A STUDY OF THE INHERITANCE OF RESISTANCE TO ANGULAR LEAF SPOT, *PHAEOISARIOPSIS GRISEOLA* (SAAC.) FERR. IN BEANS (*PHASEOLUS VULGARIS* L.) IN UGANDA.

BY

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DECLARATION

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

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ABSTRACT

A study of inheritance of resistance to angular leaf spot in beans was carried out at Kawanda Research Station, Uganda. It was found that among 343 varieties screened for resistance, about 70 were resistant and 30 susceptible. Four highly resistant varieties (Ac. No. 78, Ac. No. 312, Ac. No. 304, Ac. No. 354) and one highly susceptible variety (Ac. No. 68) were selected and used as parents to generate materials for this study. A diallel cross was performed without reciprocals except in case of the susceptible variety. This resulted into 14 F_1 populations. Some seeds of each of the F_1 populations were planted to produce F_2 seeds, some were crossed to variety Ac. No. 68 to produce backcrosses and 3-way crosses and some were left as F_1 seeds. Some of the F_1 seeds from the 14 F_1 crosses to Ac. No. 68 were planted to raise F_2 seeds. Altogether, 61 populations including the five parents were planted in wooden boxes in a shade and were artificially inoculated with 3,000 conidia/ml of water. The plants were scored for reactions to angular leaf spot 60 days after planting using a 0-5 scale. The observed numbers were used to compute the segregation ratios for the different crosses.

It was found that 3000 conidia/ml of water was the optimum concentration for artificial screening.

Since all F_1 plants were resistant, this indicated that resistance was dominant over susceptibility in all the four varieties. The F_2 generation segregated in 3 resistant: 1 susceptible, the B_1 F_1 in a 1 resistant: 1 susceptible and B_1 F_2 in a 3 resistant: 5 susceptible ratios. These segregation ratios suggested a single dominant gene involved in all crosses. The fact that the results of the reciprocal crosses did not differ has shown that there are no maternal effects influencing the inheritance of this gene for resistance. It has also been proved that all the resistant varieties had the same gene for resistance since no segregation occured in the F_2 s of the crosses between resistant varieties. Segregation which occurred in the F_2 s of the 3 way cross was in a 3 resistant: 1 susceptible as in a single cross.

It has been noticed that in a few cases the observed ratios deviated significantly from the expected ratio. This could have been due to sampling errors but more so due to the unfavourable environment prevailing at the time of inoculation, which could have prevented infection on otherwise susceptible plants.

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CHAPTER I

INTRODUCTION

Beans are the most important grain legume of East Africa. They are commonly known as the french beans, string beans, haricot beans, salad beans, runner beans, kidney beans, snap beans and frijoles in different countries depending on their type and use (Purseglove, 1969). In this text, the term 'beans' will be used to embrace all those types in the species Phaseolus vulgaris L. Beans are eaten as immature pods, dried and canned seeds, green-shelled beans and in some parts of Africa, including East Africa, young tender leaves are used as vegetables (Purseglove, 1969; Goode, 1973). The bean is an ancient crop, believed to have originated in Cental and South America and China (Purseglove, 1969). They have been given a carbon dating of 4975^{+} 200 B.C. They were taken to Europe and Africa by the early Portuguese and Spaniards (Purseglove, 1969; Greenway, 1945). The date of their first introduction to Uganda is not known, but reports by the Department of Agriculture show that by 1920 they were already well established (Anonymous, 1920). Today, beans are one of the most important food crops of Ugandan people and consumed as a protein supplement to maize, rice and other carbohydrate staple foods.

[illegible] production in terms of acreage and yields is difficult to estimate because of many reasons. In the first instance nearly all beans are interplanted with other crops like maize, sweet potato, bananas etc. on small scale farms. The different forms and stages at which beans are eaten makes yield estimates rather difficult since a large quantity never reaches the market. According to Rubaihayo et al. (1972) about 260,000 tons of beans are produced on about 43,000 ha. in Uganda. The yield of beans in Uganda ranges between 400 kg/ha (Leakey, 1970) to well over 1500 kg/ha on well managed farms where proper cultural methods are practiced.

Diseases are the main limiting factor in bean production in Uganda and elsewhere in the world (Zeumeyer, 1957). Included among the major fungal diseases are anthracnose, ashy stem blight, fusarium root rot, powdery mildew, phythium root rots, rhizoctonia root rot, rust, sclerotinia wilt, southern blight and angular leaf spot. Angular leaf spot previously considered a disease of minor importance causes heavy losses in the crop occassionally. In Uganda, the disease was first recorded by Hansford in 1937 as a very common disease especially in moist weather. Today, it is among the four major bean diseases in Uganda together with anthracnose, rust and bacterial blights (Anon, 1962; Leakey, 1970; Emechebe, 1975). Neither the

landraces in Uganda, nor the improved varieties are immune to angular leaf spot although the degree of severity varies among varieties. Simbwa-Bunya (1972) recorded an increase of 34% in yield of beans when he applied chemical control at a time when angular leaf spot was widespread and other diseases negligible. The fact that angular leaf spot can cause economic losses, especially where ideal conditions for its multiplication prevail cannot be underestimated. Much work has been done and documented on bean anthracnose, rust, bacterial blights, viruses and many other bean diseases resulting in improved methods of control of these diseases. However, literature on angular leaf spot is meagre and lacking on some of its major aspects. Very few studies have been made on its epidemiology, physiological strains, control measures and breeding resistant varieties. The use of resistant varieties is ideal and the most economical measure against control of diseases, other methods should be just complementary to it.

This study was therefore undertaken:

(1) to identify the source of resistance to angular leaf spot.

(2) to study the type and mode of inheritance.

(3) to suggest suitable breeding method(s) to develop resistant commercial varieties.

C H A P T E R 2

LITERATURE REVIEW

The angular leaf spot fungus, Isariopsis griseola, was first identified by Saccardo in Italy in 1878 and later Ferraris discovered it to be identical with the genus Phaeoisariopsis in 1909. Other workers have described it under different names. Ellis in 1881 described it as Graphium laxum Ell. and Saccardo (1886) described a similar fungus as Isariopsis laxa (Ell.) Sacc. Ellis and Evarhart described Cercospora columnare from dead leaves collected in New Jersey. All these collections and their descriptions when compared to the authentic Italian I. griseola are identical. Henceforth, the generic name Phaeoisariopsis griseola (Sacc.) Ferr. will be used in this text, as the causal organism of angular leaf spot of beans.

2.1 Economic Importance and Distribution of angular leaf spot.

In the tropical and subtropical areas where beans are grown, angular leaf spot is often encountered in fields; it is always present although at different levels of severity. As an endemic disease causing little damage, it is often mentioned just in passing as one of the diseases noticed. It is common in South American countries (Zeumeyer and

Thomas, 1957). Many workers, quoted by Zeumeyer and Thomas (1957), record it in their countries as reported by Van Poetercan (1920) in Holland, and Ryss in Germany in 1923, show that angular leaf spot is not new in Europe. In U.S.A., angular leaf spot occurs often in the southern tropical and subtropical states but in the Northern more temparate areas its occurance is sporadic (Cole Junior, 1966). It is widespread in Africa. In Sierra Leone it was first recorded by Deighton (1952). Hendrickx (1940) first observed the disease in Congo at Mulungu station in 1938, while Wallace (1952) noted how angular leaf spot spread in Tanzania. In Uganda, angular leaf spot was first recorded by Hansford (1938).

When conditions for its development are favourable, great economic losses to farmers can be caused by angular leaf spot. In 1948 in New Southwales and Victoria in Australia, losses due to angular leaf spot were greatest in seed crops and the disease was regarded as the most important, affecting seed crops on the South Coast (Brock, 1952). In Canberra in 1952, angular leaf spot was responsible for severe leaf drop and abandonment of large plantings. Tanzania had its most severe attack in 1947 due to prolonged rains resulting in a long period of cool, humid conditions for the fungus to spread and multiply (Wallace, 1952). Prior to 1953, angular leaf spot was regarded as a disease of minor

importance on economic crops in New Caledonia in 1953 (Barros, et. al., 1958). It became very important when it caused heavy losses in dry bean crops especially in Valle de Cauca (Barros, et al. 1958). In 1955, angular leaf spot was a new record on local varieties in Varacruz area of Mexico although by then it had started to be very serious in the Southern countries of Central America and Colombia (Yerkes, 1957). Angular leaf spot used to occur in the North East of U.S.A. but it was of minor importance. However, in 1954 an epidemic causing 50% losses was recorded in Wisconsin (Cardona - Alvarez, 1956). In Pennysylvania in 1963, Cole Junior reported that angular leaf spot caused 10-50% reduction in yields with a high incidence of small shrivelled beans. In the following year, severe foliage spotting, defoliation and death occurred at the grain filling period. Although no quantitative comparisons were made, visual observations indicated that lesions and consquent defoliation were primarily responsible for reduction of bean size and yield. Ethiopia experienced losses of 50-60% due to this disease (Galato, 1973), while in Argentina in 1974 Fortugno recorded 30-40% loss in beans due to angular leaf spot. In Uganda Simbwa-Bunya (1972) found that 34% increase in yield could be realised if the disease was controlled by chemicals. Although most workers realised the economic

importance of angular leaf spot, they did not follow up their observations with assessment of how much loss was caused by this disease.

2.2 Fungus Morphology.

Information collected by Zeumeyer and Thomas (1957), places P. griseola (Sacc.) Ferr. in the family Dematiaceae among the Imperfect Fungi. It has a coremium of a small number of hyphae growing erect into a sheaf-like structure. The base is dark coloured and becomes gradually lighter towards the tip. The coremia range in thickness from 20μ to 40μ They are one to three, rarely four septate, light grey, cylindrical to spindle shaped, sometimes slightly curved and not constricted. The length ranges from 50μ to 60μ and width from 7μ to 8μ.

2.3 Symptoms on the bean crop.

Although different workers have described the symptoms of angular leaf spot in different words, collectively, they all project a similar picture of this disease. Zeumeyer and Thomas (1957) reported that when P. griseola attacked a plant, spots originated on the underside of the leaf and were delimited by the veins and veinlets. At first lesions were grey, later they turned brown but did not have coloured boarders. Premature defoliation was common. Pod lesions were roughly circular and reddish brown with dark brown boarders. Stem

lesions were dark brown and elongate. On all lesions dark stroma appeared in abundance. In moist weather, microscopic coremia were formed in the stroma. A similar description was given by Cole Junior (1966). He found that severe foliage spotting in form of small angular dark brown to black lesions occurred. In all cases, the lesions contained fungal hyphae and spores of P. griseola. The spots appeared first on the lower foliage and gradually increased incidence as the season progressed. At mid-season all plants in severely affected parts of the field were dead. Gremmen's (1947) description was not different either. He said that Beka Brown beans showed quadrangular dark brown spots. He went further to give a microscopic appearance of the underside of the leaf which showed masses of dark-brown coremia, bearing elongate often slightly curved hyaline, bi to quadricellular conidia 50µ to 75µ by 7µ to 8µ.

In the laboratory inoculation tests, the symptoms appeared 8 days after inoculation (Srinivasan 1953). Cardona - Alvarez et al. (1956), found that the age of the plant at the time of inoculation, played no significant difference in reaction to the disease but all plants passed through the usual sequence of spotting, necrosis, chlorosis and defoliation.

2.4 Conditions favouring infection.

Whereas the symptoms of angular leaf spot

appear similar in all areas, authors diverge in their description of the seasons when the organism becomes virulent. In Pennyslavania, Cole Junior (1966) observed that less than normal rainfall, with periods of high humidity enhanced the disease. In Brazil, Shands et. al.(1964) stated that angular leaf spot was/dry season disease. Contrary to Cole /a Junior (1966) and Shands et al.(1964) observations, Barros et al. 1958 pointed out that the 1954 epiphytotic resulted from lack of rotation, using overhead irrigation to obtain four crops a year thus providing moisture for infection. Since 1955, the years had been dry and angular leaf spot negligible. Similarly Wallace (1952) found that prolonged rains favoured multiplication of the disease. It seems that humidity and moisture are essential for optimal infection.

Cardona - Alvarez and Walker (1956) made a critical study of this fungus under laboratory conditions. They found that light did not influence the germination of the spores but that temperatures did so. P. griseola could grow between 8°C to 28°C although germination could occur up to 32°C. The optimum temperature for germination and growth was found to be 24°C. Moisture was also essential for germination of spores. Exposure of spores to moisture for a minimum of 3 hours was enough for minimal infection but prolonged exposure for about

24 hours helped to increase infection. Once penetration occurred, the disease continued to develop in a relatively dry atmosphere and stroma were formed abundantly in substomatal cavities. High humidity was essential for coremial formation and about 48 hours of high humidity for abundant sporulation. Infection developed rapidly within the temperature range of 16°C to 18°C. Cardona-Alvarez and Walker (1956) then concluded that the most critical factor in production of epidemics in the tropical and temperate zones appeared to be moisture. Rain, dew, high humidity were essential for germination of spores and subsquent infection while relatively long moist periods were needed for sporulation. Once spores were formed, low humidity was favourable for spore release from coremia and their dissemination. Therefore, the most favourable climatic complex for epidemics include moderate temperatures, and high humidity alternating with periods of low humidity and wind action. This could explain the conflicting reports about angular leaf spot being a dry or rain season disease. Thus, the important factors causing epidemics is a climatic complex of moisture, high humidity moderate temperature and the stage of fungal development.

2.5 Transmission.

Fortugno (1978); Cardona-Alvarez (1956) and Diaz et al. (1968) found that the main source of

inoculum was infected debris from the previous season. Diaz et al., (1968) reported that the fungus could survive for 19 months over two winters. It could also be seed borne (Diaz et al, 1968; Sohi et al., 1974). When pods were kept for two days at 28°C, 4.8% seed transmission occurred, the hilum being the seat of infection (Sohi et al.,(1974).

2.6 Pathogenic Specialisation.

The presence or absence of different strains of P. griseola is a very important area which many research workers have tended to overlook. If different strains are present but not identified, confusing and conflicting results can be obtained while dealing with other aspects of the fungus especially during screening. Wallace (1952) in Tanzania demonstrated the existence of more than one strain but his work was not confirmed by any follow-up experiments. Diaz et al.(1968) noted that morphological and epidemiological data in Lake Valencia basin suggested the existence of different races but again there was no follow-up experiments on this observation. Results from field experiments in Uganda show that different cultivars react differently in different seasons. The difference, however, is very slight and sometimes can be ignored. Although experiments show no definite conclusions, the strains may be present but with very little difference in their virulence (Sengooba, personal communication). This is a field

requiring more comprehensive study.

2.7 Control methods.

(a) Cultural: As the disease is believed to spread from infected straw and volunteer plants growing out of season, Barros et al. (1958) suggested crop rotation and restricting sowing to one time of the year. Wallace (1952) suggested that on neighbouring farms sowing should not spread over a long period and straw from the previous season should be destroyed.

(b) Chemical: Among the chemicals used, Zineb (Zinc Ethylene 1, 2 - bisdithiocarbamate) appears more effective. Barros et al. (1958) found that spraying 250gl.(1137.5 litres) of zineb per hectare 5 - 6 times was effective in controlling angular leaf spot. Mauritius and Malawi, it was found that 2.5g/l could reduce the size of the spots considerably (Anon, 1959). Results based on laboratory work showed that 1% Bordeaux mixture, 1% lime sulphur, 0.5% sukol, 0.5% kumulus (micronised wettable sulphur), checked conidia of P. griseola from germinating and these could be useful in reducing the incidence of the disease (Milatovic, 1959). (Milatovic, 1959) continued to explain that it was necessary to start spraying early and if seeds were dusted with ceresan (Ethylmercurry chlorate) germisan, agrosan (phenylmercury acetate) and copper carbamate at 0.1 - 0.2%, the disease would be

reduced but this would affect germination too. Wallace (1952) and Oxenham (1957) used bordeaux mixture and sulphur dust and found them effective. Other chemicals which have been tried in Colombia by Fortugno (1978) include benzimidozole 60% at 50g/l, benomyl 50% at 40g/l or triforine 20% at 200ml/hl spraying 3 times in each case. Unfortunately, it is not stated by these workers whether the expenses involved were justified in the final increase in yield.

(c) Use of resistant Varieties: Whereas the use of resistant varieties is the cheapest and easiest means of control, it is an area which research workers have not utilized much in case of angular leaf spot. Occassionally, reports on screening of cultivars or breeding for resistance to angular leaf spot are published. In most cases the transfer of resistance is done arbitrarily with no idea of the type of genes being transferred. In such a situation, it is difficult to achieve quick results in breeding programmes.

Zeumeyer and Thomas (1957) reported that Brock (1952) screened 164 lines for resistance to angular leaf spot. Eleven lines were highly resistant and showed no lesions or defoliation on the young leaves.and very few on the first leaves. In Canberra some lines were found resistant but none was immune (Anon, 1953). Barros et al. (1957) found

several lines native and foreign to Colombia which were highly resistant but many of no commercial value. When simple crosses were made, resistance appeared to be recessive and controlled by two or three independent factors. In a very few crosses resistance was dominant. Olave (1960) screened some lines for resistance to P. griseola. Three lines were highly resistant, five moderately resistant, two susceptible and two highly susceptible.

Although some workers have tested for resistance and some have tried to incorporate it in their varieties, only Barros et al. (1957) and Santos et al. (1978) appear to have tried to find out the inheritence of this resistance. Santos et al. (1978) used 44 lines to test the resistance to P. griseola. Two lines were resistant and one very resistant. When the very resistant line was crossed with a very susceptible variety, resistance to the most pathogenic local isolate proved to be controlled by a single recessive gene.

From the above reports, it may be concluded that generally there has not been much research on this disease. However, such conditions as described by Cardon-Alvarez et al.(1956) are common in Uganda especially during the growth period and hence requires research attention.

C H A P T E R 3

MATERIALS AND METHODS

3.1 Scoring System.

Following the methods used by Rands and Brotherton (1925), Grahm (1962), and Kasirivu (1978) a number of infected plants were collected from the field and grouped into six classes representing different levels of infection. One plant, representative of each group was selected and traced on a transparent paper showing all the lesions. The lesions were cut out of the transparent paper and the whole drawing transferred on to a graph paper. The percentage infected area was worked out from the graph paper. A description of the scores is given.

Score - 0. (Highly resistant)

Infection percentage up to 1%. Almost all leaves were free of the disease. The total number of spots on the plant was less than 10.

Score - 1. (Resistant)

Percentage infection was between 1 and 10%. Most leaves were free of spots. The total number of spots on the whole plant was between 10 - 30.

Score - 2. (Moderately Resistant)

Infection percentage was between 10 - 25%. Few spots were found on most leaves. The whole plant had about 100 spots.

Score - 3. (Moderately Susceptible)

There was 25 - 50% infection with almost half of the total area of most leaves covered by spots.

Score - 4. (Susceptible)

Between 50 - 75% of the plant infected with many spots. All leaves of the plant were covered with spots which coalesced and were difficult to count.

Score - 5. (Highly Susceptible)

Infection percentage ranged between 75 - 100%. The general appearance of the whole plant was a dirty brown with yellowing and premature defoliation in some cases. The conidia could be seen on the underside of the leaf as masses of black spots.

3.2 Preliminary Screening.

Three hundred and fourty three bean varieties obtained from Kawanda Research Station, Kampala were screened for resistance to angular leaf spot under field conditions. The season was fairly hot and dry (Table 1). These varieties were planted in a 7 x 7 x 7 triple lattice design with three replicates. Single row plots of 10 plants spaced at 50 cm between rows and 10 cm between plants in a row were planted. Single Super Phosphate was applied at the rate of 125 kg/ha at planting. No artificial inoculation was done and scoring for angular leaf spot using a 0-5 scale, described above, was done 60 days after planting. Other diseases if present

Table 1: Weather conditions at Kawanda Research Station during the planting seasons in 1975, 1979 and 1980

Year	Month	Total Rainfal in mm	No of rain days	Max Temp ^{o}C	% Rela humidi
1975	Sept.	186.6	16	28.3	72
	Oct.	117	13	28.7	77
	Nov.	118.3	12	29.2	61
1979	Sept.	54.1	4	31.2	59
	Oct.	59.1	6	31.2	61
	Nov.	100.2	11	31.2	62
1980	March	68	9	31.0	59
	April	70	13	30.2	60

were also noted but were not scored. The mean disease scores and their variances were culculated. This preliminary screening for resistance and susceptibility was used as a basis for further screening. A total of 72 most resistant and 28 most susceptible varieties were selected for screening under artificial conditions.

3.3 Source and preparation of the inoculum.

A number of leaves attacked by angular leaf spot were collected from the field. The infected areas were cut out and crushed in a mortar with a small amount of sterile distilled water, following a method given by Cardona-Alvarez and Walker (1957). Ten c.c. of sterile distilled water was added and the suspension filtered through a muslin cloth. Using a sterile loop, the filterate was streaked on potato dextrose agar media in petri-dishes and the fungus kept for 10 days in the culture room. A sub-culture was then made. No effort was made to identify if biotypes of this pathogen existed but the initial isolate used was kept for all future inoculations. This isolate was kept viable by using it to re-infect new plants and making fresh cultures from these infected plants. The inoculum was prepared by cutting colonies off the culture media and mecerating them in sterile MacCartney bottles using distilled sterile water. The suspension was filtered through a triple layer of muslin cloth. The number

of conidia in a millilitre of water was determined using a hemocytometer. The suspension was diluted up to the required concentration of 3000 conidia per ml.

3.4 Determination of optimum inoculum concentration.

To find out optimum inoculum concentration two varieties namely Banja 2 (susceptible) and Ac. No. 78 (resistant) were inoculated with different conidial concentrations. The concentrations used were 0 (ordinary tap water), 1000, 2000, 3000, 4000, and 5000 conidia/ml of water. Fifteen day old seedlings, planted in claypots were placed in a high humidity chamber for 24 hours prior to inoculation. The high humidity chamber (90 - 100% relative humidity and 18^{o} - 24^{o}C temperatures) designed at Kabanyolo University farm, Kampala, by Bushoff and Kizito was used. It provided a humid and cool environment appropriate for development of angular leaf spot after inoculations. There were 12 treatments i.e., 6 concentrations and 2 varieties. The treatments were replicated 3 times in a completely randomised design. Inoculation was done using a metal atomiser and spraying the leaves until wet on both sides. The seedlings were placed in the humid chamber 24 hours before inoculation and returned to the same chamber for 15 days. The analysis of variance was carried out on the data and the mean separation made to group the concentrations which were not significantly different from each other.

3.5 Greenhouse Screening of the varieties.

Fifteen day old seedlings of the 100 selected varieties based on preliminary screening were artificially inoculated with angular leaf spot spores at a concentration of 3000 conidia/ml of water. A completely randomised design with 2 replications was used. The inoculated seedlings were kept in the high humidity chamber for 15 days before they were scored on a 0-5 scale. The analysis of variance of mean scores was calculated. The results obtained were compared with those obtained from the field screening. Finally, one highly susceptible and four highly resistant varieties were selected as parents for generating materials for genetic studies. The selected varieties were:

Ac. No. 78. Obtained from Colombia under the name of Mexico 11. It is highly resistant to angular leaf spot. It is indeterminate, late maturing with small black seeds.

Ac. No. 312. Obtained from Guatemala under the name of M 122. It is highly resistant to angular leaf spot. It is indeterminate, late maturing with small black seeds.

Ac. No. 304. Obtained from Costa Rica under the name of CR 25. It is highly resistant to angular leaf spot, indeterminate, late maturing with small yellowish-brown seeds.

Ac. No. 354. Came from U.S.A. as P.I. 313674. It is an indeterminate, late maturing variety, with small black seeds.

Ac No. 68. Is indegenous to East Africa. In Uganda it is known as Kinyobwa and in Kenya it is called Tsindola. It is a bush type, very early maturing with small but plump, pink speckled seeds. It is highly susceptible to angular leaf spot.

3.6 Diallel Crosses.

The five parents selected (Ac. No 78, Ac. No 312, Ac. No 304, Ac. No. 354, Ac. No. 68) were crossed in all possible combinations excluding reciprocals, except in case of the susceptible parent giving rise to 14 F_1 progenies. The crosses were made on potted plants kept in an open shade. Emasculation was done using a needle and a pair of forceps. Care was taken to prevent accidental selfs and contamination by removing all open flowers, by examining the pollen sacs of mature buds to see if they had already raptured and by using methylated spirit to sterilise apparatus before each cross was made. The F_1 seeds were divided into three groups. One lot was left as F_1 seeds, the second lot was planted to provide F_2 seeds and the third lot of F_1 plants was crossed to Ac. No. 68 (susceptible parent). The seeds obtained from crossing F_1 to Ac. No 68 were divided into 2 groups. One lot was left as B_1 F_1 and the second lot was planted to

produce B_1 F_2 seeds. Thus, 61 populations including the five parents were obtained and are listed below.

Parents (5): Ac. No. 78
Ac. No. 312
Ac. No. 304
Ac. No. 354
Ac. No. 68

F_1 S (14): Ac. No. 312 x Ac. No. 78
Ac. No. 304 x Ac. No. 78
Ac. No. 354 x Ac. No. 78
Ac. No. 304 x Ac. No. 312
Ac. No. 354 x Ac. No. 312
Ac. No. 354 x Ac. No. 304
Ac. No. 68 x Ac. No. 78
Ac. No. 68 x Ac. No. 312
Ac. No. 68 x Ac. No. 304
Ac. No. 68 x Ac. No. 354

Reciprocals (4): Ac. No. 78 x Ac. No. 68
Ac. No. 312 x Ac. No. 68
Ac. No. 304 x Ac. No. 68
Ac. No. 354 x Ac. No. 68

F_2 (14) of the above populations.

F_1 (14): crosses of above populations to Ac. No. 68.

(a) 3-way crosses (6): (Ac. No. 312 x Ac. No 78) x Ac. No 68

(Ac. No. 304 x Ac. No. 78) x Ac. No. 68

(Ac. No. 354 x Ac. No. 78) x Ac. No. 68

(Ac. No. 304 x Ac. No.312) x Ac. No. 68

(Ac. No. 354 x Ac. No.312) x Ac. No. 68

(Ac. No. 354 x Ac. No.304) x Ac. No. 68

(b) B_1F_1 (8):

(Ac. No. 68 x Ac. No. 78) x Ac. No. 68

(Ac. No. 68 x Ac. No.312) x Ac. No. 68

(Ac. No. 68 x Ac. No.304) x Ac. No. 68

(Ac. No. 68 x Ac. No.354) x Ac. No. 68

(Ac. No. 78 x Ac. No. 68) x Ac. No. 68

(Ac. No.312 x Ac. No. 68) x Ac. No. 68

(Ac. No.304 x Ac. No. 68) x Ac. No. 68

(Ac. No.354 x Ac. No. 68) x Ac. No. 68

F_2 (14) of the above F_1 populations.

(a) F_2 (6) of the 3-way cross.

(b) B_1 F_2 (8).

3.7 Inheritance of resistance.

The final experiment to study the inheritance of resistance to angular leaf spot included 61 populations described above. Due to the prevailing hot and dry weather in the first rain season of 1980 (Table 1), the experiment was planted in a shade in wooden boxes using a completely randomised design with 2 replications The seeds were planted at a spacing of 10 cm between plants in a row and 20 cm

between rows. The least number of plants for each generation are given below:

Generation	No. of Plants
F_1	20
F_2	60
B_1 F_1	20
B_1 F_2	60

Artificial inoculation was done 18 days after planting with a CP-3 pump, using the optimum concentration of 3000 conidia/ml water. The plants were inoculated again three weeks later because no symptoms developed after the first inoculation. The second inoculation was effective and the scores were taken 3 weeks after the second inoculation or 60 days after planting.

3.8 Statistical analysis.

3.8.1 The analysis of variance was done to test if variation between the different mean scores was significant following the method described by Leclerg et al. (1962).

3.8.2 X^2- test.

To test the goodness of fit of the expected genetic ratios in the segregating generations a X^2 test was applied.

$$X^2 = \frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}}$$

F_1 results were used to determine whether resistance to angular leaf spot was governed by dominant or recessive gene(s). The backcrosses and F_2 results were used to determine the genetic ratios and number of gene(s) involved in inheritance.

The results of the F_2 progenies among resistant parents were used to test if different parents used had the same or different gene(s) for resistance to angular leaf spot.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Determination of inoculum concentration.

Table 2a gives the mean scores of resistance to angular leaf spot of the two bean varieties, Ac. No. 78 (resistant) and Banja 2 (susceptible). The data was transformed into square roots and analysis of variance (Table 2b) showed that the differences between the mean scores were highly significant. The control treatments did not show any symptoms of the disease and recorded zero mean scores. At conidial concentrations of 1,000, 2,000, and 3,000 conidia/ml of water, the mean scores of angular leaf spot for the resistant variety (No. 78) was 0.6 in all the three concentrations while in Banja 2 (susceptible) the scores were 2.3, 3.0 and 2.3 respectively. Concentrations of 4,000 and 5,000 conidia/ml of water raised the mean score of angular leaf spot in No. 78 to 1.6 in both cases. In Banja 2, the two concentrations gave mean scores of 3.6 and 3.3 respectively. A mean separation of the transformed data put the mean scores of both controls and 1000, 2000 and 3,000 conidia/ml of water for No. 78 in one group with no significant differences between them. The mean scores for 4,000 and 5,000 conidia/ml of water on the resistant variety were grouped with 1000, and 3000 conidia/ml of

Table 2a: Mean Score of resistance to angular leaf spot of two bean varieties using 6 different inoculum concentrations.

Variety	Concentration of Conidia/ml of water					
	0	1000	2000	3000	4000	5000
C. No. 78	0	0.6	0.6	0.6	1.6	1.6
	(1)	(1.2)	(1.2)	(1.2)	(1.6)	(1.6)
Kanja 2	0	2.3	3.0	2.3	3.6	3.3
	(1)	(1.8)	(2.0)	(1.7)	(2.1)	(2.0)

Figures in parenthesis are on transformed square root value.
L.S.D. 5% 0.298.

C.V. 11.01%

Mean separation on transformed data

1.0 1.0 1.2 1.2 1.2 1.6 1.6 1.7 1.8 2.0 2.0 2.1

Table 2b: Analysis of variance for the mean scores of resistance to angular leaf spot in the two bean varieties (data transformed into square roots).

Source of Variation	df	ss	ms	F	
Treatments	11	5.205	0.473	15.26	**
Replicates	2	0.071	0.036	1.16	
Error	22	0.690	0.031		

** Significant at 1% level

water for Banja 2. They were significantly different from the first group. The mean scores for 2,000, 4,000 and 5,000 conidia/ml of water for Banja 2 formed a third group which was also significantly different from the first two groups. The results of this study indicate the effect of spore concentration on the development of symptoms especially on the resistant variety. With low concentration of 1,000, 2,000 and 3,000 conidia/ml of water, the symptoms on the resistant variety were few while the susceptible variety quickly succumbed to the disease. As the concentration increased to 4,000 conidia/ml and above the resistance of Acc. No. 78 was lowered and it was classified with susceptible variety.

The recorded mean scores for angular leaf spot was directly related to spore dosage in the resistant variety. The same relationship was apparent in the susceptible variety although less uniform. It was therefore concluded that it is important to determine the minimum spore load to produce the required symptoms for screening resistant varieties as suggested by Shreiber (1967) and Jones (1964). Bantrri and Wilcoxsin (1964) stressed the importance of spore concentration in inheritance studies as screening of varieties is influenced by the concentration of inoculum used. A concentration of 3,000 conidia/ml of water appears optimum for distinguishing susceptible and resistant varieties of beans. Above 3,000 conidia/ml of water the symptoms on the resistant variety were severe enough to classify it with the susceptible variety.

4.2 Field Screening under natural conditions.

The mean scores of the natural field screening of the 343 varieties are given in Table 3. There was a wide range of variation in reaction to angular leaf spot among these varieties. The analysis of variance (Table 4) showed highly significant differences between varieties. The results of field screening indicated that about 70 varieties were apparently resistant (up to 1% infection) and about 30 susceptible (infection of 50% and above). In general the small leaved indeterminate types were fairly resistant while the broad-leaved bush types were susceptible. However, a number of bush type varieties in the Kawanda (K) series were moderately resistant. These have been bred and selected for resistance to most of the major diseases in Uganda. Similar to the results obtained in Australia (Anon, 1953), no variety was found to be immune. The place of origin of varieties showed no relationship with the intensity of the disease. During the screening seasons the weather was not condusive to disease development as Table 1 shows. The season remained dry with low relative humidity. At the beginning either due to few spores being available or to unequal distribution of spores, the development of disease symptoms on the varieties was not uniform. Consquently some varieties escaped infection as growth of coremia and sporulation was limited. Other diseases like anthracnose and

Table 3: The mean scores of resistance to angular leaf spot and other characteristics of 343 bean varieties under field screening.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
1	Banja	Uganda	Bush	30	3.0	H.S	S	S
1/1	Banja	Uganda	Bush	32	4.0	S	MR	MR
1/2	Banja	Uganda	Bush	32	3.3	S	MR	MR
2	Laja	Uganda	Bush	32	4.0	S	-	R
3	Victory	Uganda	Bush	33	3.6	MR	-	MR
4/1	Mutike	Uganda	Semiclimber	36	2.6	-	-	MR
4/2	Mutike	Uganda	Semiclimber	36	2.6	-	MR	-
60-4-60	Mutike	Uganda	Semiclimber	36	2.3	MS	-	MR
5	Namunye	Uganda	Semiclimber	32	1.0	S	-	-
6	White kidney	-	Bush	34	1.1	S	-	-
7	Black Prince	-	Bush	33	3.3	MS	MR	-
11	Abundance	-	Climber	40	2.0	S	MR	-
12	Mbugozabagole	Uganda	Bush	32	2.6	-	-	-
13	Kade	Uganda	Semiclimber	37	3.0	HS	-	-
14	Mixed Mutike	Uganda	Semiclimber	36	2.0	S	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit
15	Bukulasa	Uganda	Bush
62-x15-1	Bukalasa	Uganda	Bush
16	Lugala	Uganda	Bush
19	Toro-yellow	Uganda	Semiclimber
20	Haricot	Uganda	Semiclimber
21	Kagi	Uganda	Semiclimber
23	Ngora runner	Uganda	Climber
24	Kigondo	Uganda	Climber
25	Hirst Col. 2	Uganda	Semiclimber
26	Hirst Col. 8	Uganda	Bush
28	Hirst Col.10	Uganda	Climber
28/6	Hirst Col.	Uganda	Climber
29	Hirst Col. 11	Uganda	Bush
30	Hirst Col. 12	Uganda	Bush
31	Hirst Col. 14	Uganda	Bush
33	Hirst Col. 20	Uganda	Semiclimber

Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
37	2.3	S	-	-
33	3.0	R	R	-
36	2.3	-	-	-
35	2.6	-	-	-
35	2.0	-	-	-
38	1.6	-	-	-
36	1.0	-	R	-
30	3.3	-	-	-
33	3.6	-	-	-
33	2.3	-	-	-
39	1.3	-	-	-
32	2.3	-	-	-
34	3.0	-	-	-
33	1.0	MS	-	S
33	3.0	MS	MS	-
33	1.6	S	MS	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
35	Hirst Col. 24	Uganda	Semiclimber	37	1.6	S	-	-
64-35-1	Hirst Col.	Uganda	Semiclimber	37	1.6	-	-	-
64-35-2	Hirst Col.	Uganda	Semiclimber	34	2.3	-	-	-
64-35-3	Hirst Col.	Uganda	Semiclimber	36	2.3	-	-	-
36	Hirst Col. 25	Uganda	Semiclimber	36	3.6	S	-	-
37	Hirst Col. 26	Uganda	Semiclimber	36	2.3	S	-	-
38	Hirst Col. 27	Uganda	Bush	30	4.0	-	-	-
39	Hirst Col. 28	Uganda	Bush	32	3.0	HS	-	-
41	Hirst Col. 30	Uganda	Semiclimber	38	2.3	-	-	-
42	Hirst Col. 31	Uganda	Semiclimber	36	3.0	MS	-	-
44	Hirst Col. 33	Uganda	Semiclimber	36	2.0	S	-	-
45	Hirst Col. 35	Uganda	Bush	32	3.6	S	-	-
47	Hirst Col. 39	Uganda	Semiclimber	38	2.0	-	-	-
49	Hirst Col. 51	Uganda	Climber	41	1.3	-	-	-
49/2	Hirst Col.	Uganda	Climber	39	1.3	-	MS	-
62-52-2	Hirst Col.	Uganda	Climber	39	2.0	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
53	Hirst Col. 60	Uganda	Climber	38	2.3	MS	-	-
56	Hirst Col. 63	Uganda	Semiclimber	39	1.6	-	-	-
57	Hirst Col. 64	Uganda	Semiclimber	36	-	HS	-	-
59	Hirst Col. 65	Uganda	Semiclimber	39	2.0	-	-	-
61	Hirst Col. 67	Uganda	Bush	31	4.0	-	-	-
62	Hirst Col. 68	Uganda	Bush	32	3.0	S	-	-
63	Hirst Col. 73	Uganda	Bush	30	3.0	-	-	-
64	Hirst Col. 74	Uganda	Semiclimber	34	3.3	HS	-	S
65	Nalongo	Uganda	Bush	34	3.6	MS	-	-
67	Mubende	Uganda	Semiclimber	33	2.3	-	-	-
68	Tsindoli	Kenya-Uganda	Bush	30	4.0	-	-	-
71	Auguche (3)	Kenya	Bush	31	3.6	-	-	-
71/1	Auguche	Kenya	Bush	32	4.0	-	-	-
72	-	Uganda	Climber	37	1.6	-	-	-
76	Diacol Nutibara	Colombia	Bush	34	3.3	-	-	S

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
77	Diacolo Nima	Colombia	Bush	36	1.6	R	-	-
78	Mexico 11	Colombia	Semiclimber	41	0.6	R	-	R
79	Mexico 12	Colombia	Semiclimber	36	3.3	-	-	R
85	Hirst Col. 68	Uganda	Bush	32	3.6	-	-	S
85/1	Hirst Col.	Uganda	Bush	32	4.0	S	-	S
86	Tanganyika black	Tanga-nyika	Climber	39	1.0	-	MS	-
89	Hirst Col. 20	Uganda	Semiclimber	33	1.3	-	S	-
90	Hirst Col.	Uganda	Semiclimber	36	1.6	-	S	-
92	-	Uganda	Semiclimber	34	1.6	-	S	-
92/1	-	Uganda	Semiclimber	33	2.0	-	S	-
92/10	-	Uganda	Bush	30	1.0	MS	MS	-
92/11	-	Uganda	Bush	34	2.6	-	-	-
92/12	-	Uganda	Bush	30	1.3	S	-	-
92/13	-	Uganda	Bush	33	2.0	-	-	-
93	-	Uganda	Semiclimber	36	2.6	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
94	-	Uganda	Semiclimber	35	2.6	-	-	-
96	Hirst Col.	Uganda	Semiclimber	36	2.6	-	-	-
97	Hirst Col.	Uganda	Semiclimber	36	1.6	-	S	-
99	Hirst Col.	Uganda	Semiclimber	36	1.3	-	S	-
100	Hirst Col.	Uganda	Semiclimber	36	1.0	-	-	-
101	Hirst Col. 35	Uganda	Semiclimber	37	2.6	-	-	-
102	Hirst Col. 38	Uganda	Semiclimber	35	3.0	S	-	-
103	Hirst Col. 38	Uganda	Semiclimber	39	1.3	-	S	-
105	Hirst Col. 38	Uganda	Semiclimber	37	1.3	-	-	-
106	Hirst Col. 51	Uganda	Semiclimber	36	1.3	S	-	-
107	Hirst Col. 52	Uganda	Bush	32	3.0	-	MS	-
109	Hirst Col. 60	Italy	Semiclimber	32	3.3	-	-	-
112	Kanyebwa	Uganda	Bush	32	3.0	-	-	-
114	Katwongere	Uganda	Semiclimber	36	3.3	S	-	-
114/2	Katwongere	Uganda	Semiclimber	38	2.6	MS	-	-
114/3	Katwongere	Uganda	Semiclimber	36	2.6	MS	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
115	Nalunkuma	Uganda	Bush	30	4.0	-	-	-
116	Katwalo	Uganda	Bush	32	4.0	S	-	-
117	Laja (brown)	Uganda	Bush	32	4.0	S	S	-
118	Kasombwa	Uganda	Semiclimber	36	2.6	S	-	-
119	Kasombwa	Uganda	Semiclimber	36	3.3	-	-	-
122	Nabitsali	Uganda	Bush	34	4.0	S	-	-
124	Namunye	Uganda	Bush	31	2.6	S	-	-
127	Kihini	Uganda	Bush	32	4.0	S	-	-
129	Lubamba	Kenya	Bush	32	2.3	S	-	-
131	Kasanduku	Uganda	Bush	32	4.0	S	-	-
132	Kayinja	Uganda	Bush	32	4.0	MS	-	-
135	Mutike	Uganda	Semiclimber	31	2.6	MS	-	-
136	Mutike	Uganda	Bush	30	4.0	-	-	-
137	Kasayi	Uganda	Bush	32	4.0	S	-	-
138	Mutiki	Uganda	Bush	31	2.6	HS	-	-
139	Kisimba	Uganda	Bush	30	3.6	S	-	S
140	Kikira	Uganda	Semiclimber	30	3.0	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
141	Bwesere	Uganda	Semiclimber	34	2.3	-	-	-
142	Nyirangoga	Uganda	Semiclimber	36	1.6	S	-	-
144	Katendeigwa	Ugada	Semiclimber	38	1.0	MS	-	-
145	Kanyamunyu	Uganda	Semiclimber	34	3.3	S	-	-
147	Oruvunyinyanza	Uganda	Bush	32	3.3	S	S	-
149	Ntahagabura	Uganda	Semiclimber	39	3.3	-	-	-
150	Nabuzara	Uganda	Semiclimber	39	2.0	-	-	-
151	-	Uganda	Bush	31	1.0	S	-	-
153	Karolina	Uganda	Bush	33	3.3	S	-	-
154	Kajsu	Uganda	Semiclimber	39	1.3	-	-	-
157	Majita	Uganda	Semiclimber	30	1.3	-	-	-
158	Beka	Holland	Bush	30	2.3	R	R	-
159	Berna	Holland	Bush	31	3.0	MS	R	-
160	Cornell-49-242	Venezuela	Semiclimber	33	1.3	R	MR	-
160B	Cornell-49-242	Venezuela	Semiclimber	32	1.0	R	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
161	59-369	U.S.A.	Bush	32	1.0	R	R	-
163	Roscoco	Kenya	Semiclimber	37	2.0	-	-	S
165	Califonia(S.W)	Australia	Semiclimber	34	2.0	-	-	-
166	Redlands (G.L)	Australia	Bush	37	3.0	S	-	-
167	Redlands (B)	Australia	Bush	35	3.6	MS	-	-
170	The Prince	-	Bush	32	4.0	S	-	-
172	Black Valentine	Tanzania	Bush	32	2.0	HS	-	-
175	Sure Crop	Tanzania	Bush	33	2.0	-	-	-
177	-	Uganda	Bush	33	3.6	-	-	-
178	-	Uganda	Bush	33	4.0	-	-	-
179	-	Kenya	Semiclimber	35	2.6	S	-	-
181	-	Kenya	Semiclimber	36	3.0	MS	-	-
182	-	Kenya	Semiclimber	36	3.0	MS	-	-
185	Banasi	Uganda	Semiclimer	36	2.3	-	S	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
186	Kisho	Uganda	Semiclimber	33	3.0	S	-	-
188	Kafaringa	Uganda	Semiclimber	34	1.6	-	S	-
190	Kayenhze	Uganda	Semiclimber	35	1.3	MS	-	S
191	Kaharakakye	Uganda	Semiclimber	35	1.6	-	-	-
192	-	Uganda	Semiclimber	30	2.6	MS	-	-
193	Mutike	Uganda	Bush	32	3.6	-	-	S
194	Katabawulu	Uganda	Semiclimber	38	1.0	-	-	-
195	-	Uganda	Semiclimber	32	2.6	HS	-	-
196	-	Uganda	Semiclimber	32	2.0	S	-	S
198	Kakhi	Uganda	Bush	32	3.3	-	-	-
199	Musindike	Uganda	Bush	30	3.3	-	-	-
200	Katabawulu	Uganda	Bush	33	3.6	-	-	-
201	Kadugala	Uganda	Semiclimber	38	1.6	-	-	-
203	Mutike	Uganda	Bush	33	4.0	MR	-	-
205	-	Uganda	Semiclimber	36	2.6	HS	-	-
207	-	Uganda	Semiclimber	31	3.0	HS	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
208	-	Uganda	Semiclimber	41	1.0	-	-	-
209	-	Uganda	Semiclimber	38	1.6	-	-	-
211	-	Uganda	Bush	32	3.6	S	-	-
212	Mexico 142	Kenya	Semiclimber	39	2.0	S	-	S
216	-	Uganda	Semiclimber	38	2.6	S	-	-
222	Kentuky wonder	U.S.A.	Climber	39	1.3	-	-	R
231	Red kidney	U.S.A.	Bush	30	2.0	S	-	-
232	Wulma	Rwanda	Semiclimber	38	1.0	-	-	-
234	Caurentino	Rwanda	Climber	40	2.3	-	-	-
262	Mexico 137	Tanga-nyika	Semiclimber	37	1.3	-	-	S
263	Tengeru 70	Tanga-nyika	Semiclimber	36	1.6	S	-	S
264	Mexico 17	Tanga-nyika	Semiclimber	37	1.3	S	-	S
265	Ecudor 66	Tanga-nyika	Semiclimber	39	1.3	-	-	S
266	Ecudor 68	Tanga-nyika	Semiclimber	34	1.6	-	-	S

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
267	Tengeru 14	Kenya	Semiclimber	33	1.0	-	S	-
268	Tengeru 19	Kenya	Semiclimber	38	1.6	-	S	-
269	Tengeru 21	Kenya	Semiclimber	38	1.0	-	-	-
270	Tengeru 54	Tanga-nyika	Bush	35	4.0	-	-	-
271	Tengeru 25	Kenya	Semiclimber	39	1.0	-	-	-
274	H.L.N. 1003	Kenya	Bush	32	4.0	-	-	S
277	H.L.N. 1006	Kenya	Semiclimber	33	-	-	-	S
278	Ecudor	Colombia	Semiclimber	41	1.0	-	-	S
280	Peru 63	Colombia	Semiclimber	41	2.3	-	-	R
281	EE.U.U. 10/	Colombia	Semiclimber	38	2.3	-	-	S
282	Ecudor 68	Colombia	Semiclimber	41	1.6	S	-	-
233	Ecudor 66	Colombia	Semiclimber	41	1.6	-	-	-
284	Diacol catio	Colombia	Bush	33	3.3	-	-	-
285	Antiquia 8	Colombia	Bush	36	3.0	MS	-	-
286	Diacol Anderio	Colombia	Bush	39	1.6	HS	-	-
301	U2	Venezue-la	-	40	1.0	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
303	U27	Venezuela	-	39	1.6	-	-	-
304	CR25	Costa Rica	Climber	38	0.6	-	-	MR
307	CR68	Costa Rica	Climber	33	2.3	-	-	-
308	M64	Mexico	-	41	1.6	-	-	-
309	M94	Mexico	-	49	1.0	HS	-	-
310	M96	Mexico	-	37	1.0	-	MS	-
311	M119	Mexico	Bush	30	1.6	-	S	-
312	M122	Guatemala	Climber	39	1.0	-	S	-
317	P125	Bolivia	-	38	2.3	MS	-	-
318	C1	Colombia	Bush	30	4.0	HS	-	-
320	C42	Colombia	-	41	1.6	S	S	-
321	C56	Colombia	-	39	1.6	S	S	-
322	C58	Columbia	-	41	1.0	S	-	-
325	C67	Columbia	-	43	1.6	HS	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
327	C234	Colombia	-	42	1.3	HS	-	-
329	C324	Colombia	-	35	1.6	HS	S	-
333	Egyptian black	Sudan	-	38	1.6	-	S	-
341	Cofunel	France	-	34	2.6	S	-	-
344	L-Sel-40	Uganda	Bush	34	3.3	-	-	-
345	L-Sel-74	Uganda	Bush	34	2.0	-	-	-
346	L-Sel-88	Uganda	Bush	34	3.0	-	-	-
349	-	Uganda	Semiclimber	32	4.0	-	-	-
350	-	Uganda	Bush	32	3.6	-	-	-
K1	-	Uganda	Bush	31	4.0	-	-	-
K2	-	Uganda	Bush	32	3.3	-	-	-
K3	-	Uganda	Bush	32	3.6	-	-	-
K4	-	Uganda	Bush	32	3.3	-	-	-
K5	-	Uganda	Bush	32	3.6	HS	-	-
K6	-	Uganda	Bush	31	3.6	HS	-	-
K8	-	Uganda	Semiclimber	39	1.3	HS	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
K9	-	Uganda	Bush	36	1.3	-	-	-
K10	-	Uganda	Bush	34	0.6	S	S	-
K11	-	Uganda	Bush	36	2.0	-	-	-
K12	-	Uganda	Bush	33	3.0	MS	S	-
K13	-	Uganda	Semiclimber	38	1.3	-	S	-
K14	-	Uganda	Bush	35	1.6	-	-	-
K15	-	Uganda	Semiclimber	38	1.6	-	-	-
K16	-	Uganda	Semiclimber	37	1.3	MS	S	-
K17	-	Uganda	Semiclimber	38	2.6	MS	S	-
K18	-	Uganda	Bush	33	3.0	-	-	-
K19	-	Uganda	Bush	34	3.3	-	-	-
K20	-	Uganda	Bush	33	3.0	MS	MS	S
K21	-	Uganda	Semiclimber	37	1.6	-	-	-
K22	-	Uganda	Bush	34	2.0	-	-	-
K23	-	Uganda	Semiclimber	39	1.0	-	-	-
K24	-	Uganda	Semiclimber	39	1.3	-	-	-
K25	-	Uganda	Bush	35	1.3	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
K26	-	Uganda	Semiclimber	38	1.0	MS	-	-
K27	-	Uganda	Semiclimber	39	1.6	MS	-	-
K28	-	Uganda	Bush	36	2.3	-	-	-
K29	-	Uganda	Bush	35	2.3	-	-	-
K30	-	Uganda	Bush	34	3.3	-	-	-
K31	-	Uganda	Bush	34	2.6	-	-	-
K32	-	Uganda	Semiclimber	39	1.3	-	-	-
K33	-	Uganda	Semiclimber	38	1.0	-	-	-
K34	-	Uganda	Bush	35	2.3	-	MS	-
K35	-	Uganda	Bush	34	3.3	-	MS	-
K36	-	Uganda	Bush	34	0.3	-	-	-
K37	-	Uganda	Semiclimber	39	1.0	-	-	-
K38	-	Uganda	Semiclimber	36	1.3	-	-	-
K39	-	Uganda	Bush	38	1.3	-	-	-
K40	-	Uganda	Semiclimber	38	2.6	-	-	-
K41	-	Uganda	Semiclimber	36	2.3	-	-	-
K42	-	Uganda	Bush	39	2.0	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
K44	-	Uganda	Bush	34	1.6	-	-	-
K45	-	Uganda	-	37	1.6	-	-	-
382	-	U.S.A.	-	-	1.6	-	-	-
K47	-	Uganda	Bush	33	1.6	-	-	-
383	-	U.S.A.	Bush	34	-	-	-	-
K49	-	Uganda	Bush	34	3.3	-	-	-
K50	-	Uganda	Bush	34	3.3	-	-	-
K51	-	Uganda	Bush	34	3.3	-	-	-
K52	-	Uganda	Bush	34	3.6	-	-	-
K53	-	Uganda	Bush	35	2.6	-	-	-
K54	-	Uganda	Bush	35	2.6	-	-	-
K55	-	Uganda	Bush	36	3.0	-	-	-
K56	-	Uganda	Bush	34	3.3	-	-	-
K57	-	Uganda	Bush	38	2.6	-	-	-
K58	-	Uganda	Bush	34	3.6	-	-	-
K59	-	Uganda	Bush	36	2.6	-	-	-
K60	-	Uganda	Bush	35	3.0	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit
K61	-	Uganda	Bush
K62	-	Uganda	Bush
K63	-	Uganda	Bush
K64	-	Uganda	Bush
K65	-	Uganda	Bush
K66	-	Uganda	Bush
K67	-	Uganda	Bush
K68	-	Uganda	Bush
K69	-	Uganda	Bush
K70	-	Uganda	Bush
K71	-	Uganda	Bush
K72	-	Uganda	Bush
K73	-	Uganda	Bush
K74	-	Uganda	Bush
K75	-	Uganda	Bush
K76	-	Uganda	Bush
K77	-	Uganda	Bush

Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
36	3.3	-	-	-
37	2.0	-	-	-
36	2.6	-	-	-
35	3.0	-	-	-
32	3.6	-	-	-
-	3.6	-	-	-
32	3.6	-	-	-
38	2.6	-	-	-
34	3.3	-	-	-
34	4.0	S	-	-
34	1.6	-	-	-
35	2.3	-	-	-
35	2.3	-	-	-
34	1.6	-	-	-
35	2.3	-	-	-
35	1.6	-	-	-
35	2.3	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
K78	-	Uganda	Bush	35	2.0	-	-	-
K79	-	Uganda	Bush	35	2.0	-	-	-
K80	-	Uganda	Bush	35	1.6	-	-	-
K81	-	Uganda	Bush	35	2.0	-	-	-
K82	-	Uganda	Bush	32	2.3	-	-	-
K83	-	Uganda	Bush	34	2.0	-	-	-
K84	-	Uganda	Bush	32	2.0	-	-	-
K85	-	Uganda	Bush	32	2.0	-	-	-
K86	-	Uganda	Bush	32	2.0	-	-	-
K87	-	Uganda	Bush	35	1.6	-	-	-
K88	-	Uganda	Bush	32	2.3	-	-	-
K89	-	Uganda	Bush	31	2.3	-	-	-
K91	-	Uganda	Bush	35	1.6	-	-	-
K92	-	Uganda	Bush	39	-	-	-	-
K93	-	Uganda	Bush	37	2.6	-	-	-
K94	-	Uganda	Bush	30	2.0	-	-	-
K95	-	Uganda	Bush	36	2.0	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
K96	-	Uganda	Bush	36	2.0	-	-	-
K97	-	Uganda	Bush	35	1.3	-	-	-
K98	-	Uganda	Bush	36	2.3	-	-	-
K99	-	Uganda	Bush	38	1.3	-	-	-
K101	-	Uganda	Bush	38	1.3	-	-	-
K102	-	Uganda	Bush	34	1.3	-	-	-
K103	-	Uganda	Bush	38	2.0	-	-	-
K104	-	Uganda	Bush	38	2.0	-	-	-
K105	-	Uganda	Bush	38	0.6	-	-	-
K106	-	Uganda	Bush	35	1.3	-	-	-
K107	-	Uganda	Bush	38	1.3	-	-	-
K108	-	Uganda	Bush	38	2.0	-	-	-
K109	-	Uganda	Bush	38	1.0	-	-	-
K110	-	Uganda	Bush	36	2.0	-	-	-
347	-	Uganda	Bush	34	2.0	-	-	-
348	-	Uganda	Bush	34	3.6	-	-	-
343	-	Uganda	Bush	33	1.6	-	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
351	-	Uganda	Bush	34	4.0	-	-	-
352	P.I. 165426	U.S.A.	Bush	37	1.3	-	-	-
353	P.I. 165435	U.S.A.	Semiclimber	37	1.3	-	-	-
354	P.I. 313674	U.S.A.	Semiclimber	41	0.6	-	-	-
355	P.I. 313702	U.S.A.	Semiclimber	36	1.33	-	-	-
356	P.I. 313709	U.S.A.	Semiclimber	36	1.0	-	-	-
357	P.I. 313867	U.S.A.	Bush	35	1.0	-	-	-
358	P.I. 313870	U.S.A.	Climber	42	1.0	-	-	-
359	Michelite	U.S.A.	Climber	41	1.0	-	-	-
360	Sanilac	U.S.A.	Climber	38	2.0	-	-	-
361	Seafarer	U.S.A.	Climber	35	3.0	-	-	-
371	Tapery	U.S.A.	Climber	39	2.3	R	-	-
372	E.I. 12719	U.S.A.	Bush	36	1.6	MR	-	-
373	G.N. Jules	U.S.A.	Bush	35	1.6	MR	-	-
374	G.N. Nebraska I	U.S.A.	Bush	37	0.6	MR	-	-
375	G.N. Nebraska27	U.S.A.	Climber	39	2.6	MR	-	-

--- cont.

Table 3: cont.

Ac. No.	Variety	Origin	Habit	Days to flower	Mean score for angular leaf spot	Anthracnose	Bacterial Blights	Rust
376	G.N. Tara	U.S.A.	Climber	40	3.0	MR	-	-
377	G.N. Valley	U.S.A.	Climber	35	2.0	MR	-	-
B7/1/1	-	Uganda	Bush	39	1.0	-	-	-
379	-	Uganda	Bush	35	3.3	-	-	-
387	-	Uganda	Climber	42	1.3	-	-	-
381	-	Uganda	Climber	40	3.0	-	-	-
B7/1/2	-	Uganda	Bush	40	3.0	-	-	-
7/6/3/3	-	Uganda	Bush	40	1.3	-	-	-
B14/1/3	-	Uganda	Bush	40	3.3	-	-	-

NB. Blank (-) no proper records available

R = Resistant

S = Susceptible

MR = Moderately resistant

MS = Moderately susceptible

HS = Highly susceptible

Table 4: The analysis of variance of mean scores of resistance to angular leaf spot in beans screened under natural infection in the field (a) Block Effects.

Source of Variation	df	ss	ms
Replicates	2	5	
Blocks			
Component a	18	10	
Component b	18	7	
Component c	108	56	
Total for blocks	144	73	0.5069 Eb
Treatments	339	815	
Error	534	350	0.655 Ee
Total	1019	1243	

(b) Completely Randomised Block Design

Source of Variation	df	ss	ms	F
Replicates	2	5		
Treatments	339	815	2.4041	3.85 **
Error	678	423	0.6239	
Total	1019	1243		

** Significant at 1.0% level

bacterial blights which are favoured by far wetter conditions were almost negligible. Although the available natural inoculum was not sufficient, the field screening helped to reduce the number of varieties for further screening.

4.3 Greenhouse Screening under artificial Conditions.

Based on field screening the 72 apparently resistant and 28 susceptible varieties were included in the artificial screening for angular leaf spot in the humid chamber. Table 5 shows the field and laboratory mean scores of angular leaf spot for these varieties. In most cases the field and greenhouse results agreed on the level of resistance of different varieties. However, some escapes occurred in the field as in the case Acc. No. 161, Ac. No. K97 and Ac. No. 49/2. Similarly other varieties were found moderately resistant or moderately susceptible in the laboratory although they showed resistance in the field. Scoring in the greenhouse was therefore much easier and reliable since it provided better screening conditions. In addition there were no other foliar diseases to confuse angular leaf spot symptoms. The analysis of variance of the mean scores (Table 6) shows that the differences between the variety scores were significant. From the greenhouse screening trials, materials showing high resistance and susceptibility were selected for genetic studies.

Table 5: Mean Scores of resistance to angular leaf spot in natural (field) and artificial (greenhouse) of the selected bean varieties.

Acc. No.	Field Score	Lab. Score	Reistance grade
304	0.6	0	Highly resistant
K10	0.6	0.5	Highly resistant
K105	0.6	2.0	Moderately resistant
354	0.6	0	Highly resistant
373	0.6	-	Highly resistant
5	1.0	-	Highly resistant
23	1.0	1.5	Resistant
30	1.0	2.0	Moderately resistant
78	0.6	0	Highly resistant
86	1.0	1.0	Resistant
92/10	1.0	0	Highly resistant
100	1.0	0.5	Highly resistant
144	1.0	1.0	Resistant
151	1.0	2.0	Moderately resistant
160 B	1.0	1.0	Resistant
161	1.0	4.0	Susceptible
194	1.0	0.5	Highly resistant
232	1.0	0.5	Highly resistant
267	1.0	1.5	Resistant
271	1.0	2.0	Moderately resistant
278	1.0	3.0	Moderately susceptible
277	0.3	-	Highly resistant
309	1.0	0.5	Highly resistant
310	1.0	2.0	Moderately resistant
312	1.0	0.5	Highly resistant
322	1.0	1.0	Resistant
K23	1.0	1.0	Resistant
K26	1.0	1.0	Resistant

--- cont.

Table 5: cont.

Acc. No.	Field Score	Lab. Score	Resistance grade
K33	1.0	2.5	Moderately resistant
K38	1.0	0.5	Highly resistant
K109	1.0	2.5	Moderately resistant
356	1.0	0	Highly resistant
357	1.0	0.5	Highly resistant
358	1.0	3.5	Moderately susceptible
28	1.3	2.0	Moderately resistant
49	1.3	0.5	Highly resistant
99	1.3	0.5	Highly resistant
103	1.3	1.0	Resistant
105	1.3	0.5	Highly resistant
106	1.3	1.5	Resistant
154	1.3	1.0	Resistant
6	1.3	5.0	Highly susceptible
160	1.3	1.0	Resistant
190	1.3	1.0	Resistant
262	1.3	1.0	Resistant
264	1.3	0	Highly resistant
265	1.3	1.0	Resistant
K8	1.3	1.0	Resistant
K9	1.3	1.5	Resistant
K13	1.3	1.5	Resistant
K16	1.3	0.5	Highly resistant
K24	1.3	1.0	Resistant
K32	1.3	1.0	Resistant
K40	1.3	1.5	Resistant
K97	1.3	4.5	Susceptible
K99	1.3	1.0	Resistant
K101	1.3	3.5	Moderately susceptible

--- cont.

Table 5: cont.

Acc. No.	Field Score	Lab. Score	Resistance grade
K102	1.3	3.0	Moderately susceptible
K106	1.3	1.0	Resistant
352	1.3	1.0	Resistant
353	1.3	0	Highly resistant
355	1.3	2.5	Moderately resistant
379	1.3	3.0	Moderately suseptible
21	1.6	-	
33	1.6	0.5	Highly resistant
35	1.6	1.0	Resistant
64-35-1	1.6	1.5	Resistant
71	3.6	5.0	Highly susceptible
1/1	4.0	4.5	Susceptible
2	4.0	3.5	Moderately susceptible
38	4.0	4.0	Susceptible
61	4.0	2.5	Moderately susceptible
68	4.0	5.0	Highly susceptible
71/1	4.0	4.0	Susceptible
85/1	4.0	4.0	Susceptible
115	4.0	5.0	Highly susceptible
116	4.0	3.5	Moderately susceptible
117	4.0	3.0	Moderately susceptible
122	4.0	3.5	Moderately susceptible
127	4.0	5.0	Highly resistant
131	4.0	3.5	Moderately susceptible
132	4.0	3.5	Moderately susceptible

--- cont.

Table 5: cont.

Acc. No.	Field Score	Lab score	Resistance grade
136	4.0	3.5	Moderately susceptible
137	4.0	4.0	Susceptible
170	4.0	2.5	Moderately resistant
178	4.0	2.5	Moderately resistant
270	4.0	0.5	Highly resistant
K1	4.0	4.0	Susceptible
49/2	1.3	4.0	Susceptible
351	4.0	4.0	Susceptible
222	1.33	1.0	Resistant
K65	3.67	4.0	Susceptible

Table 6: Analysis of variance for mean scores of resistance to angular leaf spot in beans under artificial inoculation.

Source of Variation	df	ss	Ms	F
Total	171	430.45		
Varieties	85	362.45	4.26	5.6 **
Replicates	1	4.65	4.56	6.0
Error	84	63.44	0.76	

** Significant at 1% level

4.4 Inheritance Studies.

4.4.1 Crosses with Ac. No. 78 as a common parent.

The observed number of plants resistant and susceptible to angular leaf spot in P_1, P_2, F_1, F_2, B_1 F_1 and B_1 F_2 progenies of the cross Ac. No. 68 x Ac. No. 78 and its reciprocal are shown in Table 7. The plants of Ac. No. 68 (P_1) were all susceptible and those of Ac. No. 78 (P_2) were all resistant. The F_1 plants, in both cases, were resistant indicating that resistance was dominant over susceptibility and that there were no maternal effects influencing the inheritance of resistance in both varieties. In the F_2 generation, the original cross gave rise to 78 resistant plants and 20 susceptible plants while in the reciprocal cross 123 plants were resistant and 41 susceptible. The F_2 progenies segregated in a 3:1 ratio. The culculated chi-square values in the original case (X^2 = 1.1020) as well as in the reciprocal cross (X^2 = 0) gave a good fit to the 3:1 ratio. This type of segregation suggested that resistance in Acc. No. 78 is controlled by a single dominant gene. Ali (1950) obtained similar results when working on resistance in three bean varieties to common bean mosaic virus 1 in beans. McRostie (1921) also found that some varieties gave a 3 resistant: 1 susceptible ratio in F_2 when tested for resistance to the alpha race of anthracnose. The single gene hypothesis was further demonstrated

Table 7: Observed number of resistant and susceptible plants to angular leaf spot in a bean cross, Ac. No. 68 x Ac. No. 78 and its reciprocal.

Cross	Generation	Observed Numbers		Expected ratio	Calculated x^2	P. range
		Resistant	Susceptible			
No 68	P_1		19			
No 78	P_2	29				
68x 78	F_1	15				
68x78	F_2	78	20	3:1	1.1020	.50-.25
(68x78)x68	B_1 F_1	36	22	1:1	3.3792	.10-.05
(68x78)x68	B_1 F_2	31	90	3:5	7.2864*	.01-.005
No. 78x No. 68	(reciprocal)					
78x68	F_1	17				
78x68	F_2	123	41	3:1	0	
(78x68)x68	B_1 F_1	19	11	1:1	2.1332	.25-.10
(78x68)x68	B_1 F_2	22	47	3:5	0.9284	.50-.25

* Deviation significant.

in F_1 and F_2 of the backcrosses. The B_1 F_1 segregated in a 1 resistant: 1 susceptible ratio and the B_1 F_2 in 3 resistant: 5 susceptible ratio, although the X^2 value of the observed numbers to the expected in the B_1 F_2 of the original cross did not show a good fit. This deviation from the expected ratio could have been caused by sampling error.

Ac. No. 78 was also crossed to the three resistant varieties namely Ac. No. 312, Ac. No. 304 Acc. No. 354 to determine if they possessed the same or different genes for resistance. The results of these three single crosses and the three-way crosses of the F_1 to Ac. No. 68 are shown in Table 8. In all the three single crosses, the F_1s and F_2s were resistant. Ali (1950) found that when genetically different resistant varieties were crossed they segregated in F_2 especially if one variety had a recessive gene for resistance. Therefore, the results obtained for these crosses in Table 8 indicated that the two parents which were involved in that particular cross had the same resistant gene since no segregation occurred in the F_2. Furthermore, when the F_1s were crossed to Ac. No. 68 (susceptible) all F_1s were again resistant. Segregation occurred in F_2 giving a 3:1 ratio in all the three cases. The behaviour in these crosses was similar to a single cross between a resistant and susceptible variety.

Table 8: Observed number of resistant and susceptible plants to angular leaf spot in bean crosses, Ac. No. 312 x Ac. No 78, Ac. No 304 x Ac. No 78, Ac. No 354 x Ac. No 78.

Cross	Generation	Observed Numbers		Expected ratio	Calculated x^2	P. range
No. 312xNo.78		Resistant	Susceptible			
No 312	P_1	17				
No. 78	P_2	19				
312 x 78	F_1	23				
312 x 78	F_2	103				
(312x78)x68	F_1, 3-way Cross	14				
(312x78)x68	F_2, 3-way Cross	67	19	3:1	0.3874	.75-.50
No. 304xNo. 78						
No. 304	P_1	13				
No. 78	P_2	13				
304 x 78	F_1	13				
304 x 78	F_2	72				
(304x78)x68	F_1, 3-way Cross	12				
(304x78)x68	F_2, 3-way Cross	76	16	3:1	2.8405	.10-.05

--- cont.

Table 8: cont.

Cross	Generation	Observed Numbers		Expected ratio	Calculated X^2	P. range
		Resistant	Susceptible			
No. 354x No.78						
No. 354	P_1	16				
No. 78	P_2	14				
354 x 78	F_1	21				
354 x 78	F_2	66				
(354x78)x68	F_1, 3-way Cross	10				
(354x78)x68	F_2, 3-way Cross	71	19	3:1	0.7258	.50-.25

4.4.2 Crosses with Ac. No. 312 as a common parent.

Table 9 gives the results of the cross Ac. No. 68 x Ac. No. 312 and its reciprocal. All the plants of variety Ac. No. 66 were susceptible while those of Ac. No. 312 were resistant. The F_1s were resistant in both cases suggesting that resistance in Ac. No. 312 was dominant with no reciprocal effects. The F_2 of the original cross resulted in 43 plants resistant and 11 susceptible plants while the reciprocal gave 86 resistant plants and 26 susceptible plants. The culculated chi-square values of 0.0057, and 0.1893 fitted well the expected 3:1 ratio with probabilities of P = .95 - .90 and P = .75 - .50, respectively. Therefore, it seems that resistance in variety Ac. No. 312 is controlled by a single dominant gene. In addition the F_1 and F_2 of the backcross in both cases helped to confirm these results. The resistant numbers were 19 and 24 and the susceptible were 17 and 19 in the respective crosses. The culculated X^2 for the 1:1 expected ratios were 0.[illegible]0 and 0.5812 and were a good fit. The F_2 of the backcrosses gave a good fit for the 3 resistant: 5 susceptible plants.

Acc. No. 312 was crossed to the other three resistant varieties too. The results of the cross between Ac. No. 312 x Ac. No. 78 have already bean presented in Table 8 and discussed. The results

Table 9: Observed number of resistant and susceptible plants to angular leaf spot in a bean cross Acc. No. 68 x Acc. No. 312 and its reciprocal.

Cross	Generation	Observed Numbers		Expected ratio	Calculated X^2	P. range
		Resistant	Susceptible			
No. 68	P_1		27			
No. 312	P_2	32				
68 x 312	F_1	20				
68 x 312	F_2	43	14	3:1	0.0057	.95 - .90
(68x312)x68	B_1 F_1	19	17	1:1	0.110	.75 - .50
(68x312)x68	B_1 F_2	37	47	3:5	1.536	.25 - .10
Reciprocal						
312 x 68	F_1	22				
312 x 68	F_2	86	26	3:1	0.1893	.75 - .50
(312x68)x68	B_1 F_1	24	19	1:1	0.5812	.50 - .25
(312x68)x68	B_1 F_2	36	57	3:5	0.059	.95 - .90

of Ac. No. 354 x Ac. No. 312 appear in Table 10. Since the results were similar to the cross Ac. No. 312 x Ac. No. 78 in that F_1s, F_2s and F_1s of the 3-way cross segregated in 3 resistant: 1 susceptible ratio, it proved that all the resistant parents have the same gene for resistance.

4.4.3 Crosses with Ac. No. 304 as a common parent.

It has already been proved that all the resistant parents posses the same gene for resistance. So, when Ac. No. 304 was crossed to Ac. No. 68 and a reciprocal cross made all F_1 progenies were resistant (Table 11) indicating that resistance was dominant. Segregation in F_2 gave a good fit 3 resistant: 1 susceptible ratio, while the backcross generations gave a 1:1 ratio in F_1 and 3 resistant: 5 susceptible ratio in F_2. These figures further confirm the assumption of a single dominant gene.

The crosses between Ac. No. 304 and Ac. No. 78; Ac. No. 312 have already been presented in Tables 8 and 10 and have been discussed. The results of the cross between Ac. No. 354 x Ac. No. 304 (Table 10) do not differ from all the crosses between the resistant varieties. It has already been shown that all the resistant varieties have the same gene for resistance.

Table 10: Observed number of resistant and susceptible plants in bean crosses Ac. No. 354 x Ac. No. 312, Ac. No. 304 x Ac. No. 312, Ac. No. 354 x Ac. No. 304.

Cross	Generation	Observed Numbers		Expected	Calculated	P. range
No.354xNo,312		Resistant	Susceptible	ratio	X^2	
No. 354	P_1	17				
No. 312	P_2	20				
354 x 312	F_1	25				
354 x 312	F_2	69				
(354x312)x68	F_1, 3-way cross	24				
(354x312)x68	F_2, 3-way cross	53	22	3:1	0.7510	.50 - .25
No. 304xNo.312						
No. 304	P_1	11				
No. 312	P_2	18				
304 x 312	F_1	18				
304 x 312	F_2	73				
(304x312)x68	F_1, 3-way cross	12				
(304x312)x68	F_2, 3-way cross	79	31	3:1	0.5938	.50 - .25

--- cont.

Table 10: cont.

Cross No.354xNo.304	Generation	Observed Numbers Resistant	Susceptible	Expected ratio	Calculated X^2	P. range
No. 354	P_1	15				
No. 304	P_2	18				
354 x 304	F_1	18				
354 x 304	F_2	129				
(354x304)x68	F_1, 3-way cross	56				
(354x304)x68	F_2, 3-way cross	104	22	3:1	3.841*	.05

* Deviation significant.

Table 11: Observed number of resistant and susceptible plants to angular leaf spot in a bean cross Ac. No. 68 x Ac. No. 304 and its reciprocal.

Cross	Generation	Observed Numbers		Expected ratio	Calculated x^2	P. range
		Resistant	Susceptible			
No. 68	P_1		28			
No. 304	P_2	25				
68 x 304	F_1	25				
68 x 304	F_2	166	45	3:1	1.5818	.25 - .10
(68x304)x68	B_1 F_1	17	11	1:1	1.2856	.25 - .10
(68x304)x68	B_1 F_2	19	43	3:5	1.2429	.50 - .25
Reciprocal						
304 x 68	F_1	20				
304 x 68	F_2	58	19	3:1	0.0042	.95 - .90
(304x68)x68	B_1 F_1	31	19	1:1	2.88	.10 - .05
(304x68)x68	B_1 F_2	55	66	3:5	3.2666	.10 - .05

4.4.4 Crosses with Ac. No. 354 as a common parent.

The results involving Ac. No. 354 with the susceptible variety Ac. No. 68 and its reciprocal are presented in Table 12. Similar to the forementioned crosses between the susceptible and resistant varieties, these crosses segregated with 3:1 ratio in F_2; 1:1 ration in B_1 F_1 and 3:5 ratio in B_1 F_2. B_1 F_2, however, showed significant deviation from the expected ratio. In the cross between Ac. No. 354 and Ac. No. 304 (Table 10) the expected 3:1 ratio in the F_2 of the three-way cross showed significant deviation. This could have been due to the unfavourable weather prevailing at the time of inoculation resulting in failure of infection of otherwise susceptible plants. In fact, in most crosses the susceptible plants are deficient although the numbers are not significant. As it has been shown by Cardon-Alvarez and Walker (1957) angular leaf spot development is arrested at temparatures above 28°C and low humidity. Although it will germinate, it will not grow or sporulate in low humid conditions. Therefore, the high temparatures (30.2°C) and low relative humidity (59-60%) (Table 1) could have played a part in reducing the number of susceptible plants.

4.4.5 Crosses involving Ac. No. 68 as a common parent.

In most cases Ac. No. 68 has appeared as one of

Table 12: Observed number of resistant and susceptible plants to angular leaf spot in a bean cross Ac. No. 68 x Ac. No. 354 and its reciprocal.

Cross	Generation	Observed Numbers		Expected ratio	Calculated x^2	P. range
		Resistant	Susceptible			
No. 68	P_1		32			
No. 354	P_2	33				
68 x 354	F_1	24				
68 x 354	F_2	59	30	3:1	3.5992	.10 - .05
(68x354)x68	B_1 F_1	16	10	1:1	1.3846	.25 - .10
(68x354)x68	B_1 F_2	74	90	3:5	4.0649*	.05 - 025
Reciprocal						
354 x 68	F_1	8				
354 x 68	F_2	49	15	3:1	0.0833	.90 - .75
(354x68)x68	B_1 F_1	9	9	1:1	0	.95
(354x68)x68	B_1 F_2	17	30	3:5	0.035	.90 - .75

* Deviation significant.

the parents. It has been shown in all cases (Tables 7-12) that the gene for susceptibility was recessive.

The varieties carrying the gene for resistance do not have the desired agronomic characters and hence inferior and commercially unacceptable. Resistance found in these varieties is due to a single dominant gene and can be transferred by the backcross method to a commercial variety. As this is a major gene conferring resistance, it can lose effectiveness should there be a change in the biotype of the pathogen. Different reactions were obtained for the different varieties during screening. It may be that these other varieties have different genes for resistance. If these are found to be different, the formation of a multiline variety would be advantageous in overcoming losses due to new races which might occur.

SUMMARY AND CONCLUSION

1. The inheritance study involving P_1, P_2, F_1, F_2, B_1 F_1, B_1 F_2 and F_1 and F_2 of the 3-way populations arising from crosses of 4 resistant bean varieties (Ac. No. 78, Ac. No. 312, Ac. No. 304, Ac. No. 354) and 1 susceptible variety (Ac. No. 68) confirmed that resistance to angular leaf spot was governed by a single dominant gene and that the resistant gene in all the four varieties was the same.

2. A Backcross method was suggested in transfer of the resistance gene from any of these varieties to commercially acceptable varieties.

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