X.92 x NB-123, NB-123 x GLP-2 an NB-123 x GLP-X.92 were very susceptible to the virus isolate. The F_1, F_2 and F_3 progenies of the crosses GLP-2 x GLP-24, GLP-2 x M535, GLP-288 x GLP-24, GLP-24 x GLP-2, GLP-24 x M535, GLP-X.92 x M535, M535 x GLP-2, M535x GLP-288, M535 x GLP-24 and M535 x GLP.X.92 were highly tolerant to the virus isolate both in the greenhouse and in the field. NB-123 was rated resistant to *Pseudomonas phaseolicola* both in the greenhouse and in the field. The cultivars GLP-2, GLP-288, GLP-24, GLP-X.92, M535 and L226-10(52) were tolerant to *Pseudomonas phaseolicola* in the greenhouse and in the field. The F_1, F_2 and F_3 progenies with NB-123 and M535 as one of the parents were resistant to the pathogen both in the greenhouse and in the field. NB-123 was rated resistant to *Colletotrichum lindemuthianum* both in the greenhouse and in the field. The cultivars GLP-2, GLP-288, GLP-X.92, M535 and L226-10(52) were tolerant to *Colletotrichum lindemuthianum* in the greenhouse and in the field. The F_1, F_2 and F_3 progenies with M535 and NB-123 as one of the parents had

a high degree of resistance to the pathogen both in the greenhouse and in the field.

The segregation of the F_2 and F_3 progenies of the crosses GLP-2 x L226-10(52), GLP-X.92 x L226-10(52) and their reciprocals did not differ from the expected ratios 3:1 (resistant:susceptible) and 2:1 (segregating:non-segregating) respectively and therefore indicated that resistance to BCMV in L226-10(52) is governed by a single dominant gene. The segregation of the F_2 and F_3 progenies of the crosses; GLP-2 x NB-123, GLP-X.92 x NB-123 and their reciprocals differed from the expected ratio 3:1 (resistant:susceptible) and 2:1 (segregating:non-segregating) respectively showing that resistance to halo blight *P. phaseolicola* is not governed by a single dominant gene. The segregation of the F_2 and F_3 populations for resistance to *C. lindemuthianum* in the crosses GLP-2 x NB- 123, GLP-X.92 x NB-123 and their reciprocals did not segregate significantly different from the expected ratios 3:1 (resistant:susceptible) and 2:1 (segregating:non-segregating) respectively indicating that resistance to *Colletotrichum lindemuthianum* in NB-123 is governed by a single dominant gene.

When compared with the control BCMV caused the highest reduction in branching, podding, seeding abilities, 100-seed weight and dry matter weight (gms) of the parental bean material, F_2 and F_3 progenies among the three pathogens. This was an indication that the virus isolate was very virulent since it had also reduced the height, pod number, seed weight and dry matter weight (g) of the cultivar 'Canadian Wonder', 'Rose Coco' and 'Mwezi Moja' by an average of 55.3, 55.9, 63.0 and 27.2% respectively (Omunyin, 1984). *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum* did not bring

pout such a great reduction of the above mentioned parameters which was an dication that the pathogenic strains were not very virulent and the bean materials tested so carried adequate genes for resistance.

On the basis of high yield, disease resistance and tolerance, good adaptability and eed acceptability, the F_2 and F_3 progenies of the crosses GLP-2 x GLP-24, GLP-2 x GLP- X.92, GLP-2 x M535, GLP-24 x GLP-X.92, M535 x GLP-2 and M535 x GLP-24 ere selected for further improvement.

REFERENCES

Ali, M.A. 1950. Genetics of resistance to common bean mosaic virus (Bean virus 1) in the bean *Phaseolus vulgaris* L. Phytopathology 40(1). 69-79.

Andrus, C.F. and B.L. Wade 1942. The factorial interpretation of anthracnose resistance in beans. Tech. Bull. Res. Dept. Agri. 810.

Barrus, M.F. 1911. Variation in varieties of beans in their susceptibility to anthracnose. Phytopath. 1:190-193.

Barrus, M.F. 1918. Varietal susceptibility of beans to strains of *C. lindemuthianum*. Phytopath. 8: 589-614.

Blondet, A. 1962. L'anthracnose du harico Estude des races physiologigies Francasces de *C. lindemuthianum*. These Fac. Sci. Paris, Orsay 160. In Leakey C.L. and Simbwa-Bunnya 1972. Race of bean anthracnose and implications to bean breeding in Uganda. Annls Appl. Biol. 70: 25-34.

Bock, K.K.; E.J. Guthrie; G.E. Meredith and J.M. Njuguna. 1976. Viruses of food legumes. Ann. Rept. East African Agricultural and Forest Research Organization EAAFRO 1976, pp. 138-139.

Boyd, O.C. 1942. Recent observations on plant disease in Massachussets. Pl. Dis. Reptr. 26: 335.

Buishand, T.J. 1956. The crossing of beans (*Phaseolus* spp.). Euphytica 5: 41-50.

Burkholder, W.H. 1923. The gamma strain of *C. lindemuthianum*. Phytopath. 13: 316-323.

Buruchara, R.A. 1979. Identification of a severe strain of bean commom mosaic virus isolated from beans *Phaseolus vulgaris* L.'Canadian Wonder' in Kenya. Msc Thesis; University of Nairobi.

Chaves, G. 1980. Anthracnose. In bean production problems. ed. Howard, F. Schwartz and G.E. Galvez. C.I.A.T.- Colombia: 37-54.

Coyne, D.P. and M.L. Schuster 1979. Bacterial diseases of legumes: A summary of breeding and resistance. In M.H. Dickson (ed). Annu. Rpt. Bean Improvement Coop. 22: 21-22. Mimeo, N.Y. Agri. Sta. Geneva, N.Y.

Daniel De Bouck, A.I. GX and M.S. Rigoberto Hidelgo H., 1986.morphology of the common bean plant *Phaseolus vulgaris*. Centro International de Agricultura Tropical CIAT.

Deverall, B.J. 1965. The physical environment for fungal growth in "the fungi". An advanced treatise, Vol. 1 pp. 543-550. Academic Press, New York.

Drijfhout, E. 1978. Genetic interaction between *Phaseolus vulgaris* L. and bean common mosaic virus with implications for strain identification. Centre for Agricultural Publishing and documentation pp. 53-60 Wageningen.

natten, C.L.M. van 1975. Report of literature review and field study of Agriculture in Kirinyaga District with special reference to beans *Phaseolus vulgaris*. Univ. of Nairobi, Dept. of Crop Sci. Tech. Communication No. 13. 35p.

pton, H.A.S. and B.J. Deverall, 1965. Physiological races of *Pseudomonas phaseolicola* causing halo blight of beans. Plant Pathology 14: 53-54.

eytag,G.F.; J.D. Kelly; M.W. Adams and R.J. Lopez 1985. registration of two navy bean germplasm lines L226-10 and L227-1. Crop Sci. 25:714

eytag, G.F. 1965. Classification of common bean *Phaseolus vulgaris* L. and related species. Ceiba (Honduras) 11(1): 51-64.

athuru, E.M. 1975. The identification of a new strain of bean common mosaic virus, as a seed borne virus of bean *Phaseolus vulgaris* L. from East Africa.M.Sc. Thesis Univ. Maryland, U.S.A. 71 pp.

rogan, R.G. and K.A. Kimble. 1967. The role of seed contamination in the transmission of *Pseudomonas phaseolicola* in *Phaseolus vulgaris* L. Phytopathology 57(1): 28-31.

agedorn, D.J.; E.K. Wade and G. Weis, 1969. Chemical control of bacterial diseases in Wisconsin. Plant Dis. Reptr. pg. 178-181.

Hale, L.N. and J.D. Taylor. 1973. Races of *Pseudomonas phaseolicola* causing halo blight in beans in New Zealand. New Zealand Journal of Agricultural Research 16:147-149.

Hamton, R.O. 1975. The nature of bean yield reduction by yellow and common mosaic virus. Phytopathology 65 (12): 1342-1346.

Hill, K., Coyne, D.P. Schuster, M.L. 1972. Leaf pod and stem chlorosis reactions in *Phaseolus vulgaris* L. to halo blight controlled by different genes. J. Amer. Soc. Hort. Sci. 97(4): 494-498.

Hoffman, G.M.; M. Schnock and J. Kruger, 1974. Zum auftreten einen neuer physiolochen Rasse Von. *C.lindemuthianum* in *P. vulgaris*. Zeit. fur Plans. und Pflanz. Inst. Phytopath. Mun. Hen W.Germany.8:(8):490-493.

Hubbeling, N. 1957. New aspects of breeding for disease resistance in beans. Euphytica 6: 111-141.

Hubbeling, N. 1961. Inheritance and interaction of genes for disease resistance in beans *Phaseolus vulgaris* L. Mededeling No. 277, Instituut Voor lantenxiektenkundig Onderzock: 6 pp.

Hubbeling, N. 1974. Resistance in beans to the lambda race of *C. lindemuthianum* Proc. 19th Int. Hort. Congress, T.A. 293

Johnson, J.C. 1969. 'Halo-less' halo blight of french bean in Queensland. Queensland Journal of Agricultural and Animal Science 26: 293-302.

Kay, E. 1979. Food legumes, pp. 124-176. Tropical Products Institute, London pp. 124-176.

Kimani P.M.;Githiri and Kamau J.K. 1990. Breeding beans for resistance to diseases. Proceedings of the second Workshop on Bean Research in Eastern Africa. Serie 7.

Kimani, P.M. 1988. Improvement of food beans *Phaseolus vulgaris* L. through mutation breeding. Acta Hort. 218: 251-260.

Kinyua, G.K. 1976/77. Laboratory and field screening for resistance to bean anthracnose. Ministry of Agriculture (NHRS-Thika) 3 pg. (Unpublished).

Krueger, J.; G.M. Hoffman and N. Hubbeling, 1977. The kappa race of *Colletotrichum lindemuniathum* and source of resistance to anthracnose in *Phaseolus* beans. Euphytica 26(1): 23-25.

Kulkerni, H.Y. 1972. Notes of East African plant virus disease. IV. Bean common mosaic virus. East African Agricultural and Forestry Journal 39(1): 72-76.

Leakey, C.C.A.; and Simbwa-Bunya, 1972. Races of *Colletotrichum lindemuthianum* and implications for bean breeding in Uganda. Ann. Appl. Biol. 70: 25-34.

Mastenbroek, C. 1960. A breeding programme for resistance to anthracnose in dry shell haricot beans, based on new gene. Euphytica 9(2): 177-258.

Morales, F.J. 1979. Purification and serology of bean common mosaic virus. Turrialba 29(4): 320-323.

Mukunya, D.M. and S.O. Keya. 1975. *Phaseolus* bean production in East Africa. Reprt. Faculty of Agriculture, Dept. of Crop Science,University of Nairobi.

Mukunya,D.M.and Keya S.O.,1978.Yield performance and selection for resistance in beans *Phaseolus vulgaris* L.to common bean diseases in Kenya. E.Afri. Agri.For. J. 43(4):390-398.

Mutitu, E.W. and A.B. Musyimi, 1980. Bean diseases in Central and Eastern provinces of Kenya. Long rains,1980 (Unpublished).

Mwangi, S.F.M. 1986. Pathogenic variation in *Colletotrichum lindemuthianum* (Sacc. and Magn) Schrib.the cause of bean anthracnose and its implication to bean improvement in Kenya. M.Sc. thesis, University of Nairobi.

Okiror,M.A.,1981. Genetic and biochemical differences between susceptible and resistant lines of common bean, *Phaseolus vulgaris* L.to anthracnose *Colletotrichum lindemuthianum*.M.Sc.Thesis. Faculty of Agriculture, University of Nairobi.

Omunyin, E. M. 1984. Studies on bean common mosaic virus on beans *Phaseolus vulgaris* L. in Kenya. M.Sc.thesis, University of Nairobi.

Patel, P.M.; and J.C. Walker, 1966. Inheritance of tolerance to halo blight in bean. Phytopathology 56:681-682.

Purseglove, J.W. 1968. Tropical Crops Dicotyledons 1. pp. 310. Longmans Green and Co. Ltd., London pp 310.

Reddick, D. and V.B. Stewart. 1919. Transmission of the virus of bean mosaic in seed and observatins on thermal death point of seed virus. Phytopath. 9: 445-450.

Rheenen, H.A. Van; D.E. Hassel Bach and S.G.S. Muigai 1981. The effect of growing beans together with maize on the incidence of bean diseases and pests. Neth. J. Pl. Path. 87: 193-199.

Roemer und Rudolf, 1962. Handbuck der pflanzenzuchtung, Band III 2. Auflage S. 369-407. Verlag Paul Parey, Berlin and Hamburg.

Saettler,A.N.; H.S. Potter, 1970. Chemical control of halo blight in field beans. Michigan Agr. Expt. Sta. Res. Rept. 98 pp.

Schonherr, J. and E.S. Mbugua. 1976. Bean production in Kenya's Central and Eastern Provinces.Survey of the situation analysis of problems, recommendation for extension and other infrustructural support. Joint Survey of I.D.S. U.o.N. and Thika Bean Research team 88 pp.

Schroth, M.M.; V.B. Vitanza and D.C. Hildebrand 1971. Pathogenic and nutritional variation in halo blight group of fluorescent *Pseudomonads* on beans.

Schuster, M.C, 1953. A method of testing resistance of bean bacterial blights. Phytopathology 45: 519-520.

hwartz, H.F. and G.E. Galvez. 1980. Bean production problems: Disease, insect, soil and climate constraints of *Phaseolus vulgaris*. Central International de Agricultura Tropical (CIAT). Apartado Aero 6713, Cali, colombia 424 pp.

ttler, F.W. and R.E. Wilkinson 1966. Effect of probing behaviour and starvation of *Myzus persicae* on transmission of bean common mosaic virus. Phytopathology 56(9): 1079-1082

mith, M. 1972. Plant virus diseases pp. 60-75. Longmans Group Limited, London.

teel, R.G.D. and J.H. Torrie. 1960. Principles and procedures of statistics McGraw-Hill Book Company Inc. New York, Toronto, London.

aylor, J.D. and C.L. Dudley. 1977. Effectiveness of late copper and streptomycin sprays for the control of halo blight of beans *Pseudomonas phaseolicola*. Annals of Applied Biology 5(2): 217-221.

mwesigye,1988. Heterosis and Combining Ability in Common Bean *Phaseolus vulgaris*. Msc-Thesis ; University of Nairobi

n der Plank, J.E. 1968. Disease resistance in plants. Academic Press, New York 206 pp.

allen, V.r. 1968. Identification of races of *Pseudomonas phaseolicola* from Quebec bean fields.Canadian Plant Disease Survey 48(3): 97-98.

rkes, Jr. D. W. 1958. Additional new races of *C. lindemuthianum* in Mexico. Pl. Dis. Reptr. 42(3): 329.

umeyer, W.J. and H.K. Thomas. 1957. A monographic study of bean diseases and methods of their control. USIDA. Agric. Tech. Bull. 868, 255p.

Appendix 1: Mean squares for plant traits of bean cultivars inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum* in the greenhouse at Kabete.

Source	df	Mean squares				
		Primary branches/ plant	Pods/ plant	Seeds/ plant	100-seed weight	Weight dry matter
Block	3	0.6	2.8NS	26.6*	10.4NS	0.1
Inoculations	3	1.8NS	437.4**	11429.2**	4992.2**	22.9**
Error (a)	9	1.5	1.1	6.7	5.6	0.1
Cultivars Inoculations	6	0.8NS	59.1**	1576.7**	2324.6**	1.8**
Cultivars	18	0.4NS	13.4**	245.2**	227.3**	0.9**
Error (b)	72	0.5	5.6	12.9	3.7	0.1
Total	111					
CVa(%)		9.7	4.6	3.1	2.2	3.4
CVb(%)		19.6	27.9	11.4	4.7	8.7

Description of notations:

df - degrees of freedom

CV - coefficient of variation

NS - Not significant

** - Significant at 1% level

* - Significant at 5% level.

ix 2: Mean squares for plant traits of F_2 progenies inoculated with bean common mosaic virus, *Pseudomonas phaseolicola* and *Colletotrichum lindemuthianum* in the greenhouse at Kabete.

	df	Mean square				
		Primary branches/ plant	Pods/ plant	Seeds/ plant	100 seed weight	Weight of dry matter
	3	0.6NS	8.7NS	138.3NS	13.1NS	2.8*
ations	3	41.7**	2341.9**	46980.4**	21551.9**	624.1**
(a)	9	2.2	3.5	120.4	3606.8	0.7
es	27	2.9NS	33.9**	1227.9**	1119.8**	11.5**
lations						
sses	81	1.15NS	8.1	237.6**	208.3**	7.3**
(b)	324	4.4	4.3	72.6	1.5	0.4
	44.7					
		7.6	3.9	6.8	26.9	2.0
		57.3	22.9	28.1	2.9	9.0

ption of notations:

df - degrees of freedom

CV - coefficient of variation

NS - not significant

** - significant at 1% level

* - significant at 5% level.

Appendix 3: Mean squares for plant traits of F_3 progenies inoculat with bean common mosaic virus, *Pseudomonas phaseolico* and *Colletotrichum lindemuthianum* in the greenhouse Kabete.

Source	df	Mean squares				
		Primary branches/ plant	Pods/ plant	Seeds/ plant	100-seed weight	eight dry we
Block	3	1.6NS	8.5**	18.9NS	3.4NS	0.1
Inoculations	3	84.9**	2280.4**	49147.8**	21479.6**	616.4
Error (a)	9	0.7	0.9	30.1	1.1	0.2
Crosses	27	2.1NS	28.2**	865.7**	1513.9**	10.2
Inoculations x crosses	81	2.4NS	11.5**	332.7**	103.9**	5.6
Error (b)	324	0.6	1.4	68.2	1.2	0.2
Total	447					
CVa %		3.8	1.9	3.1	4.7	1.2
CVb %			19.3	12.9	25.1	6.4

Description of notations:

df - degrees of freedom

CV - coefficient of variation

NS - not significant

** - significant at 1% level

* - significant at 5% level.

endix 4: Success rate of the diallel crossing

ss	No. of crosses	No. of successful crosses	No. of seeds per cross	Success rate (%)
GLP-2 x GLP-288	42	30	150	71.4
GLP-2 x GLP-24	40	28	112	70.0
GLP-2 x GLP-X.92	39	33	132	84.0
GLP-2 x M535	38	35	175	92.0
GLP-2 x NB-123	45	28	112	62.0
GLP-2 x L226-10(52)	46	27	108	58.0
GLP-288 x GLP-2	35	32	128	91.4
GLP-288 x GLP-24	50	34	102	68.0
GLP-288 x GLP-X.92	48	34	136	70.8
GLP-288 x M535	41	30	120	73.3
GLP-288 x NB-123	42	34	102	80.9
GLP-288 x L226-10(52)	45	29	116	64.4
GLP-24 x GLP-2	38	34	170	89.5
GLP-24 x GLP-288	48	34	136	70.8
GLP-24 x GLP-X.92	47	29	145	61.7
GLP-24 x M535	46	34	170	73.9
GLP-24 x NB-123	38	34	136	89.5
GLP-24 x L226-10(52)	40	32	160	80.0
GLP-X.92 x GLP-2	40	35	105	87.5
GLP-X.92 x GLP-24	43	36	144	83.7
GLP-X.92 x GLP-288	38	30	90	78.9
GLP-X.92 x M535	42	34	106	80.9
GLP-X.92 x NB-123	47	30	90	63.8
GLP-X.92 x LL226-10(52)	48	29	87	60.4
M535 x GLP-2	41	35	175	85.4
M535 x GLP-288	42	35	175	83.3
M535 x GLP-24	43	34	136	79.1
M535 x GLP-X.92	38	33	165	86.8
M53 x NB-123	90	30	120	76.9
M535 x L226-10(52)	35	28	140	80.0
NB-123 x GLP-2	36	34	136	94.4
NB-123 x GLP-288	40	33	132	82.5
NB-123 x GLP-24	41	34	102	82.9
NB-123 x GLP-X.92	46	38	190	82.6
NB-123 x 535(M9)	45	40	160	88.8
NB-123 x L226-10(52)	47	41	164	87.2
L226-10(52) x GLP-2	48	36	180	75.0
L226-10(52) x GLP-288	50	37	185	74.0
L226-10(52) x GLP-24	51	38	152	74.5
L226-10(52) x GLP-X.92	48	35	140	72.9
L226-10(52) x M535	42	36	144	85.9
L226-10(52) x NB-123	42	38	190	90.5

ppendix 5: Dry bean acreage, yield and production in the world during 1970.

tinent	Area harvested 1000 ha	Yield kg/ha	Production 1000 MT
ca	2131	603	1285
America	2767	794	2198
rica	5271	519	5736
	13640	526	7176
ia	10	797	8
	52	1865	94
	1501	467	701

O Production yearbook (1979)

Appendix 6: Estimated bean yield losses attributed to plant pathogens

Plant disease	Estimated yield loss %	Reference Area
Bean common mosaic virus	53-68	USA
	16-95	Latin America
Bean golden mosaic virus	48-85	Brazil
Common bacterial blight	10-38	USA
	18-45	Colombia
Rust	38-50	Brazil
	40-80	Colombia, USA
Angular leaf spot	50	USA
	40-60	Colombia

Source: FAO Production yearbook (1979).

Appendix 7: Reaction of the parents to common blight, (*Xanthomonas phaseoli*) angular leaf spots, *Isariopsis griseola* and rust, *Uromyces phaseoli* in the field at Kabete.

Cultivar	Pathogen		
	Common blight	Angular leaf-spot	Rust
GLP-2	2	2	2
GLP-288	2	2	1
GLP-24	2	3	1
GLP-x.92	1	3	4
M535	1	2	1
L226-10(52)	1	2	1
NB-123	2	2	1

ndix B: Reaction of the F_1, F_2, and F_3 progenies to common blight, *Xanthomonas phaseoli* angular leaf spots, *Isariopsis griseola* and rust, *Uromyces phaseoli* in the field at Kabete.

	Common blight			Angular leafspot			Rust		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
2×GLP-288	2	2	2	1	2	2	2	1	2
2×GLP-24	1	2	2	2	2	3	1	1	2
2×GLP-x.92	1	1	2	2	3	3	3	4	2
2×M535	1	2	1	2	1	1	1	2	1
2×L226-10(S2)	1	1	2	2	1	2	1	1	2
2×ND-123	2	2	1	2	2	2	1	1	2
2×GLP-2	2	2	2	2	1	2	2	1	2
288×GLP-24	2	1	2	2	3	2	2	1	1
288×GLP-x.92	2	1	1	2	3	3	3	3	4
288×M535	1	1	2	2	1	2	1	1	2
24×GLP-2	2	1	2	2	2	3	1	1	2
24×GLP-x.92	2	1	1	2	3	2	4	3	3
24×M535	2	2	1	2	2	2	1	1	1
x.92×GLP-2	2	1	2	2	2	3	4	3	3
x.92×M535	1	1	2	2	2	3	4	2	3
x.92×GLP-24	1	1	2	2	2	3	3	3	4
x.92×L226-10(S2)	1	1	2	2	3	2	3	3	2
x.92×ND-123	2	2	1	3	3	3	4	4	3
GLP-2	1	2	2	2	2	3	1	1	2
GLP-288	1	1	2	2	3	2	1	1	2
GLP-24	1	2	1	2	2	3	1	2	1
GLP-x.92	1	1	2	3	2	2	3	3	4
-10(S2)×GLP-2	2	1	2	2	2	2	1	1	2
-10(S2)×GLP-x.92	1	2	1	2	3	3	4	3	3
3×GLP-2	2	2	2	2	3	2	1	1	2
3×GLP-x.92	2	1	2	2	3	2	4	4	3