HOST RANGE AND SURVIVAL OF SPHACELOMA SP AND ITS INTERACTION WITH COWPEA LINES IN NORTHERN NIGERIA

BY

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THESIS

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DECLARATION

I hereby declare that the whole of the work submitted as a Thesis for the Master of Science degree in Crop Protection of Ahmadu Bello University is the result of my investigation (except where reference is made to published literature and where assistance is acknowledged) and has not been part of any presentation for any other qualifications.

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I. INTRODUCTION

The cowpea, Vigna unguiculata (L) Walp., is a herbaceous short duration annual grain legume which is now cultivated in many tropical and sub-tropical countries (Klages, 1954). In Nigeria, the cowpea is the most important food legume with widespread distribution and great diversity of seed types, plant habits and photoperiodic response (Steele, 1965).

The cowpea is important as a food through out West Africa, being second only to groundnut as a cultivated legume (Purseglove, 1974). It is used both as a vegetable and as a pulse. According to Purseglove (1974) the grains are used for human consumption while the herbage is used for green manuring and for animal feed; the ash from the burnt herbage is also used as potash for cooking. In many farming districts in northern Nigeria, the young succulent leaves are eaten as vegetables. Cowpeas are capable of fixing atmospheric nitrogen through their symbiotic association with nitrogen fixing bacteria and thereby enriching tropical soils (Ezedinma, 1961).

The cowpeas form. an important source of cheap vegetable containing about 25% protein (Oyenuga, 1959). Thus, the seed form a major source of storable and transportable protein in the lowland tropics (Purseglove 1974; Rachie and Rawal, 1976).

In 1971, the world production of cowpea was estimated at about 1.14 million metric tons of dry seeds (Rachie and Roberts, 1974). Out of this, Africa produced 94%, with Nigeria alone producing 60%.

Despite the importance of cowpea in the Nigerian diet and economy, its production has remained in the hands of peasant farmers whose traditional methods do not sufficiently meet the challenges of our fast developing country (Ezedinma, 1961). Seed yields at peasant farmers' level are very poor, averaging about 150 - 200 kg/ha in northern Nigeria (Raheja, 1976), where about 80% of the country's crop is produced (Raheja and Apeji, 1979; Emecehbe and MacDonald, 1979; and Emechebe, 1980). The annual production of cowpea in Nigeria has been estimated recently to be between 700,000and 800,000 tons (Raheja and Apeji, 1979).

Cowpea production is most suitable to areas with an annual rainfall of 750 - 1500mm (Anthonio, 1979). Ojomo (1967) observed that in Nigeria, 50 - 127mm of rainfall per month is required from seedling to flowering; after this, less rainfall and more sunshine for seed ripening are required.

In Nigeria, the wetter southern parts have two crop seasons, namely, early season (March - July) and late season (August - November). Although cowpeas are grown during both seasons, better quality seeds

are usually produced from the late season crop than from early one. This is because the amount and distribution of rainfall often exceed the optimum requirements of the crop during the early season; there is also the danger of having insufficient sunlight to secure the ripening and drying of pods of the early crop which is more susceptible to the attack of disease (Ebong, 1965).

Ebong (1965) also noted that in the drier north there is a long season extending between June and November. This season provides adequate rains for increased vegetative vigour and sufficient sunlight for the hastening of maturity so that more cowpea is produced in the north than in the south. He pointed out that these conditions in the north also encouraged the production of high quality cowpea seeds.

Cowpea is attacked by various diseases and pests wherever it is grown in the field. Almost every part of the plant is attacked.

Williams (1975) and Singh and Allen (1979) listed over 35 diseases of cowpea. Most of these are caused by fungi, viruses, bacteria and nematodes. The most important fungal disease of cowpea in northern Nigeria is cowpea scab caused by Sphaceloma sp. (Emechebe, 1980), the second most important is brown blotch caused by Colletotrichum capsici (Syd) Butler and Bisby) (Emechebe, 1979). Other important fungal diseases

of cowpea especially in southern Nigeria include anthracnose caused by Colletotrichum lindemuthianum (Sacc. and Magn.) Bri and Cav,, Cercospora leaf spot caused by Cercospora canescens Elus and Martins and C cruenta Sacc.; seedling mortality caused by Pythium aphanidermatum (Edson) Fitzp. and Corticium solani (Prill and Delact.) Bourd and Glaz., rust caused by Uromyces appendiculatus (Pers) Fitzp), web blight (Corticium solani) and Pythium stem rot caused by P aphanidermatum.

The most important bacterial diseases of cowpea in Nigeria are the bacterial pustule caused by Xanthomonas sp. and bacterial blight caused by Xanthomonas vignicola Burkholder. The most important viral diseases are those caused by cowpea mottle virus, Tobacco mosaic virus (cowpea strain). Cowpea yellow mosaic virus and cowpea aphid borne mosaic virus (Williams, 1975).

Aims of the Present Study

Because cowpea is the most important food grain legume in this country and because scab is the most destructive disease of cowpea in northern Nigeria, where more than 80% of the country's total crop is grown (Emechebe, 1980) there is a need to formulate integrated control measures to contain scab. Before this can be done, it is necessary to determine how the pathogen survives in the absence of its host, especially during the period between two successive rainy seasons. It was, therefore, considered necessary to study the

survival of the pathogen in infested trash under different conditions in potted soil. The result would help in formulating appropriate field sanitation methods of controlling the disease.

In addition, the host range of the pathogen was considered necessary to be studied to determine on which crop or weed hosts, if any, the pathogen survives in the absence of cowpea. The information obtained would be valuable in formulating suitable control measures such as appropriate crop rotation and/or proper weed control practices.

Furthermore, it was considered desirable to study the reaction of cowpea lines to scab under high disease pressure in the field. The information obtained would determine if any of the existing lines/varieties could be used by the plant breeders as sources of resistance to this important disease of cowpea.

II REVIEW OF LITERATURE

I. Legume Affected By Scab

Apparently very little study has been done on cowpea scab. However, a lot of work has been done on the pathogen, Sphaceloma spp. (the imperfect or anemorphic state) and Elsinoe spp. (the perfect or teleomorphic state). One of the earliest mentions of Elsinoe spp. was by Jenkins (1930) who reported E. canavaliae as the pathogen of scab Lima beans (Phaseolus lunatus var. macrocarpus Benth) in Cuba and Puerto Rico. The fungus attacks leaves, stems, flowers and pods. Jenkins (1933) later reported Lima bean scab from Costa Rica, Nicaragua, Guatemala and El Salvador. Indeed the Guatemala specimen was one of the earliest; having been collected in 1890 (Jenkins, 1933).

There has also been a report of this disease on French beans (Phaseolus vulgaris) in Zimbabwe where the disease was earlier confused with anthracnose (Bates, 1955). Brooks (1955) considered the disease to be of economic importance on French beans in Zimbabwe and Malawi. In 1956, losses due to this disease in Zimbabwe were between 10 and 20% of grain yield of French beans (Brooks, 1956).

In Japan, Kurata and Kuribayashi (1954) have described soya bean scab caused by Sphaceloma glycine Kurata and Kuribayashi.

There has also been a report from Kenya on scab of Vigna unquiculata (Anon, 1957) and from Surinam on scab of V. sesquipedialis (Anon, 1966a). In both cases the casual organism was said to be E. phaseoli Jenkins (Anon 1957; 1966a). Earlier Hansford (1933) reported scab of Dolichos lablab in Uganda and thought that the fungus was probably related to S. citri. Sphaceloma arachidis Bitancourt and Jenkins has also been reported on groundnut (Bitancourt and Jenkins, 1940).

In Nigeria, there has been a report of what is now known to be scab on cowpea since 1967 (Onazi and Caswell, personal communication) and up til 1976 it was known as cowpea X (Caswell, personal communication). In 1969, because of the favourable conditions for disease development there was an epidemic of what was at the time thought to be a viral disease. Emechebe (1980) established that the disease is caused by Sphaceloma sp. and noted that no Elsinoe stage was observed either in culture or on naturally infected tissue.

2. Disease Development and Symptoms of Cowpea Scab

Emechebe (1980) was the first to describe in detail the scab disease of cowpea which affects all above ground parts of the plant and is typified by symptoms on the leaves, stems, peduncles and pods. The following account of the disease is based on the account by Emechebe (1980). "The earliest sympton is the puckering of the lamina of young leaves. From the fourth day of



Plate 1: Cowpea leaves affected by scab, showing whitish lesion, distor tion of leaves and shot-holes spots.



Plate 2: Discrete and coalescing scab lesions on the stems of cowpea

inoculation, heavily puckered portions of the lamina become pale green or yellowish green and develop tiny white spots. Well formed scab lesions appear six to eight days after inoculation on leaves, stems and pods.

Individual lesions on leaf veins are mostly white, elongate and 1 - 15mm long while interveinal spots of the leaflets are circular (1 - 5mm diameter) and white with or without narrow reddish brown margins. Petiole lesions are oval to oblong-elliptical. Young lesions are less than 1mm but older lesions measure about 1 x 2.5mm. (Plate 1).

On stems, the mature lesions are oblong to elongate and under conditions favourable for the disease, the lesions coalesce and entirely cover varying lengths of the stem which become rough and grayish white (Plate 2). Lesions on the peduncle are similar to those on the stem (Plate 3). Heavy scabbing of the flowering axis causes flower and/or pod abortion or completely prevents flower formation. It is this phase of the disease that may result in total loss of crop (Plate 3 & 4).

3. Host Range of the Pathogen and related Spp. or Members

Bruner and Jenkins (1933) studied the identity and host range of Elsinoe of Lima bean in Cuba. From their experiment and field observations, they showed that the species of Elsinoe which caused Lima bean scab had been tentatively identified by



Plate 3: Peduncle and flowering cushion phases of cowpea scab resulting in the flowerlessness and/or podlessness of flowering cushion

Plate 4: Cowpea pods with clear scab lesions.

Jenkins as E. canavaliae was not pathogenic on Canavalia gladiata, C. ensiformis, Calopogonium caerileum, Dolichos lablab (Lablab niger), Stizolobium daeringianum and Phaseolus vulgaris. It is mostly for this reason that they proposed that the Lima bean scab pathogen be designated as E. phaseoli. They further showed that under suitable conditions, E. canavaliae readily infected uninjured leaves and pods of lima beans but inoculation on other legumes gave negative results.

In Japan, Kurata and Kuribayashi (1954) found that the soya bean scab pathogen, S. glycine was weakly pathogenic to Dolichos lablab on artificial inoculation but not under natural conditions. The fungus proved unable to infect seven other crop legumes tested.

The isolate of Sphaceloma sp. that induced scab on D. lablab also caused scab in Canavalia ensiformis when the latter was artificially inoculated with the pathogen but other legumes studied by Hansford (1934) were unaffected.

Experiments by Enechebe (1980) showed that of many crop and forage legumes artificially inoculated with cowpea scab pathogen, Sphaceloma sp. only Asparagus pea, Vigna sesquipedalis, showed scab symptons similar to those on cowpea. Hyacinth bean (Lablab niger) was affected by typical but mild lesions, while the following legumes were not affected: black gram, (Phaseolus mungo), green gram (P. aureus), French

beans (P. vulgaris), Lima beans (P. lunatus), ground-nut (Arachis hypogea) and Soya bean (Glycine max).

Apart from legumes, species of both Elsinoe and Sphaceloma infect many other hosts. Thus Elsinoe thea has been reported on tea plant from Sao Paulo (Bitancourt and Jenkins, 1939), while cassava is attacked by Sphaceloma manihoticola in Brazil Nicaragua, Guatemala and Dominician Republic (Bitancourt and Jenkins, 1951).

The scab of citrus caused by S. fawcetti has been reported from Brazil, Argentina, Paraguay and Uraguay (Jenkins, 1936). Jenkins and Bitancourt (1936) found the teliomorphic state of the sweet orange scab on fruits of Bahlia Navel orange from Sao Paulo and named it E. australlis, the anemorphic stage was correspondingly designated as S. australlis (Bitancourt and Jenkins, 1936).

In Tanzania, Wallace and Wallace (1953) reported pawpaw scab in a plantation near Moshi and the fungus was designated as Sphaceloma papaye.

New Brazilian species of Elsinoeae were described by Bitancourt and Jenkins (1950). Among these was Sphaceloma psidii, the pathogen of spotted anthracnose of guava. Also Jenkins and Viegas (1934) described stem and flower scab of sweet potatoes in Brazil and attributed it to S. batatas.

Marchianatho (1934), reported leaf and fruit scab on apple in Argentina due to S. (Elsinoe) piri. Sugar cane is also affected by scab (Jenkins and Bitancourt, 1960). Arruda (1957) first observed this disease 'White rash', on sugar cane at Piracaba, Sao Paulo and Brazil and identified the pathogen as Elsinoe sp. Jenkins and Bitancourt, (1960) identified the fungus on sugar cane from Formosa as Sphaceloma sacchari. This was believed to represent the anemorphic stage of Arruda's (1957) Elsinoe sp.

4. Dissemination and Survival of Scab Pathogen.

McCubbin (1933) reported that the spores of Elsinoe canavaliae are wind borne. His conclusion was based on the observation that 80 - 90% of the pods were infected despite the fact that it was several years since Lima beans had been grown on the site and that at the time of infection, the nearest fields with infected plants were two miles away. McCubbin (1933) further reported that local growers thought that stormy weather increased the incidence of scab. He also reported that the fungus survived the period between two successive crops on living wild or volunteer Lima bean plants left by poor ploughing or in old fields remaining fallow during summer.

Jenkins (1933) failed to isolate E. canavaliae from dry pods after nearly five months in storage either at room temperature or 17°c she concluded that the fungus was no longer viable.

Staples (1958) reported that the French bean scab pathogen, E. phascoli f. sp. vulgare, was seed borne.

III MATERIALS AND METHODS

1. Isolation of the Pathogen.

a) Isolation from dry materials

Lesions were cut off from the infected stems and pods. Ten grams (dry weight) of these pieces of lesioned materials were surface sterilized in 0.5% solution of sodium hypochlorite and crushed in a sterilized blender containing 100ml of sterile distilled water. A 10ml portion of the suspension was diluted five times with sterile distilled water and plated out by flooding plates of potato dextrose agar + streptomycin and Rose Bengal (PDASR). The plates were then incubated at room temperatures (20 - 35°c) for 7 days and examined daily, beginning 4 days after inoculation, for the presence of Sphaceloma sp. Pure cultures on PDASR were maintained in an incubator at 22 - 23°c.

b) Isolation from fresh scabbed materials

Pieces of fresh young lesions were cut off from scabbed leaves and stems and surface sterilized with 0.5% solution of sodium hypochlorite for 3 minutes and rinsed in sterile distilled water and plated out in Petri-dishes containing PDASR. The plates, incubated at room temperatures (20 - 35°c) for 7 days, were examined daily for the presence of Sphaceloma sp. Pure cultures were maintained as described above.

2. Host Range of Cowpea Isolate of Sphaceloma sp.

Twenty one plant species (Table 1) were used for this study. The seedlings of each species were raised in three plastic pots (12cm wide and 10cm deep), the seeds being sown in three holes, two seeds per hole. A week after planting, the number of seedlings was thinned down to three per pot. The plants were then inoculated 8 weeks after planting.

To obtain inoculum, the fungus was grown at 22 - 23°c in 9cm petri dishes containing potato dextrose agar (PDA). A conidial suspension was obtained from 7 day old cultures and used to flood inoculate plates containing PDA. The plates were then incubated for 7 days at 22 - 23°c. To prepare and standardize inocula, the agar containing the fungus in each set of 10 plates was crushed in 250ml of sterile distilled water using a blender which had been sterilized by soaking in 70% ethyl alcohol for 30 minutes and rinsed three times with sterile distilled water.

The plants were inoculated by brush-inoculating the stems and both surfaces of the leaves with the conidial and mycelial slurry. The inoculated plants were then immediately placed in moistened polythene bags for 72 hours. The control plants were similarly treated except that their shoots were brushed with agar slurry made from 7 - day incubated, uninoculated agar. To aerate the plants during this period, the bags were removed, remoistened and placed back every morning and evening. From the fourth day of inoculation, the inoculated plants were examined for scab symptons. These observations continued every

Table 1: Plants used in studying the host range of Cowpea isolate of Sphaceloma sp.

	Common name of plant	Botanical name	Variety and/or Source of seed
1.	Cowpea	Vigna unguiculata (L.) Walp	353, Ife Brown, "Zebra" (Local variety from chip) Kagana local
2.	Soya bean	Glycine max. (L.) Merr	Malayan
3.	Yardlong bean (Asparagus Pea)	Vigna sesquipedalis (L.)	Samaru
4.	Lima bean	Phaseolus lunatus (L.)	Samaru
5.	Bamabara nut	Voandzeia subterranea (L.) Thor	Samaru
6.	Green gram	Phaseolus aureus Roxb	Samaru
7.	Hyacinth bean	Laplab niger Medik	Shika
8.	Pigeon pea	Cajanus cajan (L.) Millsp	Samaru
9.	Winged bean	Psophocarpus tetragonoloeus (L.) Dc	Samaru
10.	Black gram	Phaseolus mungo L	Samaru
11.	Groundnut	Arachis hypogeae L	F. 452.4
12.	Tomato	Lycopersicum esculentum Mill	Enterpriser & Merzanino
13.	Sword bean	Canavalia gladiata (Jacq.) Dc	Samaru
14.	Sweet pepper	Capsicum anuum L.	L 5962 - 2
15.	Bird chilli	Capsicum frutescens L.	Cayenne long sten
16.	Maize	Zea mays L.	TZ B
17.	Sorghum	Sorghum bicolor (L) Moench	Fara Fara & Short Kaura

Table I cont'd

	Common name of plant	Botanical name	Variety and/or source of seed
18.	Millet	Pennisetum typhoides (Burm F.) Stapf 88 Hubbard	Ex Brono
19.	Wheat	Triticum aestivum L.	ex Samaru
20.	Weed (Wild groundnut)	Casia tora	Samaru
21.	Spinach	Amaranthus viridis L.	Samaru

other day up to 22nd day of inoculation.

3. Survival of Cowpea Scab Pathogen

Cowpea stems naturally infected by scab were collected two weeks after harvest from the field and cut into equal lengths (5cm), having approximately the same intensity of scab. Pieces of naturally infected pod shells were similarly prepared. The pieces of stems and pod shells were treated in one of the following ways:-

i) Placed on the surface of dry normal soil
ii) Buried in dry normal soil
iii) Placed on surface of moist normal normal soil
iv) Buried in moist normal soil
v) Placed on the surface of dry autoclaved soil
vi) Buried in dry autoclave soil
vii) Placed on the surface of moist autoclaved soil
viii) Buried in moist autoclaved soil

In all the above cases, the soil was contained in plastic pots (12cm diameter and 10cm deep). To facilitate recovery, plant materials were first placed in nylon mesh bags (six pieces per bag) before burying in or placing on the surface of the soil. Two bags were buried at a depth of 5cm in treatments (ii), (iv), (vi) and (viii) above. Each treatment consisted of 18 pots, nine of which were inside the glasshouse while the others were kept on benches in an open space outside the glasshouse.

The soil in treatments (iii), (iv), (vii) and (viii) were kept moist by adding 150ml of water into each pot every Monday, Wednesday and Friday. Pots of all treatments were placed in completely randomized positions both inside and outside the glasshouse.

The experiments began on December 29th, 1981 and continued up to October 4th, 1982. The first and second samples were taken on July 15th and August 16th, 1982 respectively. Subsequent samples were taken at weekly intervals. The respective plant materials were washed gently in tap water to remove adhering soil particles.

The survival of the fungus in respective treatments was determined by bioassay method. This method involved placing the excised, young shoots bearing the two youngest trifoliate leaves of 28-day old cowpea plant on three layers of sterilized, moistened filter paper in sterile 9cm Petri dishes. The excised shoot included about 5cm of internode below the node of the older of the two leaves. The recovered and gently washed plant material to be assayed were crushed in sterile mortar, wetted with sterile distilled water and then placed on the lamina and petiole of each leaf, the axil of the penultimate leaf and the terminal internode. The plates were then kept at room temperatures (20 - 35^{o}c) for 7 days. From the fourth day the leaves and stems were examined for scab lesions.

The control consists of similarly treated excised shoots placed in moistened filter paper in Petri dishes incubated at room temperature (20 - 35°c).

A similar experiment began on October 4th, 1982. This was because the results of the first experiment showed that in some treatments (iii, iv, vii, and viii) the pathogen did not survive up to July 15th, 1982 when the first samples were assayed.

4. Screening Cowpea Lines for Resistance to Scab

Cowpea lines were screened for resistance to scab pathogen under field and glasshouse conditions.

a) Screening for disease resistance in the field.

One hundred and seven lines of cowpea were planted in the field in two replicates in 1981 using a randomized complete block design. In each replicate, each line was shwn on a single 3m long plot in which the seeds were planted in 30 holes, two seed per hole, the distance between the holes being 10cm. Rows of cowpea lines were separated from each other by 2m of clean, weeded ground. Line 353, known to be highly susceptible to scab was used as an indicator line and was planted after every 10 rows.

Four weeks after planting (WAP) the plants were inoculated by placing two pieces of dry, naturally infected cowpea pod shells or stems from the previous year's crop in the axils of the upper leaves of the first two plants at both ends of each row.

At 7 WAP, the lines were examined for scab lesions and the lines in which no plant was affected by scab were re-inoculated with infected trash to eliminate the possibility of disease escape being confused with true resistance.

Scores were taken for the incidence and severity of the cowpea scab on the leaves, stems, peduncles, flowering cushions and pods at weekly intervals beginning at 8 WAP. A visual assessment scale was used and is described below (see section 4(c)). To minimize insect damage, the plants in all plots were routinely sprayed weekly with insecticide (Cymbush e.c. 50ml/10l of water) beginning at 7 WAP.

b) Screening for disease resistance in the glasshouse

The above 107 lines plus another 17 lines of cowpea were screened for resistance to the cowpea scab pathogen under glasshouse conditions. The seeds of each line were planted in three pots. In each pot, seeds were sown in three holes. One pot consistituted a replicate, each line being replicated twice. The third pot served as a check.

A week after sowing, the seedlings were thinned down to three plants per pot. The plants were inoculated at 8 WAP using the procedure similar to that described above in section 2 (pp16). The plants were

examined for scab lesions every other day beginning 4 days after inoculation for 3 weeks.

c) Visual disease severity assessment scale for different phases of scab

The following scales were used to assess the severity of the different phases of scab either in the field or in the glasshouse.

i) Leaf scab

1. No symptoms
2. Few, small spots on leaves
4. Many, small spots on leaves
6. Many, large spots on leaves
8. Many large, coalescing spots with shot-hole spots
10. Many large, coalescing spots with marked leaf distortion

ii) Stem scab

1. No symptoms
2. Few, scattered pin point lesions on lower stem
4. Few, scattered small lesions spreading up stem
6. Extensive scabbing of young stem
8. Stem lesions coalescing, covering also the branches
10. Stem severely damaged with marked stem stunting

iii) Peduncle scab

1. No symptoms
2. Few, scattered pin point lesions on lower peduncle

4. Scattered small lesions spreading up peduncle.

6. Extensive scabbing of young peduncle

8. Peduncle lesions coalescing, covering also flowering cushion

10. Peduncle severely damaged with marked peduncle stunting.

iv) Flowering cushion scab

1. No symptoms

2. Few scattered lesions on flowering cushions

4. Numerous, small lesions on flowering cushions

6. Large lesions on older flowering cushions

8. Large lesions on young cushions not associated with floral abortion.

10. Large coalescing lesions with abortion of flowers and/or pods.

v) Pod Scab

1. No symptoms

2. Few scattered minute lesions on older pods

4. Scattered small lesions on most pods

6. Extensive discrete scabbing of young pods

8. Large, numerous coalescing lesions on pods

10. Severe scabbing of pods with shrivelling and mummification of old pods and/or abscission of young pods.

IV RESULTS

1. Host Range of Cowpea Scab Pathogen, Sphaceloma sp.

The results obtained after inoculating various plant species with the cowpea isolate of Sphaceloma sp. (Table 2) showed that apart from cowpea (which is the main economic host) the following plants were susceptible to the pathogen: yard long bean (Vigna sesquipedalis), hyacinth bean (Lablab niger), bambara nut (Voandzeia subterranea) and the weed (Casia tora). In Table 2, the plants are arranged in descending order of their susceptibility to scab. All other species used for the study (see Table I) were not infected.

Of the above susceptible plants, cowpea was severely affected by scab. Bambara nut had a severe leaf phase but a mild stem phase. Yardlong bean and hyacinth bean had mild lesions on their leaves and stems while the weed was affected only by mild stem scab, the leaf phase being absent.

In all varieties of cowpea and in bambara nut, the symptoms appeared from the 4th day while in yardlong beans, the weed and hyacinth beans, the first symptoms were observed on the 6th day after inoculation.

Table 2. Species and/or varieties of plants infected by scab following inoculation by cowpea isolate of Sphaceloma sp*

Leaf phase of scab			stem phase of scab		
Common name	Botanical name	Variety and/or Source of seed	Common name	Botanical name	source of seed
1. Cowpea	Vigna unguiculata (L) Walp	353, Ife Brown	1. Cowpea	Vigna unguiculata	353, Ife Brown
2. Bambara	Voandzeia subterranea (l) Thor	Samaru Local	2. Cowpea	Vigna Unguiculata	Kagana Local
3. Cowpea	Vigna unguiculata	Kagana local	3. Cowpea	Vigna unguiculata	Chip local
4. Cowpea	Vigna unguiculata	Chip local	4. Bambara nut	Voandzeia sub-terranea	Samaru local
5. Yardlong bean	Vigna sesquipedalis (L)	Samaru local	5. Yardlong bean	Vigna sesquipedalis	Samaru local
6. Hyacinth bean	Lablab niger Medik	Shika local	6. Hyacinth bean	Lablab niger	Shika local
			7. Wild groundnut	Casia tora	Samaru

* Hosts are arranged in descending order of their susceptibility to the pathogen

2. Survival of Sphaceloma sp. on Infected Cowpea Stems and Pod Shells

The results of these studies are presented in tables 3 to 12. Table 3 shows that the fungus survived on infected stems and pod shells buried in dry natural soil in the glasshouse throughout the experimental period of 39 weeks. However, the fungus on infected tissue did not survive more than 32 weeks in dry, natural soil outside the glasshouse. When infected tissues were placed on the surface of dry, natural soil, the fungus survived for 39 weeks in the glasshouse (Table 4). Survival periods in the same type of potted soil outside the glasshouse were 33 and 28 weeks on stems and pod shells respectively.

Table 5 shows that the survival periods of the fungus on infected stems and pod shells buried in moist natural soil outside the glasshouse were 22 and 20 weeks, respectively. Inside the glasshouse the fungus survived on stems and pod shells buried in moist, natural soil for 23 and 20 weeks, respectively. When infected tissues were placed on the surface of moist natural soil in the glasshouse, the fungus survived for 24 and 22 weeks on stems and pod shells respectively, while corresponding figures for similarly treated stems and pod shells outside the glasshouse were 23 and 21 weeks respectively (Table 6).

Table 3: Survival of Sphaceloma sp. on infected stems and pod shells buried in dry* natural soil

Sampling date in 1982	Time (wks) after commencing experiment	Location of Pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Pod shells	Stems	Pod shells
July 15th	28	++	++	+	+
Aug 16th	32	++	++	+	0
Aug 23rd	33	++	++	0	0
Aug 30th	34	++	++	0	0
Sept 6th	35	++	++	0	0
Sept 13th	36	++	++	0	0
Sept 20th	37	++	++	0	0
Sept 27th	38	++	++	0	0
Oct 4th	39	++	++	0	0

++ = Survived with severity of disease more than 5

+ = Survived with severity of disease less than 5

0 = No survival

* = The rains came as from April 18 and lasted till September 27, making the soil in pots outside moist

Table 4: Survival of Sphaceloma sp. on infected stems and pod shells placed on surface of dry* natural soil

Sampling date in 1982	Time (wks) after commencing experiment	Location of Pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Podshells	Stems	Pod shells
July 15th	28	++	++	+	+
Aug 16th	32	++	++	+	0
Aug 23rd	33	+	++	+	0
Aug 30th	34	++	++	0	0
Sept 6th	35	++	++	0	0
Sept 13th	36	++	++	0	0
Sept 20th	37	++	++	0	0
Sept 27th	38	++	++	0	0
Oct 4th	39	++	++	0	0

++ = Survived with severity of diseases more than 5

+ = Survived with Severity of disease less than 5

0 = No Survival

* = The rains came as from April 18 and lasted till September 27, making the soil in pots outside moist

Table 5: Survival of Sphaceloma sp. on infected stems and pod shells buried in moist natural soil

Sampling date in 1983	Time (wks) after commencing experiment	Location of pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Pod shells	Stems	Pod shells
Feb 21st	20	+	+	+	+
Feb 28th	21	+	0	+	0
March 7th	22	+	0	+	0
March 14th	23	+	0	0	0
March 21st	25	0	0	0	0
March 28th	25	0	0	0	0

++ = Survived with severity of disease more than 5

+ = Survived with severity of disease less than 5

0 = No survival

Table 6: Survival of Sphaceloma sp. on infected stems and pod shells placed on surface of moist Natural soil

Sampling date in 1982	Time (wks) after commencing experiment	Location of pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Pod shells	Stems	Pod shells
Feb 21	20	+	+	+	+
Feb 28	21	+	+	+	+
March 7	22	+	+	+	0
March 14	23	+	0	+	0
March 21	24	+	0	0	0
March 28	25	0	0	0	0

++ = Survived with severity of disease more than 5

+ = Survived with severity of disease less than 5

0 = No survival

The survival of Sphaceloma sp. on infected material placed on the surface of dry autoclaved soil is shown in Table 7 which shows that the pathogen survived throughout the experimental period of 39 weeks on stems and pod shells inside the glasshouse. The survival periods, however, was shorter outside the glasshouse, being 35 and 33 weeks for stems and pod shells respectively.

Table 8 shows that the cowpea scab fungus survived throughout the experimental period of 39 weeks on infected stems and pod shells buried in dry autoclaved soil inside the glasshouse. When the pots were placed outside the glasshouse, the survival periods on the stem and pod shells were 34 and 32 weeks respectively.

The results obtained with moist autoclaved soil are presented in Tables 9, 10, and 11. The cowpea scab fungus on stems and pod shells buried in moist autoclaved soil inside the glasshouse survived for 25 and 23 weeks respectively (Table 10). Outside the glasshouse, the fungus survived 25 weeks on the stems and 22 weeks on the pod shells (Table 10). Tables 9 and 11 show that the fungus on infected stems and pod shells placed on the surface of moist autoclaved soil inside the glasshouse survived for 28 and 25 weeks respectively. However, outside the glasshouse, the corresponding survival periods were 25 and 24 weeks for stems and pod shells.

Table 12 summarizes the above results. It shows that the fungus tended to survive longer on infected stems than on infected pod shells; the data are presented pictorially in Fig. 1.

Table 7: Survival of Sphaceloma sp. on infected stems and pod shells placed on surface of dry * autoclaved soil

Sampling date in 1982	Time (wks) after commencing experiment	Location of Pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Pod shells	Stems	Pod shells
July 15th	28	++	++	++	+
Aug 16th	32	++	++	+	+
Aug 23rd	33	++	++	+	+
Aug 30th	34	++	++	+	0
Sept 6th	35	++	++	+	0
Sept 13th	36	++	++	0	0
Sept 20th	37	++	++	0	0
Sept 27th	38	++	++	0	0
Oct 4th	39	++	++	0	0

++ = Survived with severity of disease more than 5

+ = Survived with severity of disease loss than 5

0 = No survival

* = The rains came as from April 18 and lasted till September 27, making the soil in pots outside moist.

Table 8: Survival of Sphaceloma sp. on infected stems and pods shells buried in dry* autoclaved soil

Sampling date in	Time (wks) after commencing experiment	Location of pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Pod shells	Stems	Pod shells
July 15th	28	++	++	+	+
Aug 16th	32	++	++	+	+
Aug 23rd	33	++	++	+	0
Aug 30th	34	++	++	+	0
Sept 6th	35	++	++	0	0
Sept 13th	36	++	++	0	0
Sept 20th	37	++	++	0	0
Sept 27th	38	++	++	0	0
Oct 4th	39	++	++	0	0

++ = Survived with severity of disease more than 5

+ = Survived with severity of disease less than 5

0 = No survival

* = The rains came as from April 18 and lasted till September 27, making the soil in pots outside moist.

Table 9: Survival of Sphaceloma sp. on infected stems and pod shells placed on surface of moist auclaved soil

Sampling	Time (wks) after commencing experiment	Location of Pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Pod shells	Stems	Pod shells
July 15th	28	+	0	0	0
Aug 16th	32	0	0	0	0
Aug 23rd	33	0	0	0	0
Aug 30th	34	0	0	0	00
Sept 6th	35	0	0	0	0
Sept 13th	36	0	0	0	0
Sept 20th	37	0	0	0	0
Septh 27th	38	0	0	0	0
Oct 4th	39	0	0	0	0

++ = Survived with severity of disease more than 5

+ = Survived with severity of disease less than 5

0 = No survivn l

Table 10: Survival of Sphaceloma sp. on infected stems and pod shells buried in moist autoclaved soil

Sampling date in 1982	Time (wks) after commencing experiment	Location of pots			
		Inside glasshouse		Outside glasshouse	
		Sten	Pod shells	Sten	Pod shells
Feb 21	20	+	+	+	+
Feb 28	21	+	+	+	+
March 7	22	+	+	+	+
March 14	23	+	+	+	0
March 21	24	+	0	+	0
March 28	25	+	0	+	0

++ = Survived with severity of disease more than 5

\+ = Survived with severity of disease less than 5

0 = No survival

Table 11: Survival of Sphacelona sp. on infected stems and pod shells placed on surface of moist autoclaved soil

Sampling date in 1982	Time (wks) after commencing experiment	Location of pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Pod shells	Stems	Pod shells
Feb 21	20	+	+	+	+
Feb 28	21	+	+	+	+
Mar 7	22	+	+	+	+
Mar 14	23	+	+	+	+
Mar 21	24	+	+	+	+
Mar 28	25	+	+	+	0

++ = Survived with disease severity more than 5

\+ = Survived with disease severity less than 5

0 = No survival

Table 12: Length of survival of Sphaceloma sp. on infected cowpea stems and pod shells

	Location of infected materials in pots	Survival Period in Wks			
		Location of Pots			
		Inside glasshouse		Outside glasshouse	
		Stems	Pod shells	Stems	Pod shells
1	On surface of dry natural soil	39	39	33	28
2	Buried in dry natural soil	39	39	32	28
3	Buried in dry autoclaved soil	39	39	34	32
4	On surface of dry autoclaved soil	39	39	35	33
5	On surface of moist natural soil	24	22	23	21
6	Buried in moist natural soil	23	20	22	20
7	Placed on surface of moist autoclaved soil	28	25	25	24
8	Buried in moist autoclaved soil	25	23	25	22

Fig. 1: Survival of Sphaceloma sp. on infected cowpea materials inside glasshouse (A) and outside the glasshouse (B)

A_1 & A_2 Placed on surface of dry natural soil

B_1 & B_2 Buried in dry natural soil

C_1 & C_2 Placed on surface of moist natural soil

D_1 & D_2 Buried in moist natural soil

E_1 & E_2 Buried in dry autoclaved soil

F_1 & F_2 On surface of dry autoclaved soil

G_1 & G_2 Placed on surface of moist autoclaved soil

H_1 & H_2 Buried in moist autoclaved soil

The rains came as from the 16th week of the experiment making the soil in the pots outside the glasshouse moist.

▨ Survival on pod shells

□ Survival on stems

3 Reaction of Cowpea lines to Cowpea isolate of Sphaceloma sp

The results obtained in the field and in the glasshouse are presented below:

a) Screening cowpea lines for resistance to scab in the field in 1981

Under humid field conditions, most of the lines suffered from scab. Although all phases of scab were observed on the susceptible varieties, the most devastating phases were the scabs of flowering cushions and young pods which resulted in the abortion of flowers and/or young pods and in the shrivelling of pods. (Plate 3 and 4).

The mean scab severity on the leaves, stems, peduncles, flowering cushions and pods of 107 lines have been computed. Using the disease severity score on each of these organs, the lines have been grouped into four different classes as follows:

Scab severity scores	Host reaction group
≤ 2.5	Highly resistant (HR)
2.51 - 5.0	Moderately resistant (MR)
5.01 - 7.5	Susceptible (S)
7.51 - 10.0	Highly susceptible (HS)

Table 13 shows the separation of the 107 lines of cowpea into the above four classes on the basis of the severity of leaf scab. Thus four and eight

Table 13: Classification of cowpea lines according to their resistance to scab disease on the basis of leaf lesion severity in the fidd in 1981

Highly resistant (HR)	Moderately Resistant (MR)	Susceptible (S)	Highly	Susceptible (HS)	
TVU 1583	TVU 433	178	353	29	30
TVU 851	TVU 201	75	34-77	341-7	341
35-4	456	TVU 3236	83	176B	51
Vita 3	TVU 1404	100	45	82-2	31593-14
	TVU 1486	149	TVU 625	80	69
	TVU 853	148	74	184	TVU 1592
	TVU 1890	183	Sokoto local	199	139
	1 26	200	191	3	28
		128	355	115 B	39
		94	3/741-2k	335	341-14
		71	99	58	144
		TVU 2455-2	77	157	
			TVU 810	129-5	
		341-8	TVU 4410	82 - 1	
			3/593-16	Ife Brown	
			20	162	
			356 B	167	
			101	1696	
			74 - 23	25	
			29/7009-25-10	31	
			TVU 1330	166	
			Iloje Benue	48	
			23/1987-3k-2	145	
			-2	129 - 17	
			129 - 9	193	
			129	TVU 483-2	
			85	341 - 23	
			H - 53-1	TVU 410	
			B - 7	339 - 1	
			1 5 4	1 4 1	
			7	2 3	
			7 2	5 6	
			1 88	1 2	
			TVU 196	8 8	
			354	9 5	
			53	2/7009-35-1	

Summary:	HR:	MR	S	HS
	4	8	13	82

and
lines were highly/moderately resistance respectively, while 13 and 82 lines were respectively susceptible and highly susceptible.

When stem scab was used to separate the lines into the four classes, it was found that five lines were highly resistant while 9, 52 and 41 lines were moderately resistant, susceptible and highly susceptible respectively (Table 14).

Table 15 shows that when peduncle scab was the parameter for grouping the lines into different classes, four lines were highly resistant while six lines were moderately resistant. Furthermore, 84 lines were susceptible, the remaining 13 lines being highly susceptible.

Using flowering cushion scab as the criterion for line classification, five, six, 36 and 60 lines were found to be highly resistant, moderately resistant, susceptible and highly susceptible, respectively (Table 16).

When pod scab was the basis for classification (Table 17) nine lines were found to be highly resistant while nine, 73 and 16 lines were respectively moderately resistant, susceptible and highly susceptible.

Table 14: Classification of Cowpea lines according to their resistance to scab disease on the basic of sten lesion severity in the field in 1981

Highly resistant (HR)	Moderately resistant (MR)	Susceptible (S)		Highly Susceptible
35-4	TVU 456	TVU 201		Ife Brown 99
TVU 1486	100	31		34-77 139
TVU 433		149		83 77
TVU 851	TVU 1404	176 B	28	356B 1 44
TVU 1583	TVU 853	148	128	29 TVU 810
	Vita 3	115 B	39	199 TVU 4410
	71	166	126	25
	TVU 1592	129-17	341 - 14	341-7
	TVU 1890	183	354	353
	341-8	200	184	101
		193	53	3
		TVU 483-2	3/593-16	74-23
		23/1987-3k-2-2	162 82-1	29/7009-25-10
		45	16 7	335
		341 - 23	178	48
		58	75	TVU 1330
		TVU 410	20	145
		82 - 2	1696	Iloje Benue
		339 - 1	TVU 3236	129 - 9
		141		TVU 625
		85		74
		23		Sokoto local
		12		129
		95		56
		2/7009-35-1		H - 53 - 1
		10		191
		94		B - 7
		51		8 8
		3/593 -14		3 0
		3 5 5		3 41
		6 9		1 54
		129 - 5		1 57
		TVU 2455-2		7
		1 8 8		72
		TVU 196		3/741 - 1-2k

Summary	HR	MR	S	HS
	5	9	52	41

Table 15: Classification of cowpea lines according to their resistance to scab disease on the basis of peduncle lesion severity in the field in 1981

Highly resistant (HR)	Moderately resistant (MR)		Susceptible (S)		Highly Susceptible (HS)
Tvu 1486	1696	3/593-16	Sokoto	77	34 - 77
35 - 4	200	Ife Brown	Tvu 410	28	83
Tvu 1404	45	162	128	39	Tvu 3236
Tvu 1890	B - 7	167	82 - 2	126	25
	Tvu 851	178	339 - 1	341 - 14	335
	Tvu 1583	75	141	341 - 8	48
		20	23	354	193
		Tvu 433	56	184	Ileje Benue
		356 B	4 - 53 - 1	144	23/1987-3k-2
		29	12	Tvu 810	429
		199	191	82 - 1	85
		341 - 7	88	Tvu 4410	53
		Tvu 201	95	3/74-1-2k	353
		Tvu 456	2/7009-35-1	Tvu 2455-2	
		100	10		
		31	30		
		149	Tvu 853		
		176 B	Vita 3		
		148	94		
		101	341		
		3	154		
		74- 23	71		
		29/7009-25-10	157		
		115 B	51		
		166	7		
		Tvu 1330	3/593-14		
		145	355		
		129 - 17	69		
		183	129 - 5		
		Tvu 483 - 2	72		
		129 - 9	Tvu 1592		
		341 - 23	186		
		Tvu 625	99		
		74	139		
		53	Tvu 196		

Summary:	HR:	Mt:	S:	HS
	4	6	84	13

Table 16: Classification of cowpea lines according to their resistance to scab disease on the basis of flowering cushion lesion severity in the field in 1981

Highly resistant (HR)	Moderately resistant(MR)	Susceptible (S)	Highly susceptible (HS)	
Tvu 1486	162	167	3/593 - 16	10
1696	200	173	Ife Brown	94
Tvu 1404	45	20	34 - 77	147
35 - 4	Tvu 625	Tvu 3236	75	51
Tvu 1890	Tvu 851	356 B	83	7
	B - 7	Tvu 201	Tvu 433	3/593-14
		Tvu 456	29	355
		100	199	69
		149	25	129 - 5
		148	341 - 7	72
		101	353	Tvu 2455-2
		3	31	3/741-1-2k
		74 - 23	176 B	99
		145	29/7009-25-10	139
		129 - 17	115 B	Tvu 196
		Tvu 483 - 2	335	28
		341 - 23	166	341 - 8
		58	48	341 - 14
		Sokoto	Tvu 1330	354
		Tvu 410	183	134
		128	193	53
		191	Iloje Benue	144
		2/7009-35-1	23/1987/3k-2-2	82 - 1
		30	129 - 9	Tvu 4410
		Tvu 853	74	
		Vita 5	129	
		341	82 - 2	
		154	339 - 1	
		71	85	
		Tvu 1592	141	
		Tvu 1583	23	
		108	56	
		77	4 - 53 - 1	
		39	12	
		426	88	
		Tvu 810	95	

Summary:	HR	MR	S:	HS
	5	6	36	60

Table 17: Classification of cowpea lines according to their resistance to scab disease on the basis of pod lesion severity in the field in 1981

Highly resistant(HR)	Moderately resistant(MR)	Susceptible (S)		Highly Susceptible(HS)
		23		
1696	162	3/593 - 16	56	Ife Brown
Tvu 625	34 - 77	178	4-53-1	167
Sokoto local	20	75	12	Tvu 433
Tvu 1404	83	Tvu 3236	191	353
B - 7	Vita 3	356 B	88	25
Tvu 1486	200	29	95	335
35 - 4	45	199	2/7009-35-1	48
Tvu 1890	Tvu 851	341 - 7	10	74
39	Tvu 810	Tvu 201	30	141
		Tvu 456	Tvu 853	85
		100	3	355
		31	94	69
		149	341	72
		176 B	154	144
		148	71	82 - 1
		101	157	Tvu 4410
		128	51	
		74 - 23	7	
		29/7009-25-10	3/593 - 14	
		115 B	129 - 5	
		166	Tvu 2455-2	
		Tvu 1330	Tvu 1592	
		145	3/741-1/2k	
		129 - 17	Tvu 1583	
		183	188	
		193	99	
		Ileje Benue	139	
		Tvu 483 - 2	196	
		23/1987-3k-2-2	77	
		129 - 9	28	
		341 - 23	126	
		58	341 - 14	
		129	341 - 8	
		Tvu 410	354	
		82 - 2	104	
		339 - 1	53	

Summary	HR:	MR:	S:	HS:
	9	9	73	16

b. Grain yields of cowpea lines in relation to their resistance or susceptibility to scab in the field

Presented in Table 18 are five each of the most resistant and the most susceptible lines of cowpea, together with their mean yields per row of 30 plants in 1981. The reactions of the lines to the flowering cushion phase of scab (which is considered to be the most destructive phase) are also given in Table 18.

The table reveals that the grain yields of the most resistant varieties ranged from 750g to 1,200g while those of the most susceptible varieties ranged from 150g to 650g. Among the resistant lines only 35 - 4 gave a yield of less than 1000g while the susceptible category, only line 144 gave a yield of up to 650g. The mean grain yield for the 5 most resistant lines (1080g) was clearly greater than that for the five most susceptible lines (407g).

Table 18: Flowering cushion scab severity and grain yields of 5 most resistant and 5 most susceptible lines of cowpea

Most Resistant Lines			Most Susceptible Lines		
Lines	Mean flowering Cushion scab severity	Yield/ row of 30 plants (g)	Lines	Mean flowering cushion scab severity	Yield/ row of 30 plants (g)
TVU 1486	0.875	1200	74	9.00	150
1696	2.250	1150	141	9.00	565
TVU 1404	2.00	1100	48	8.750	200
35-4	1.000	750	53	9.00	470
TVU 1890	1.375	1200	144	9.00	650
Total	7.500	5,400	Total	44.75	2,035
Mean	1.5	1,080	Mean	8.90	400

C. Screening cowpea lines for resistance to scab in the glasshouse

Under glasshouse conditions, 124 lines of cowpea (the above 107 lines plus 17 other lines) were screened for their resistance to scab disease. The mean scab severity on the leaves, stems, peduncles, and flowering cushions have been computed. Using the disease severity scores on each of these organs, the lines have been grouped into four different classes as described in sub-section (3a) of this chapter.

Table 18: Flowering cushion scab severity and grain yields of 5 most resistant and 5 most susceptible lines of cowpea

Most Resistant Lines			Most Susceptible Lines		
Lines	Mean flowering Cushion scab severity	Yield/ row of 30 plants (g)	Lines	Mean flowering cushion scab severity	Yield/ row of 30 plants (g)
TVU 1486	0.875	1200	74	9.00	150
1696	2.250	1150	141	9.00	565
TVU 1404	2.00	1100	43	8.750	200
35-4	1.000	750	53	9.00	470
TVU 1890	1.375	1200	144	9.00	650
Total	7.500	5,400	Total	44.75	2,035
Mean	1.5	1,080	Mean	8.90	400

C. Screening cowpea lines for resistance to scab in the glasshouse

Under glasshouse conditions, 124 lines of cowpea (the above 107 lines plus 17 other lines) were screened for their resistance to scab disease. The mean scab severity on the leaves, stems, peduncles, and flowering cushions have been computed. Using the disease severity scores on each of these organs, the lines have been grouped into four different classes as described in sub-section (3e) of this chapter.

Table 19 shows the separation of the 124 lines of cowpea into the four classes on the basis of the severity of the leaf scab. Thus five, 11, 75 and 33 lines were highly resistant, moderately resistant, susceptible and highly susceptible, respectively. On the other hand, when stem scab was used as the basis for classification (Table 20) it was found that four lines were highly resistant while 11, 96 and 13 lines were moderately resistant, susceptible and highly susceptible respectively.

Using peduncles scab as the parameter four grouping the lines into different classes revealed that three lines were highly resistant while 13 others were moderately resistant (Table 21). In addition, 84 lines and 24 lines were susceptible and highly susceptible respectively.

Using flowering cushion scab as the criterion for the line classification showed that three and 13 lines were highly and moderately resistant respectively, while 89 and 19 lines were found to be susce tible and highly susceptible, respectively (Table 22).

Table 19: Classification of cowpea lines according to their resistance to scab on the basis of leaf lesion severity in the glasshouse

Highly resistant (HR)	Moderately resistant (MR)	Susceptible (S)		Highly Susceptible (HS)
Tvu 1404	Tvu 433	3/593 - 16	95	148
Tvu 1486	Tvu 201	Ife Brown	2/7009-35-1	101
35 - 4	Tvu 851	162	10	74 - 23
81 - 27	Tvu 1583	34 - 77	30	29/7009-25-10
81 - 40	Chip local	167	Vita 3	335
	81 - 38	178	94	145
	81 - 39	75	154	129 - 17
	81 - 63	20	71	183
	81 - 64	83	157	200
	81 - 36	1696	51	193
	Tvu 1890	Tvu 3236	7	Ileje Benue
		356 B	3/593 - 14	Tvu 483 - 2
		29	69	129 - 9
		199	129 - 5	45
		25	72	341 - 23
		341 - 7	Tvu 2455-2	Tvu 625
		Tvu 456	Tvu 1592	441
		100	3/741-1-2k	85
		31	188	23
		149	Tvu 196	H - 23 - 1
		176B	28	12
		3	34 - 14	191
		115 B	354	Tvu 853
		166	184	341
		48	53	355
		Tvu 1330	144	99
		23/1987-3k-2-2	82-1	139
		58	Kanan noda	77
		Sokoto local	81-1	39
		129	81 - 25	126
		Tvu 410	81 - 29	Tvu 810
		128	81 - 30	Tvu 4410
		82 - 2	81 - 33	353
		339 - 1	81 - 37	
		56	81 - 65	
		B - 7	81 - 66	
		88	341 - 8	
		74		

Summary	HR	MR	S	HS
	5	11	75	33

Table 20: Classification of cowpea lines according to their resistance to scab on the basis of stem lesion severity in the glasshouse

Highly resistant (HR)	Moderately resistant (MR)	Susceptible (S)			Highly Susceptible (HS)
35 - 4	Tvu 433	Ife Brown	Sokoto local	341 - 14	3/593 - 16
Tvu 1890	Tvu 456	162	129	341 - 8	1696
81 - 40	Tvu 404	34 - 77	Tvu 410	184	101
Tvu 1486	Tvu 853	167	82 - 2	53	353
	Vita 3	178	339 - 1	144	145
	Tvu 851	20	56	Tvu 810	129 - 17
	Tvu 1583	83	H - 53 -1	82 - 1	183
	341 - 8	Tvu 3236	12	Chip local	
	Tvu 4410	356 B	B - 7	Kanon noda	341 - 23
	81 - 27	199	88	81 - 1	128
	81 - 64	25	95	81 - 25	141
	81 - 65	341 - 7	2/7009-35-1	81 - 29	85
		Tvu 201	10	81 - 30	12
		100	30	81 - 35	
		31	94	81 - 36	355
		149	341	81 - 37	99
		176 B	154	81 - 38	
		148	71	81 - 39	
		3	157	81 - 63	
		74 - 23	51	81 - 66	Tvu 625
		29/7009-25-10	7	354	
		115 B	3/593- 14	Tvu 196	
		335	335	29	
		166	69	188	
		48	129 - 5	75	
		Tvu 1330	72	128	
		200	Tvu 2455-2	45	
		193	Tvu 1 592		
		Ileje Benue	3/741-122k		
		Tvu 483 - 2	99		
		23/1987-3k-2-2	139		
		129 - 9	77		
		341 - 23	28		
		74	39		
		58	126		

Summary	HR	MR	S	HS
	4	11	96	13

Table 21: Classification of cowpea lines according to their resistance to scab on the basis of peduncle lesion severity in the glasshouse

Highly resistant (HR)	Moderately resistant (MR)	Susceptible (S)			Highly Susceptible (HS)
				82 - 1	
Tvu 1404	200	Ife Brown	23	Kanan koda	3/593 - 16
35 - 4	45	162	56	81 - 1	167
Tvu 1486	Vita 3	34 - 77	B-53-1	81 - 25	170
	Tvu 1890	75	191	81 - 33	88
	Tvu 1583	20	B - 7	81 - 37	199
	Chip local	1696	88	81 - 38	25
	81 - 27	Tvu 433	95	81 - 39	176 B
	81 - 29	Tvu 3236	10	81 - 40	3
	81 - 30	356 B	Tvu 853	81 - 64	115 B
	81 - 36	29	94	81 - 66	116
	81 - 63	341 - 7	341	30	48
	81 - 65	Tvu 201	154	129 - 5	Tvu 1330
	Tvu 851	Tvu 456	71	Tvu 4410	129 - 17
		100	157	Tvu 810	183
		31	51		193
		149	7	341 - 8	341 - 23
		148	3/593- 14		50
		101	6 9		141
		74 - 23	72		85
		29/7009-25-10	Tvu 2455-2		12
		335	Tvu 1592		2/7009-35-1
		145	3/741-1-2k		355
		Ileje Benue	188		99
		Tvu 483 - 2	139		353
		23/1987-3k-2-2	Tvu 196		
		129 - 9	77		
		Tvu 625	28		
		74	39		
		Sokoto local	126		
		129	341 - 14		
		Tvu 410	184		
		128	354		
		82 - 2	53		
		339 - 1	144		

Summary	HR	MR	S	HS
	3	13	84	24

Table 22: Classification of cowpea lines according to their resistance to scab on the basis of flowering cushion lesion severity in the glasshouse

Highly resistant (HR)	Moderately resistant (MR)	Susceptible (S)			Highly Susceptible (HS)
Tvu 1404	200	2/593-16	129	82 - 1	167
35 - 4	45	162	Tvu 410	Kanan noda	178
Tvu 1486	Tvu 625	Ife Brown	128	81 - 25	Tvu 3236
	Tvu 851	20	82 - 2	81 - 27	25
	Tvu 1890	83	339 - 1	81 - 33	129 - 17
	39	Tvu 433	141	81 - 36	191
	81 - 1	356 B	85	81 - 38	Tvu 853
	81 - 29	29	23	81 - 39	Vita 3
	81 - 30	199	56	81 - 66	94
	81 - 37	341 - 7	4 - 53 - 1	6696	341
	81 - 40	Tvu 201	12	176 B	154
	81 - 64	Tvu 456	B - 7		157
	81 - 65	100	88	Tvu 583	355
		31	95	Tvu 196	77
		149	2/7009-35-1	126	341 - 14
		101	10	28	Tvu 810
		3	30	148	Chip local
		74 - 23	71	Tvu 4410	81 - 63
		29/7009-25-10	51	75	353
		115 B	7		
		335	2/593-14	34 -77	
		166	69		
		48	129 - 5		
		Tvu 1330	72		
		145	Tvu 2455-2		
		183	Tvu 1592		
		193	3/741-1-2k		
		Ileje Benue	180		
		Tvu 483 - 2	99		
		23/1987-3k-2 2	139		
		129 - 9	341 - 8		
		341 - 23	354		
		74	184		
		58	53		
		Sokoto local	144		

Summary	HR:	MR:	S	HS
	3	13	89	19

d. Evaluation of resistance using disease indices obtained both in the glasshouse and in the field.

Table 23 summarizes the reactions of each of the 107 lines as estimated by various disease indices in the glasshouse and in the field. Table 23 shows that 94 lines reacted in the same way in the glasshouse and in the field. Out of these lines, 83 were either susceptible or highly susceptible to all the four phases of the disease both in the glasshouse and in the field; these lines are indicated with the asterick.

On the other hand, the following five lines were found to be moderately or highly resistant, depending on the phase of scab, in both environments: TVU 1404, TVU 1486, TVU 851, TVU 1.[illegible]0 and 35-4 (which is the only line that was highly resistant to all phases of scab in both the glasshouse and the field). These lines are indicated with two astericks. Out of the 94 lines, the remaining 6 lines (indicated with three astericks) reacted consistently in both environments since they were both susceptible and/or susceptible to one or more scab phases, while remaining very resistant and/or resistant to the other phases. The remaining 25 lines reacted inconsistently. For example, some that were resistant to one or more phases of scab in the glasshouse were found to be susceptible to these particular phases in the field and vice versa.

Table 23 Summary table for the classification of Cowpea lines according to their resistance to scab disease on the basis of lessons on their (87) Leaves, Stems, Peduncles, Flowering cushions (glasshouse) and pods (Field)

	Cowpea Lines	Glasshouse Screening				Field Screening				
		Leaf	Stem	Ped	Cush	Leaf	Stem	Ped	Cush	Pod
1	3/593-16*	S	HS	HS	S	HS	S	S	HS	S
2	Ife Brown*	S	S	S	S	HS	HS	S	HS	HS
3	162	S	S	S	S	HS	S	S	MR	MR
4	34 - 77*	S	S	S	S	HS	HS	HS	HS	MR
5	167*	S	S	HS	HS	HS	S	S	S	HS
6	173*	S	S	HS	HS	S	S	S	S	S
7	75*	S	S	S	S	S	S	S	HS	S
8	20*	S	S	S	S	HS	S	S	S	MR
9	83*	S	S	HS	S	HS	HS	HS	HS	MR
10	1696	S	HS	S	S	HS	S	MR	MR	MR
11	TVU 433***	MR	MR	S	S	MR	MR	S	HS	HS
12	TVU 3236*	S	S	S	HS	S	S	HS	S	S
13	356B*	S	S	S	S	HS	HS	S	S	S
14	29*	S	S	S	S	HS	HS	S	HS	S
15	199*	S	S	HS	S	HS	HS	S	HS	S
16	25*	S	S	HS	HS	HS	HS	HS	HS	HS
17	341 - 7*	S	S	S	S	HS	HS	S	HS	S
18	TVU 201***	MR	S	S	S	MR	S	S	S	S
19	TVU 456	S	MR	S	S	MR	MR	S	S	S
20	353*	HS	HS	HS	HS	HS	HS	HS	HS	HS
21	100	S	S	S	S	S	MR	S	S	S
22	31*	S	S	S	S	HS	S	S	HS	S
23	149*	S	S	S	S	S	S	S	S	S
24	176B*	S	S	HS	S	HS	S	S	HS	S
25	143*	HS	S	S	S	S	S	S	S	S
26	101*	HS	HS	S	S	HS	HS	S	S	S
27	3*	S	S	HS	S	HS	HS	S	S	S
28	74-23*	HS	S	S	S	HS	HS	S	S	S
29	29/7009--25-16*	HS	S	S	S	HS	HS	S	HS	S
30	115B*	S	S	HS	S	HS	S	S	HS	S

Table 23 Cont'd

	Cowpea Lines	Glasshouse screening				Field screening				
		Leaf	Stem	Ped	Cush	Leaf	Stem	Ped	Cush	Pod
31	335*	HS	S	S	S	HS	HS	HS	HS	HS
32	166*	S	S	HS	S	HS	S	S	HS	S
33	48*	S	S	HS	S	HS	HS	HS	HS	HS
34	TVU 1330*	S	S	HS	S	HS	HS	S	HS	S
35	145*	HS	HS	S	S	HS	HS	S	S	S
36	129-17*	HS	HS	HS	HS	HS	S	S	S	S
37	183*	HS	HS	HS	S	S	S	S	HS	S
38	200***	HS	S	MR	MR	S	S	MR	MR	MR
39	193*	HS	S	HS	S	HS	S	HS	HS	S
40	Ileye Benue*	HS	S	S	S	HS	HS	HS	HS	S
41	TVU 433-2*	HS	S	S	S	HS	S	S	S	S
42	23/1967-3k*-2-2	S	S	S	S	HS	S	HS	HS	S
43	129-9*	HS	S	S	S	HS	HS	S	HS	S
44	45***	HS	HS	MR	MR	HS	S	MR	MR	MR
45	34-23*	HS	S	HS	S	HS	S	S	S	S
46	TVU 625***	HS	HS	S	MR	HS	HS	S	MR	MR
47	74*	S	S	S	S	HS	HS	S	HS	HS
48	58*	S	S	S	HS	HS	S	S	S	S
49	Sokoto local*	S	S	S	S	HS	HS	S	S	MR
50	129*	S	S	S	S	HS	HS	HS	HS	S
51	TVU 410*	S	S	S	S	HS	S	S	S	S
52	420*	S	S	S	S	HS	S	S	S	S
53	[illegible]-2*	S	S	S	S	HS	S	S	HS	S
54	329-1*	S	S	S	S	HS	S	S	HS	S
55	141*	HS	HS	HS	S	HS	S	S	HS	HS
56	23*	HS	HS	S	S	HS	S	S	HS	S
57	56*	S	S	S	S	HS	HS	S	HS	S
58	35*	HS	HS	HS	S	HS	S	HS	HS	HS
59	H-53-1*	HS	S	S	S	HS	HS	S	HS	S
60	TVU 1404**	HR	MR	HR	HR	MR	MR	HR	HR	HR
61	12*	HS	S	HS	S	HS	S	S	HS	S
62	191*	HS	HS	S	HS	HS	HS	S	S	S

Table 23 Cont'd

	Cowpea Lines	Glasshouse screening				Field Screening				
		Leaf	Stem	Ped	Cush	Leaf	Stem	Ped	Cush	Pod
63	B - 7	S	S	S	S	HS	HS	MR	MR	MR
64	83*	S	S	S	S	HS	HS	S	HS	S
65	95*	S	S	S	S	HS	S	S	HS	S
66	2/7009-35-1*	S	S	HS	S	HS	S	S	S	S
67	10*	S	S	S	S	HS	S	S	HS	S
68	30*	S	S	S	S	HS	HS	S	S	S
69	TVU 1486*	HR	HR	HR	MR	MR	MR	HR	HR	HR
70	TVU 853	HS	MR	S	HS	MR	MR	S	S	S
71	35-4**	HR	HR	HR	HR	HR	HR	HR	HR	HR
72	94*	S	S	S	HS	S	S	S	HS	S
73	Vita 3	S	MR	MR	HS	HR	MR	S	S	S
74	341*	HS	S(	S	HS	HS	HS	S	S	S
75	154*	S	S	S	HS	HS	HS	S	S	S
76	TVU 851**	MR	MR	MR	MR	HR	HR	MR	MR	MR
77	71	S	S	S	S	S	MR	S	S	S
78	157*	S	S	S	HS	HS	HS	S	HS	S
79	51*	S	S	S	S	HS	S	S	HS	S
80	7*	S	S	S	S	HS	HS	S	HS	S
81	31593-14*	S	S	S	S	HS	S	S	HS	S
82	355*	HS	S	HS	HS	HS	S	S	HS	HS
83	69*	S	S	S	S	HS	S	S	HS	HS
84	129-5*	S	S	S	S	HS	S	S	HS	S
85	72*	S	S	S	S	HS	HS	S	HS	HS
86	TVU 2455-2*	S	S	S	S	S	S	S	HS	S
87	TVU 1592	S	S	S	S	HS	MR	S	S	S
88	TVU 4890**	MR	MR	MR	MR	MR	MR	HR	HR	HR
89	3/741-1-2K*	S	S	S	S	HS	HS	S	HS	S
90	TVU 1583***	MR	MR	MR	S	HR	HR	MR	S	S
91	188*	S	S	S	S	HS	S	S	S	S
92	99*	HS	S	HS	S	HS	HS	S	HS	S
93	159*	HS	S	S	S	HS	HS	S	HS	S
94	TVU 196*	S	S	S	S	HS	S	S	HS	S
95	77*	HS	S	S	HS	HS	HS	S	S	S
96	28*	S	S	S	S	S	S	S	HS	MR

Table 23 Cont'd

	Cowpea Lines	Glasshouse screening				Field screening				
		Leaf	Stem	Pod	Cush	Leaf	Stem	Pod	Cush	Pod
97	39	HS	S	S	MR	HS	S	S	S	MR
98	126	HS	S	S	S	MR	S	S	S	S
99	341-14*	S	S	S	HS	HS	S	S	HS	S
100	341-8	S	S	S	S	S	MR	S	HS	S
101	354*	S	S	S	S	HS	S	S	HS	S
102	184*	S	S	S	S	HS	S	S	HS	S
103	53*	S	S	S	S	HS	S	HS	HS	S
104	144*	S	S	S	S	HS	HS	S	HS	HS
105	TVU 810*	HS	S	S	HS	HS	HS	S	S	MR
106	82-1*	S	S	S	S	HS	S	S	HS	HS
107	TVU 4410*	HS	S	S	S	HS	HS	S	HS	HS

e. Correlation and Regression analysis of the various disease indices obtained while screening for resistance in the field and in the glasshouse

(i) Correlation analyses

These analyses were done by the computer.

Table 24 summarizes the analyses of correlations between pairs of different disease indices recorded in the field in 1981. This table shows that the severity as well as incidences of any two phases of scab were positively and significantly correlated (P = 0.01). For example, the correlation coefficients between the severities of stem, peduncle, flowering cushion and pod scabs on the one hand and the severity of foliar scab on the other hand were 0.81, 0.47, 0.46 and 0.35, respectively. This means that 66%, 22%, 21% and 12% of the variations in the stem, peduncle, flowering cushion and pod scab severities were, respectively, associated with variations in foliar scab severity. Similarly, 61%, 52% 50% and 37% of the variations in the incidence of scab on the above mentioned plant parts were, respectively, associated with variations in the foliar scab incidence.

Table 24 also shows that the significant (P=0.01) correlation coefficient between the severities of scab on the peduncle, flowering cushion and pod on the one hand and the severity of scab on the stem on the other were 0.51, 0.48 and 0.39, respectively. This indicates that 26%, 23% and 15% of the variations in

Table 24. Correlation analysis of pairs of disease indices obtained in screening for scab resistance in the field

	Pairs of indices	Correlation Coefficient (r)	Coefficient of determination (r^2)
1.	Severity of foliar scab and severity of stem scab	0.81**	0.66
2.	Severity of foliar scab and severity of peduncle scab	0.47**	0.22
3.	Severity of foliar scab and severity of flowering cushion scab	0.46**	0.21
4.	Severity of foliar scab and severity of pod scab	0.35**	0.12
5.	Severity of scab and severity of peduncle scab	0.51**	0.26
6.	Severity of stem scab and severity of flowering cushion scab	0.48**	0.23
7.	Severity of stem scab and severity of pod scab	0.39**	0.15
8.	Severity of Peduncle scab and severity of flowering cushion scab	0.91**	0.83
9.	Severity of peduncle scab and severity of pod scab	0.78**	0.61
10.	Severity of flowering cushion scab and severity of pod scab	0.86**	0.74
11.	Incidence of foliar scab and incidence of stem scab	0.78**	0.61

Table 24. cont'd

Pairs of indices	Correlation Coefficient (r)	Coefficient of determination (r^2)
12. Incidence of foliar scab and incidence of peduncle scab	0.72**	0.52
13. Incidence of foliar scab and and incidence of flowering cushion scab	0.71**	0.50
14. Incidence of foliar scab and incidence of pod scab	0.61**	0.37
15. Incidence of stem scab and incidence of peduncle scab	0.77**	0.59
16. Incidence of stem scab and incidence of flowering cushion scab	0.76**	0.58
17. Incidence of stem scab and incidence of pod scab	0.69**	0.48
18. Incidence of peduncle scab and incidence of flowering cushion scab	0.99**	0.98
19. Incidence of peduncle scab and incidence of pod scab	0.93**	0.86
20. Incidence of flowering cushion scab and incidence of pod scab.	0.93**	0.86

** = Highly significant
(P = 0.01)

the severity of peduncle, flowering cushion and pod scabs, respectively, were associated with variations in the severity of stem scab. Similarly 59%, 58% and 48% of the variations in the peduncle, flowering cushion and pod scab incidences, respectively, were associated with variations in stem scab incidence.

The significant ($P = 0.01$) correlation coefficient between the severity of flowering cushion scab and the severity of peduncle scab was 0.91 while that between pod scab and peduncle scab severities was 0.78 indicating that 83% and 61% of the variations in the severities of the flowering cushion and pod scabs, respectively, were associated with variations in the severity of peduncle scab. Similarly 98% and 86% of the variations in the flowering cushion and pod scab incidences, respectively, were associated with variations in peduncle scab incidence. There is also a positive, significant ($P = 0.01$) correlation ($r = 0.86$) between the severities of pod scab and flowering cushion scab. This means that 74% of the variations in pod scab severity were associated with variations in the flowering cushion scab severity. Similarly, 86% of the variations in the incidence of pod scab were associated with variations in flowering cushion scab incidence.

Table 25 summarizes the analyses between pairs of different disease indices recorded in the glasshouse. This table shows that the severities as well as incidences of any two phases of scab were positively and significantly correlated ($P = 0.1$). For example, the correlation

coefficients between the severities of stem, peduncle and flowering cushion scab on the one hand and the severity of foliar scab on the other hand were 0.75, 0.62 and 0.58, respectively. This means that 56%, 38% and 34% of the variations in the stem, peduncle and flowering cushion scab severities were, respectively, associated with variations in foliar scab severity. Similarly, 55%, 27% and 21% of the variations in the incidences of scab on the above mentioned parts were, respectively, associated with variations in the incidence of foliar scab.

Also, correlation coefficients between the severities of the peduncle and flowering cushion scabs on the one hand and stem scab severity on the other were 0.64 and 0.59, respectively. This indicates that 41% and 34% of the variations in the severitities of peduncle and flowering cushion scabs were, respectively associated with variations in the severity of stem scab. Similarly, 32% and 27% of the variations in the peduncle and flowering cushion scab incidences, were, respectively associated with variations in stem scab incidence.

The significant ($P \doteq 0.01$) correlation coefficient of 0.82 between the severity of flowering cushion scab and the severity of peduncle scab indicates that 67% of the variations in the severity of flowering cushion scab were associated with variation in the severity of peduncle scab. Similarly, 58% of the variations in flowering cushion scab incidence were associated with variations in the peduncle scab incidence.

Table 25. Correlation analyses of pairs of disease indices obtained in screening for scab resistance in the glasshouse

Pairs of indices	Correlation Coefficient (r)	Coefficient of determination (r^2)
1. Severity of foliar scab and severity of stem scab	0.75 **	0.56
2. Severity of foliar scab and severity of peduncle scab	0.62 **	0.38
3. Severity of foliar scab and severity of flowering cushion scab	0.58 **	0.34
4. Severity of stem scab and severity of peduncle scab	0.64 **	0.41
5. Severity of stem scab and severity of flowering cushion scab	0.59**	0.35
6. Severity of peduncle scab and severity of flowering cushion scab	0.82**	0.67
7. Incidence of foliar scab and incidence of stem scab	0.74**	0.55
8. Incidence of foliar scab and incidence of peduncle scab	0.52**	0.27
9. Incidence of foliar scab and incidence of flowering cushion scab	0.46**	0.21
10. Incidence of stem scab and incidence of peduncle scab	0.57 **	0.32
11. Incidence of stem scab and incidence of flowering cushion	0.52**	0.27

Table 25 cont'd

Pairs of indices	Correlation Coefficient (r)	Coefficient of determination (r^2)
12 Incidence of peduncle scab and incidence of flowering cushion scab	0.76**	0.58

** = Highly significant
(P = 0.01)

(ii) Regression analyses

Regression analyses were done by the computer but only for those pairs of disease indices with correlation coefficients greater than 0.50. In all these cases, the regression coefficients were highly significant (P - 0.01). The details of the analyses are presented in Appendices 1 - 14.

The regression analyses of pairs of disease indices obtained in the field are presented in Figs. 2 - 9 below and in Appendices 1 - 8.

The linear regression of the severity of stem scab on severity of foliar scab is presented in Fig. 2. The regression equation [illegible] that there was 0.66 unit change in the severity of stem scab for every unit change in the severity of foliar scab. Similarly, the regression equation given in Fig. 3 indicates that there was 0.72 unit change in the severity of the peduncle scab for every unit change in the severity of stem scab.

Graphically presented in Figs. 4A and 4B are the regressions of the severities of scab of the flowering cushion and pod on the severity of the peduncle scab. These graphs indicate that for every unit change in the severity of the peduncle scab there were 1.10 and 1.07 unit changes in the severities of scab of the flowering cushion and pod respectively. Also, Fig. 5 indicates that for every unit change in the severity of the flowering cushion scab there was 0.89 unit change in the severity of pod scab.

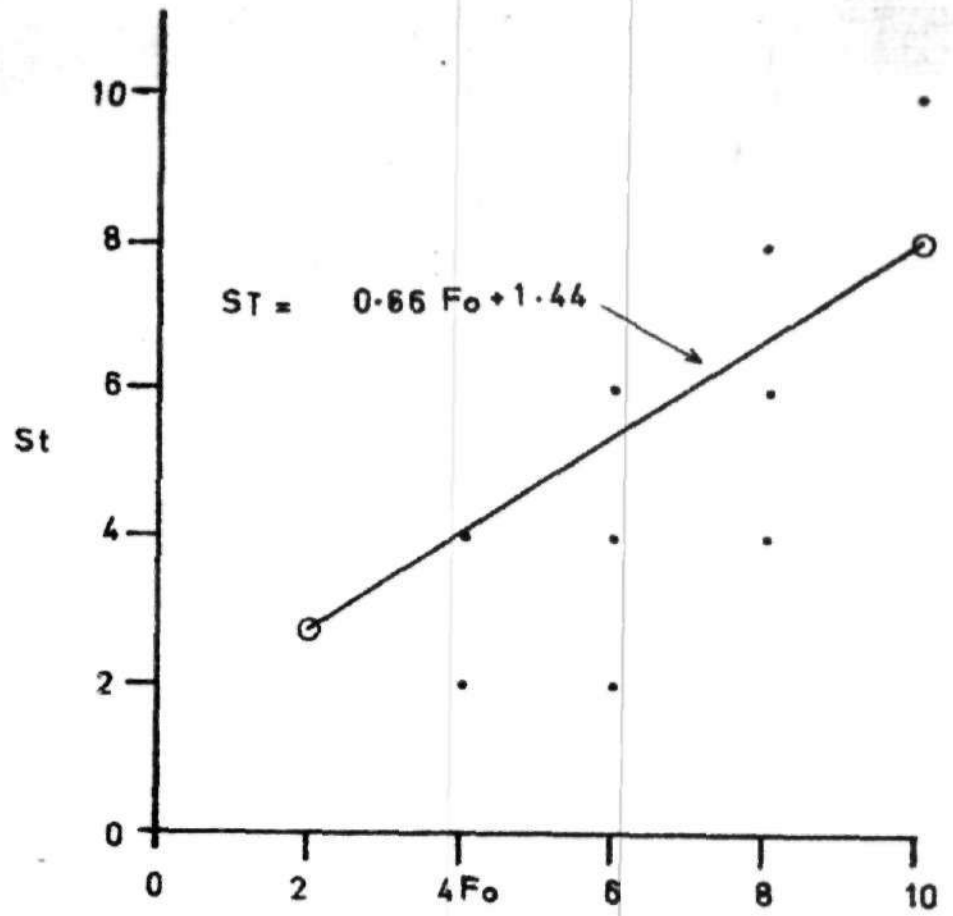


Fig. 2 Linear regression of:

: Stem scab severity (st) on foliar scab severity (Fo)

● Mathematically determined points used in filling regression line

. Points obtained by plotting actual experiment data

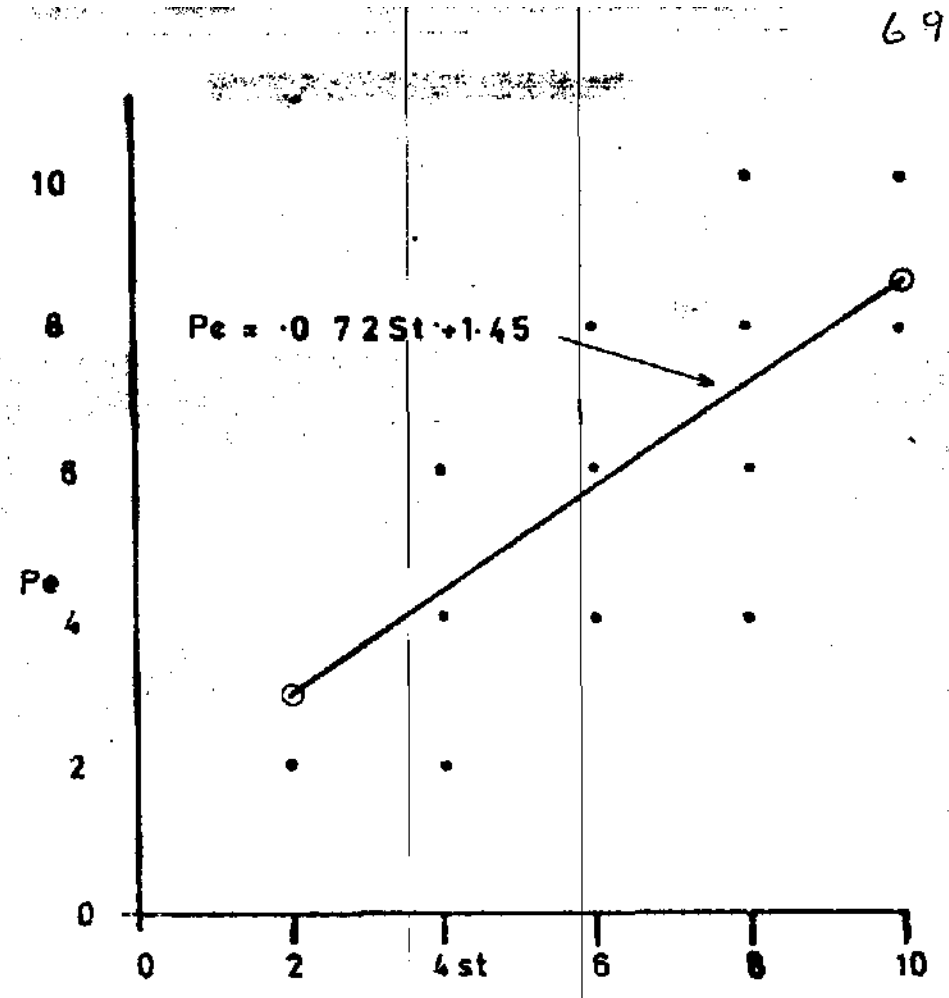


Fig. 3: Linear regression of:

Pe Pseudo Scab Severity (Pe) on Stem Scab Severity (St)

0 = Theoretically determined points used in fitting regression line

• = Points obtained by plotting actual experimental data

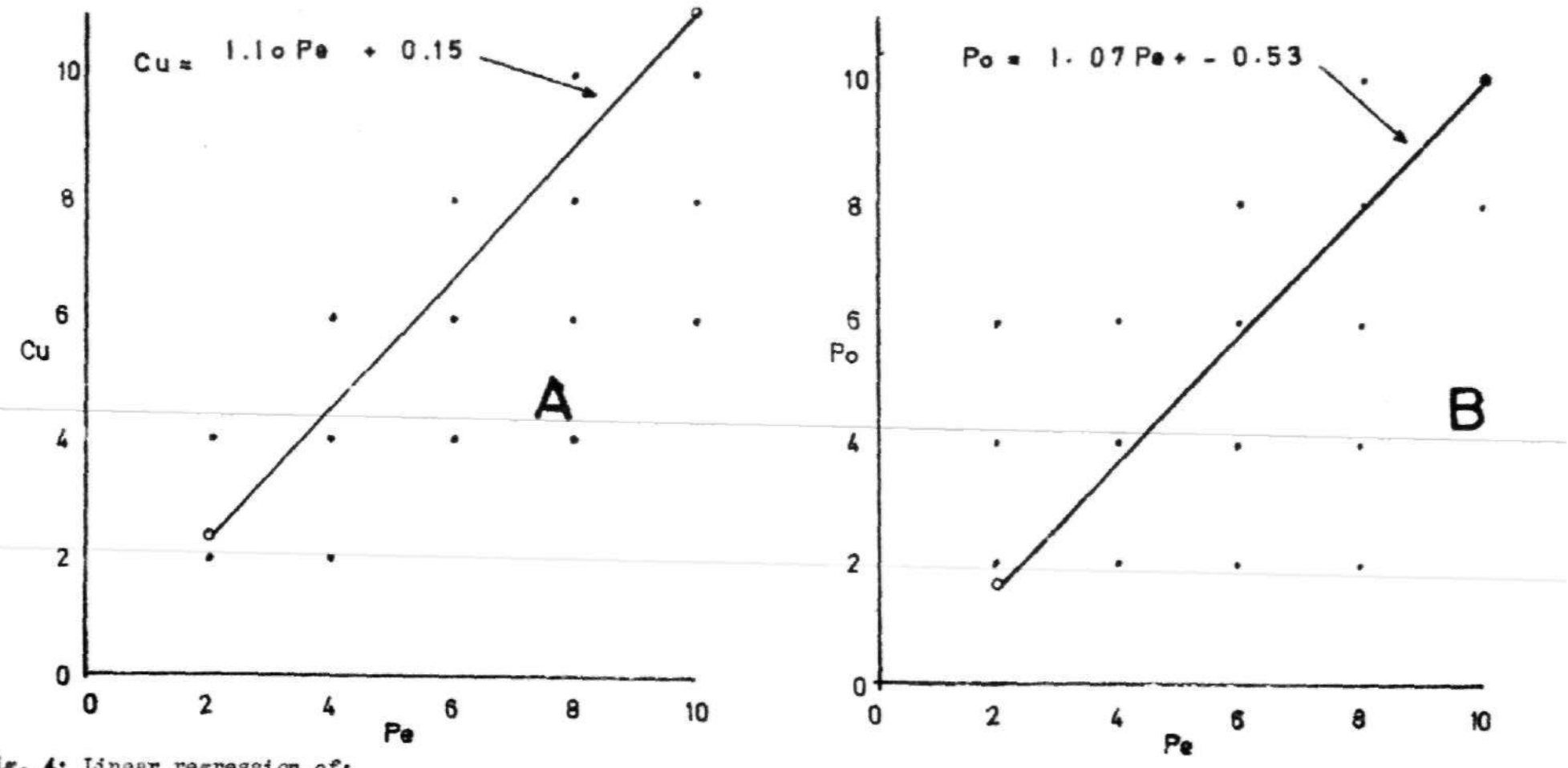


Fig. 4: Linear regression of:

A: Flowering cushion scab severity (Cu) on Peduncle scab severity (Pe)

B: Pod scab severity (Po) on Peduncle scab severity (Pe)

0: Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data

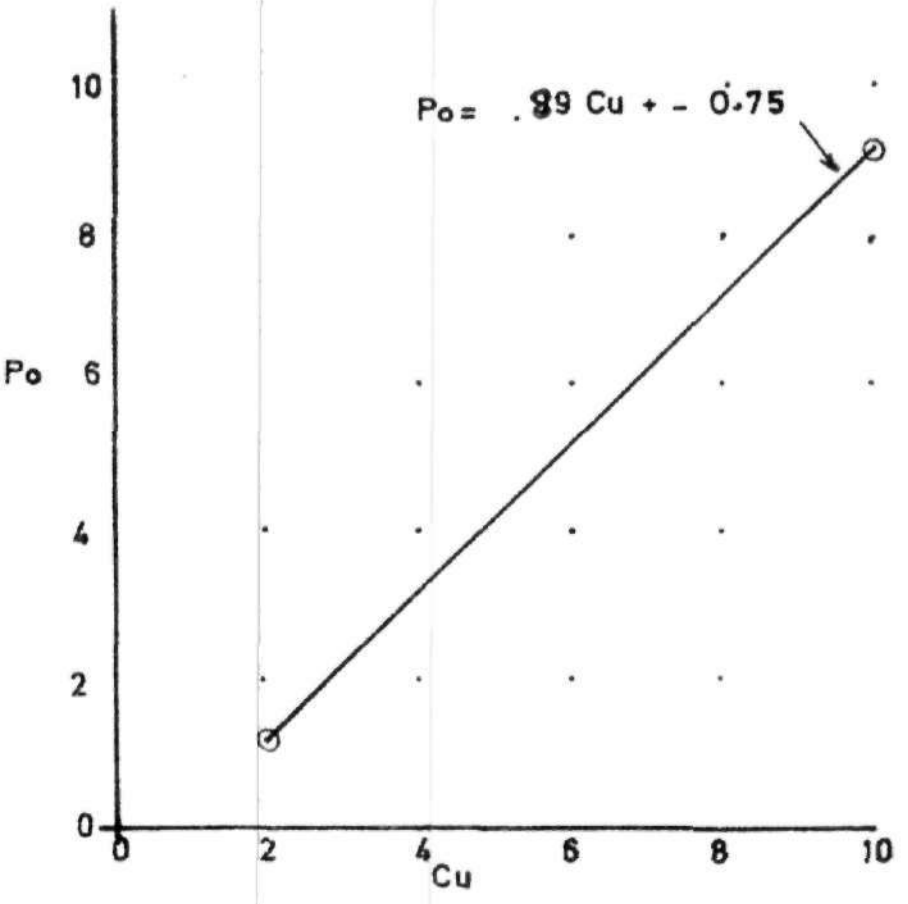


Fig. 5: Linear regression of:

Pod scab severity on flowering cushion scab severity (Cu)

0 Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data

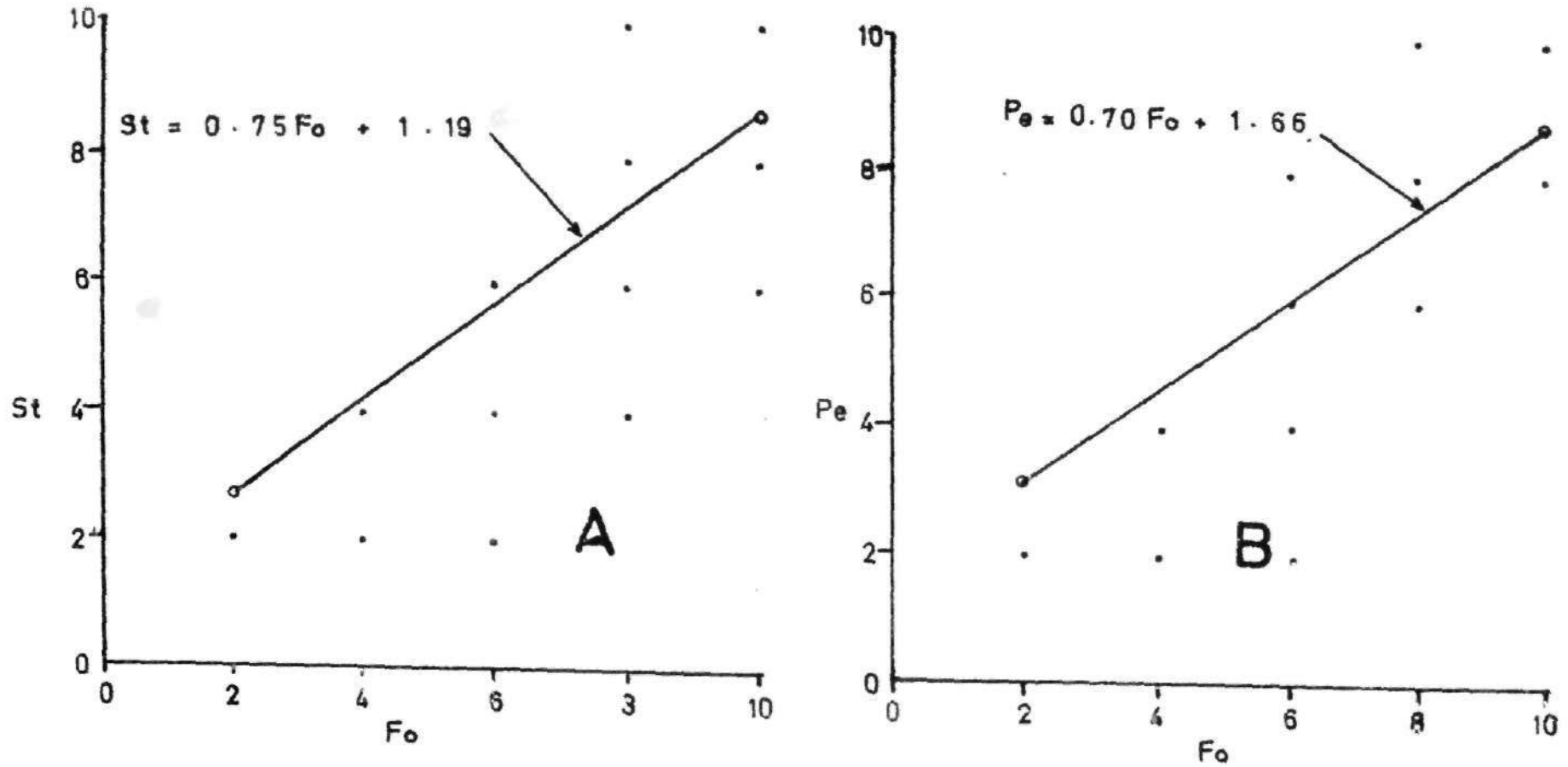


Fig. 10: Linear regression of:

A: Severity of stem scab (St) on severity of foliar scab (Fo)

B: Severity of Peduncle scab (Pe) on severity of foliar scab (Fo)

O: Mathematically determined points used in fitting regression line

•= Points obtained by plotting actual experimental data

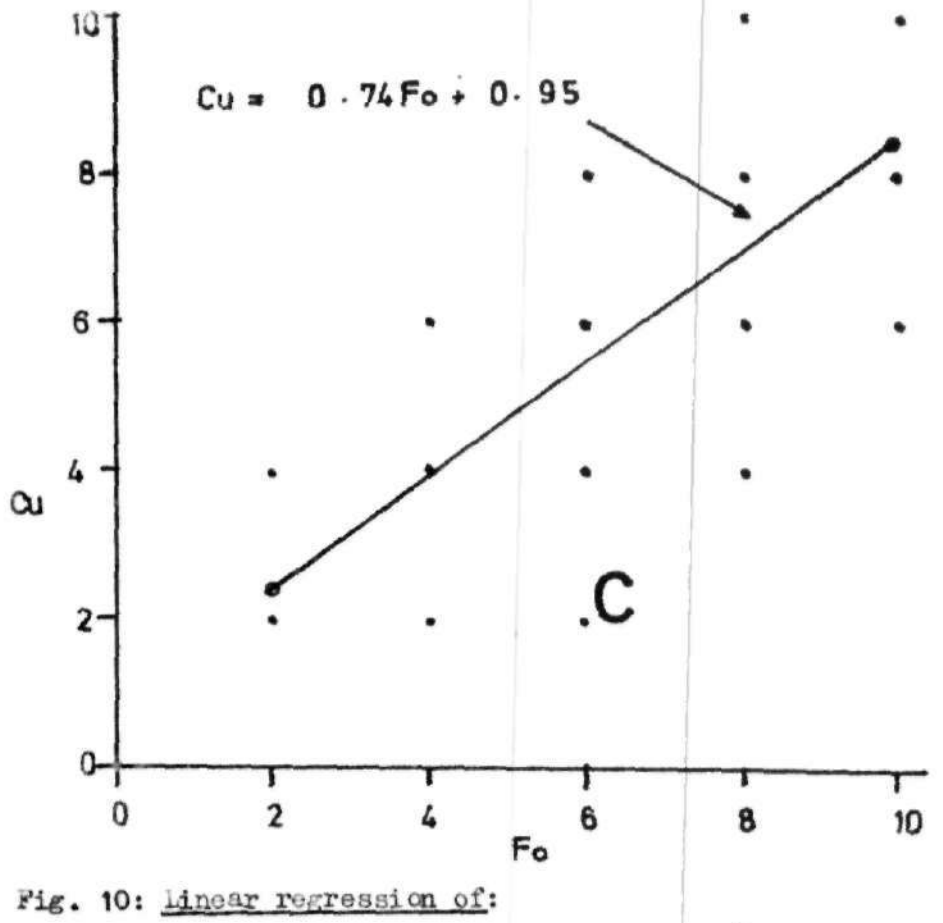


Fig. 10: Linear regression of:

C: Severity of flowering cushion scab (Cu) on severity of foliar scab (Fo)

O: Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data.

Figs. 6A - B represent the linear regression of the incidence of stem, peduncle, flowering cushion and pod scabs on the incidence of foliar scab. These Figs. indicate that for every unit increase in the incidence of foliar scab, there were 1.01, 1.13, 1.31, and 1.01 unit changes in the incidence of stem, peduncle, flowering cushion and pod scabs respectively. Similarly, Figs 7A - 7C indicate that for every unit change in the incidence of stem scab there was 0.94, 0.93 and 0.88 unit changes in the peduncle, flowering cushion and pod scab incidences, respectively, while 8A - 8B revealed that for every unit change in the incidence of peduncle scab there were 0.98 and 0.96 unit changes in the incidence of flowering cushion and pod scab, respectively.

Fig. 9 represents the linear regression of pod scab incidence on the incidence of flowering cushion scab. It showsthat for every unit change in the incidence of the flowering cushion scab there was 0.99 unit change in the incidence of pod scab.

Regression analyses for pairs of disease indices obtained in the glasshouse are presented in Figs. 10 - 15 and in Appendices 9 - 14.

The linear regression of the severity of stem scab, peduncle scab and flowering cushion scab on severity of foliar scab are presented in Figs. 10A - 10C. The regression equations reveal that for every unit change in the severity of foliar scab, there were 0.75, 0.70 and 0.74 unit changes in the severities of the stem, peduncle and flowering cushion scabs respectively. Similarly,

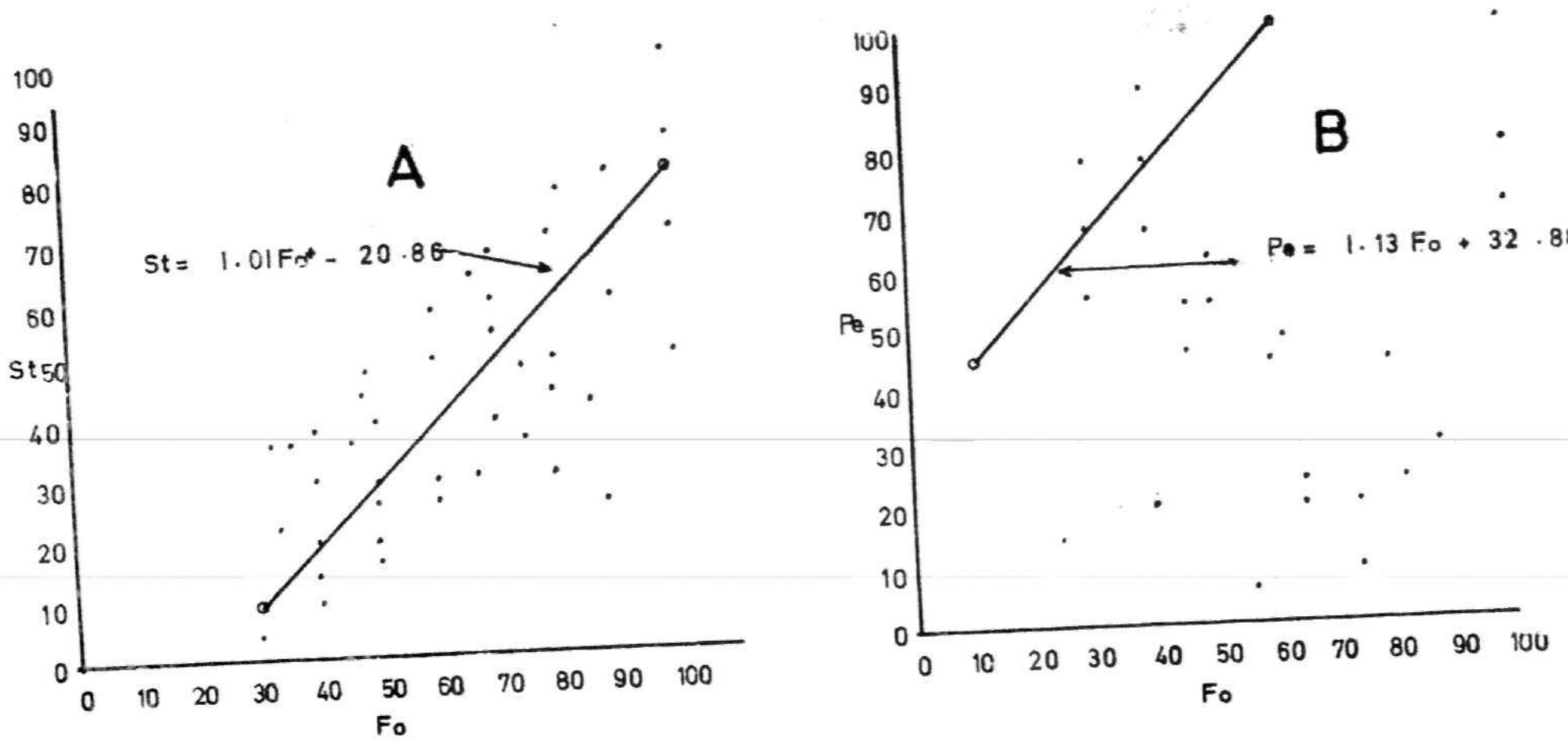


Fig. 6: Linear regression of:

A: Stem scab incidence (St) on foliar scab incidence (Fo)

B: Peduncle scab incidence (Pe) on foliar scab incidence (Fo)

●: Mathematically determined points used in fitting regression line

•= Points obtained by plotting actual experimental data

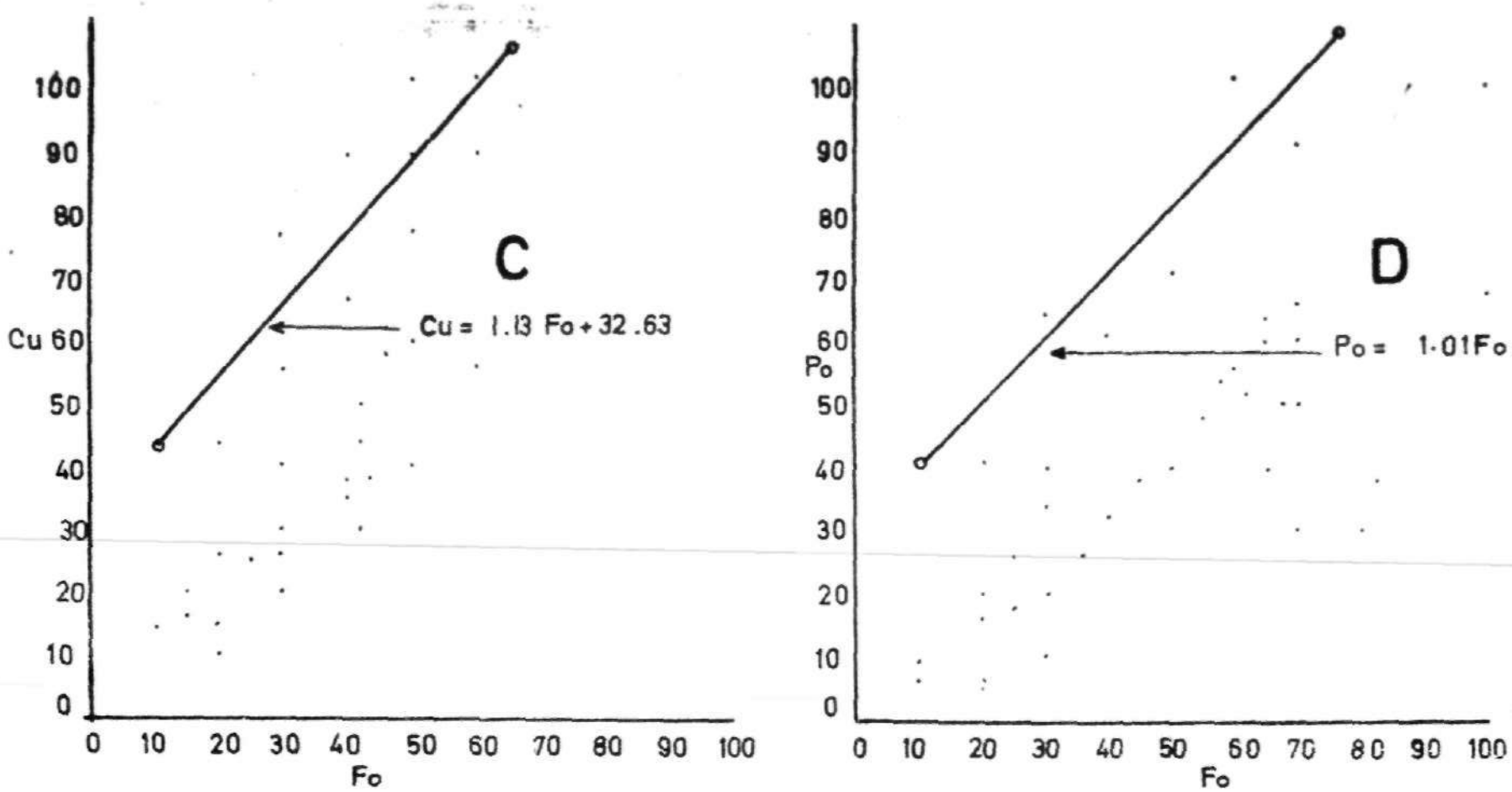


Fig. 6: Linear regression of:

C: Flowering cushion scab incidence (Cu) on foliar scab incidence (Fo)

D: Pod scab incidence (Po) on foliar scab incidence (fo)

O: Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data.

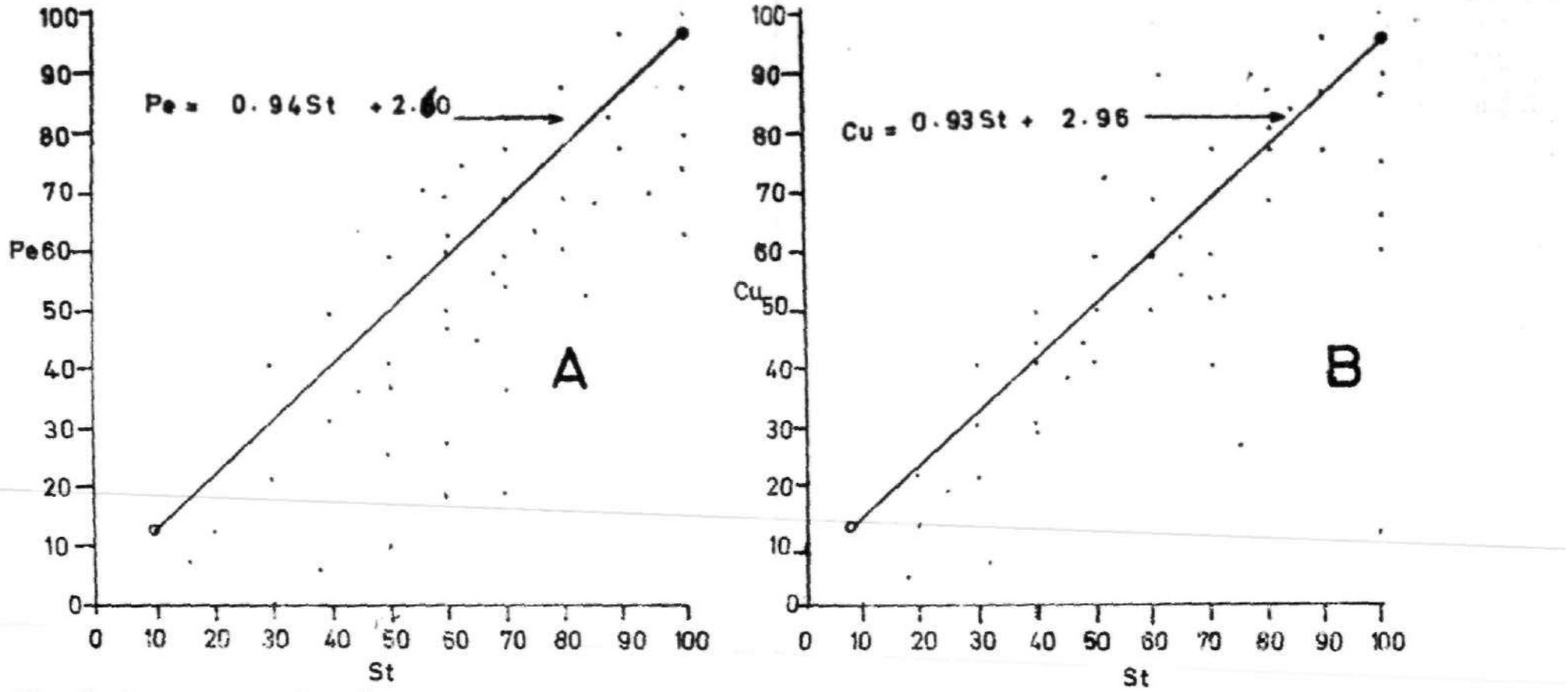


Fig. 7: Linear regression of:

A: Peduncle scab incidence (Pe) on stem scab incidence (St)

B: Flowering cushion scab incidence (Cu) on stem scab incidence (St)

O: Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data.

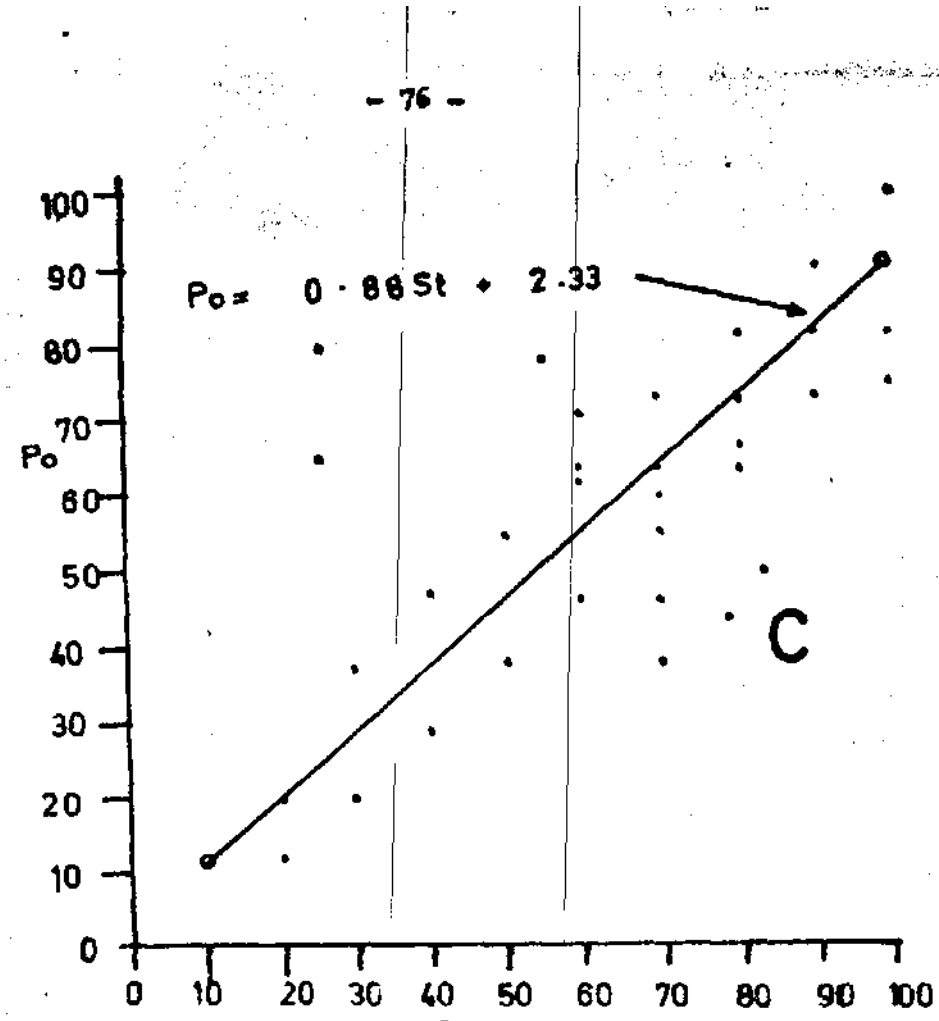


Fig. 7: Linear regression of:

C: Pod scab incidence (Po) on stem scab incidence (St)

O= Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data

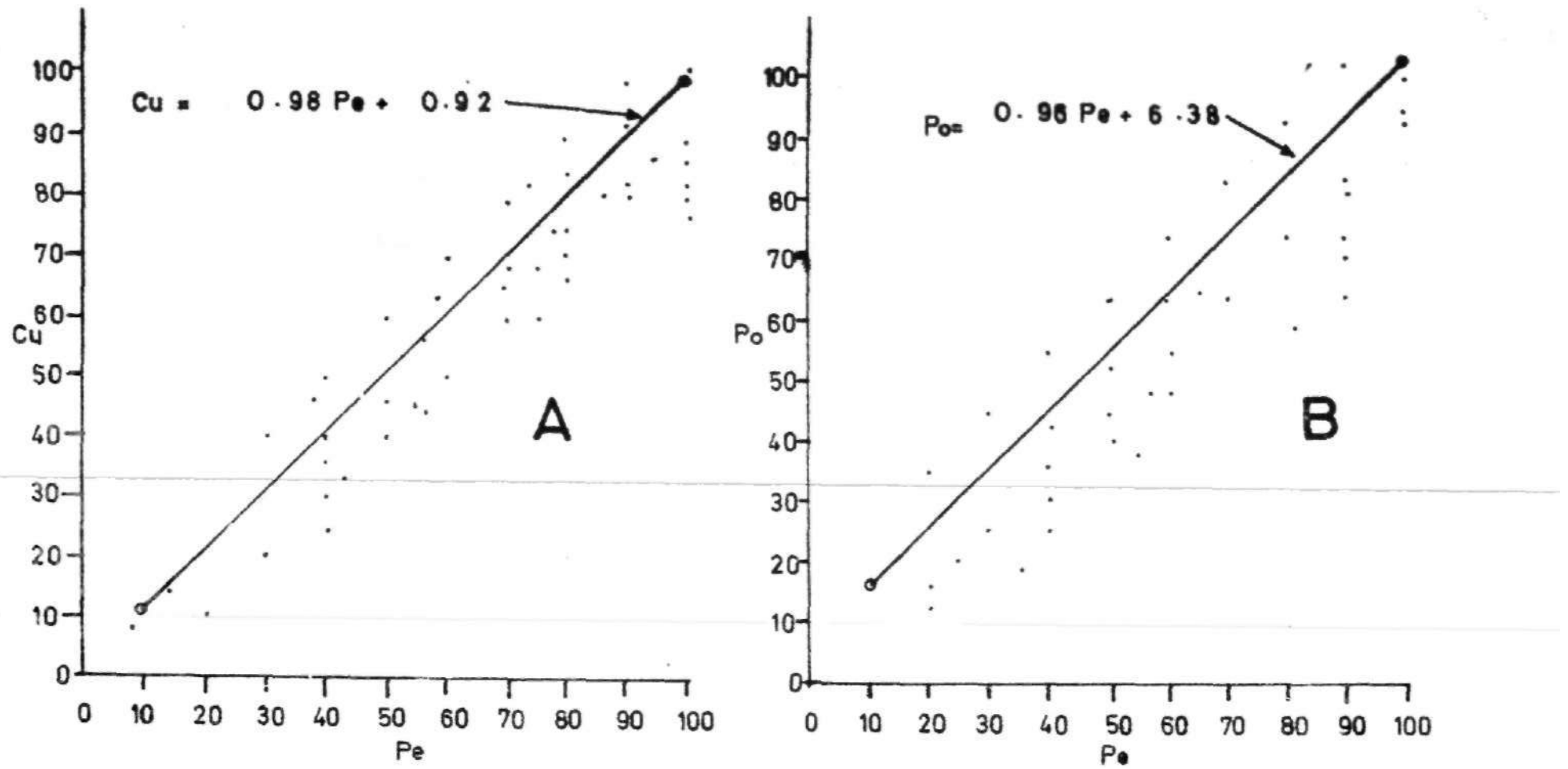


Fig. 8: Linear regression of:

A: Flowering cushion scab incidence (Cu) on peduncle scab incidence (Pe)

B: Pod scab incidence (Po) on peduncle scab incidence (Pe)

O: Mathematically determined points used in fitting regression line

. Points obtained by plotting actual experimental data

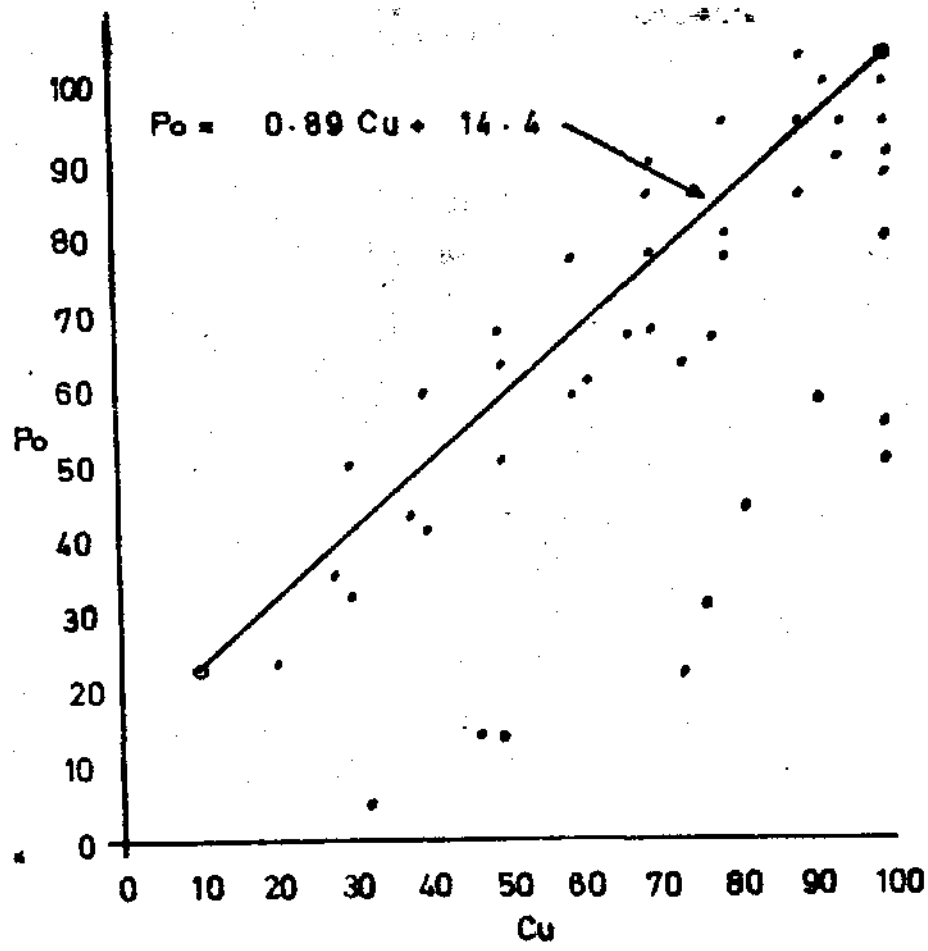


Fig. 9: <u>linear regression of</u>:

Pod scab incidence (Po) on flowering cushion scab incidence

O: Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data

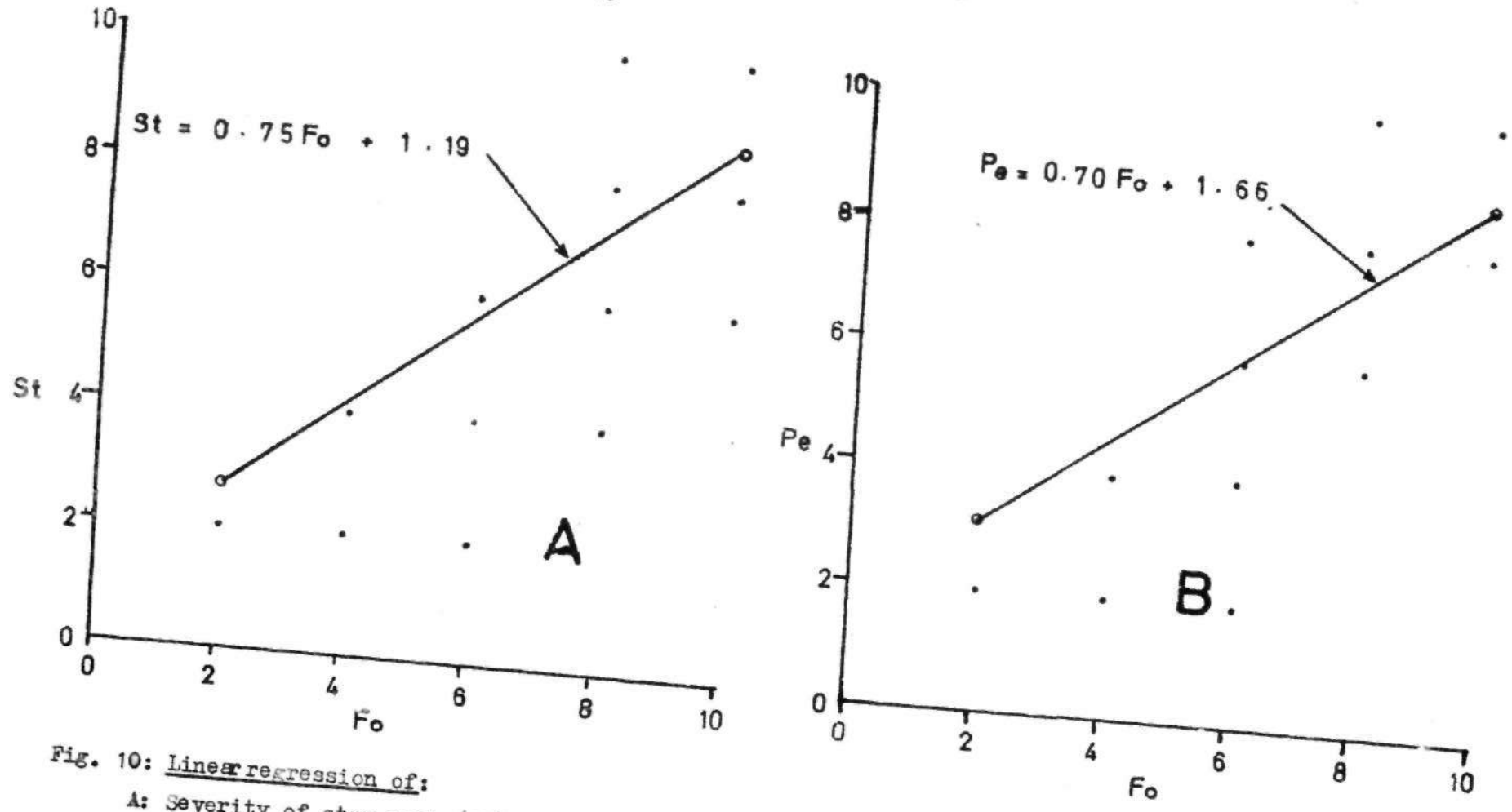


Fig. 10: Linear regression of:

A: Severity of stem scab (St) on severity of foliar scab (Fo)

B: Severity of Peduncle scab (Pe) on severity of foliar scab (Fo)

0: Mathematically determined points used in fitting regression line

: Points obtained by plotting actual experimental data

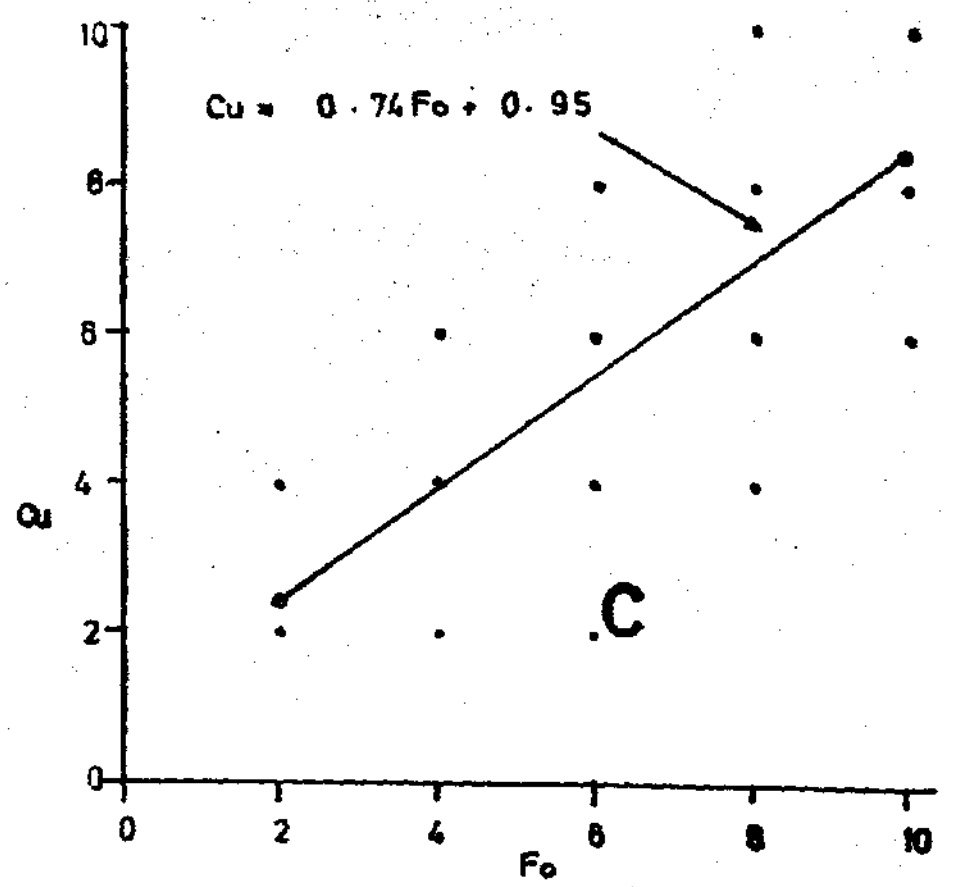


Fig. 10: Linear regression of:

C: Severity of flowering cushion scab (Cu) on severity of foliar scab (Fo)

O: Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data.

Figs. 11A and 11B reveal that there were 0.72 and 0.74 unit changes in the severities of the peduncle and flowering cushion scabs, respectively, for every unit change in the severity of the stem scab, while Fig. 12 indicates that for every unit change in the severity of the peduncle scab there was 0.93 unit change in the severity of flowering cushion scab.

Figs. 13A and 13B represent the linear regressions of the incidences of stem and peduncle scab on foliar scab incidence. These Figs. show that for every unit increase in the incidence of foliar scab there were 0.76 and 0.75 unit changes in the incidences of stem and peduncle scabs, respectively. Similarly, Figs. 14A and 14B indicate that for every unit change in the incidence of stem scab there were 0.79 and 0.77 unit changes in the peduncle and flowering cushion scab incidences, respectively, while Fig. 15 reveals that for every unit change in the incidence of peduncle scab there was 0.81 unit change in the incidence of the flowering cushion.

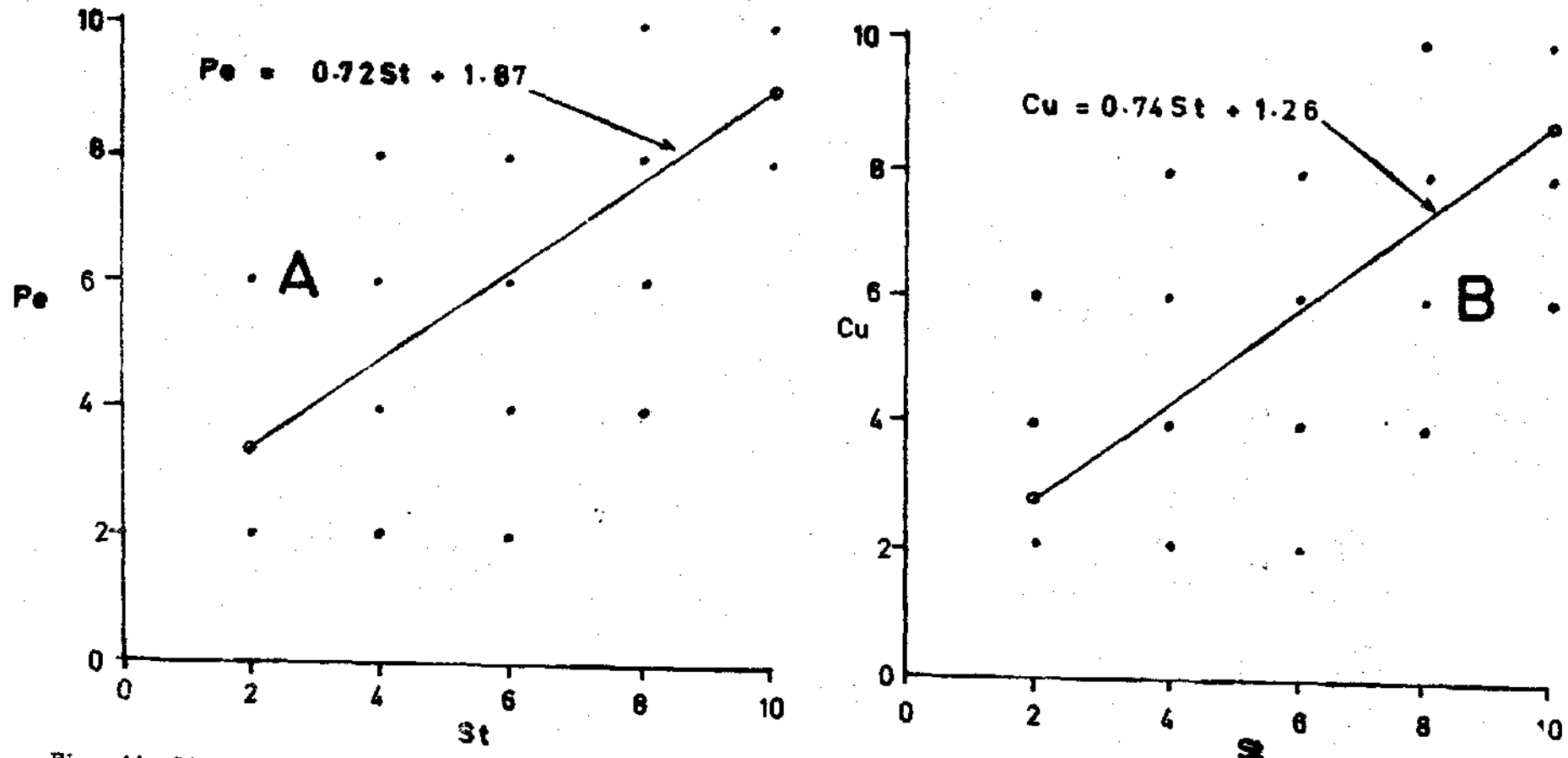


Fig. 11: Linear regression of:

A: Severity of Peduncle scab (Pe) on severity of stem scab (St)

B: Severity of flowering cushion scab (Cu) on severity of stem scab (St)

O: Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data

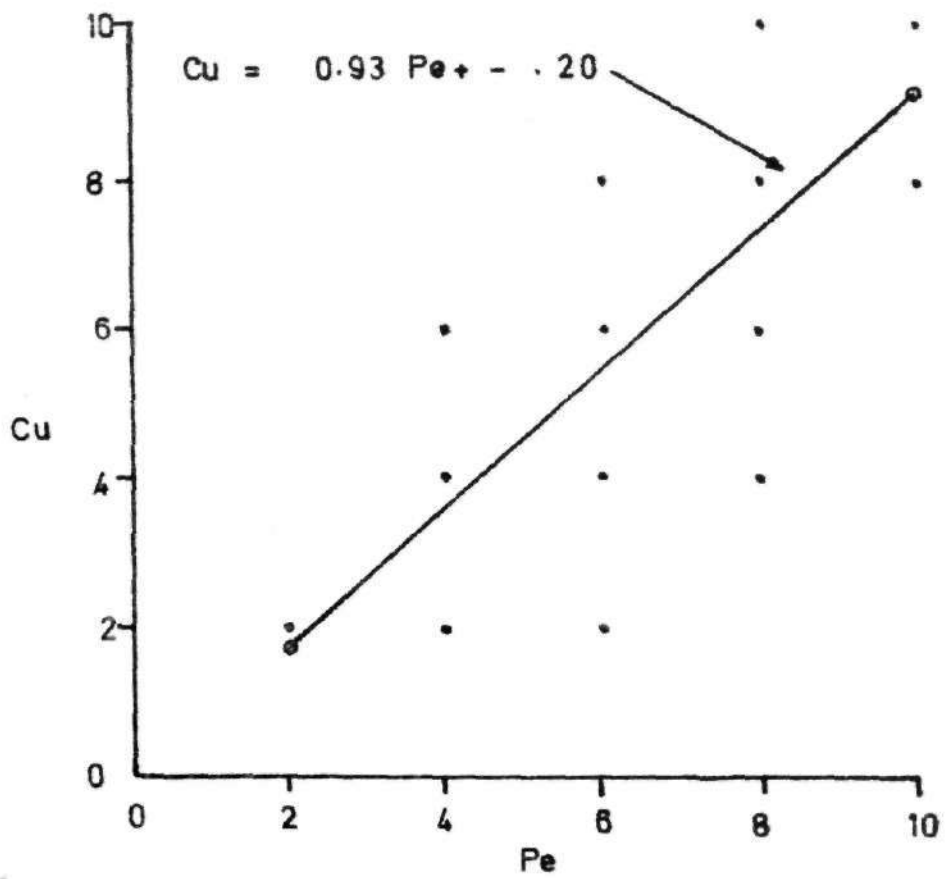


Fig. 12: Linear regression of:

Severity of flowering cushion scab (CUO on peduncle scab severity (Pe)

O: Mathematically determined points used in fitting regression line

.= Points obtained by plotting actual experimental data

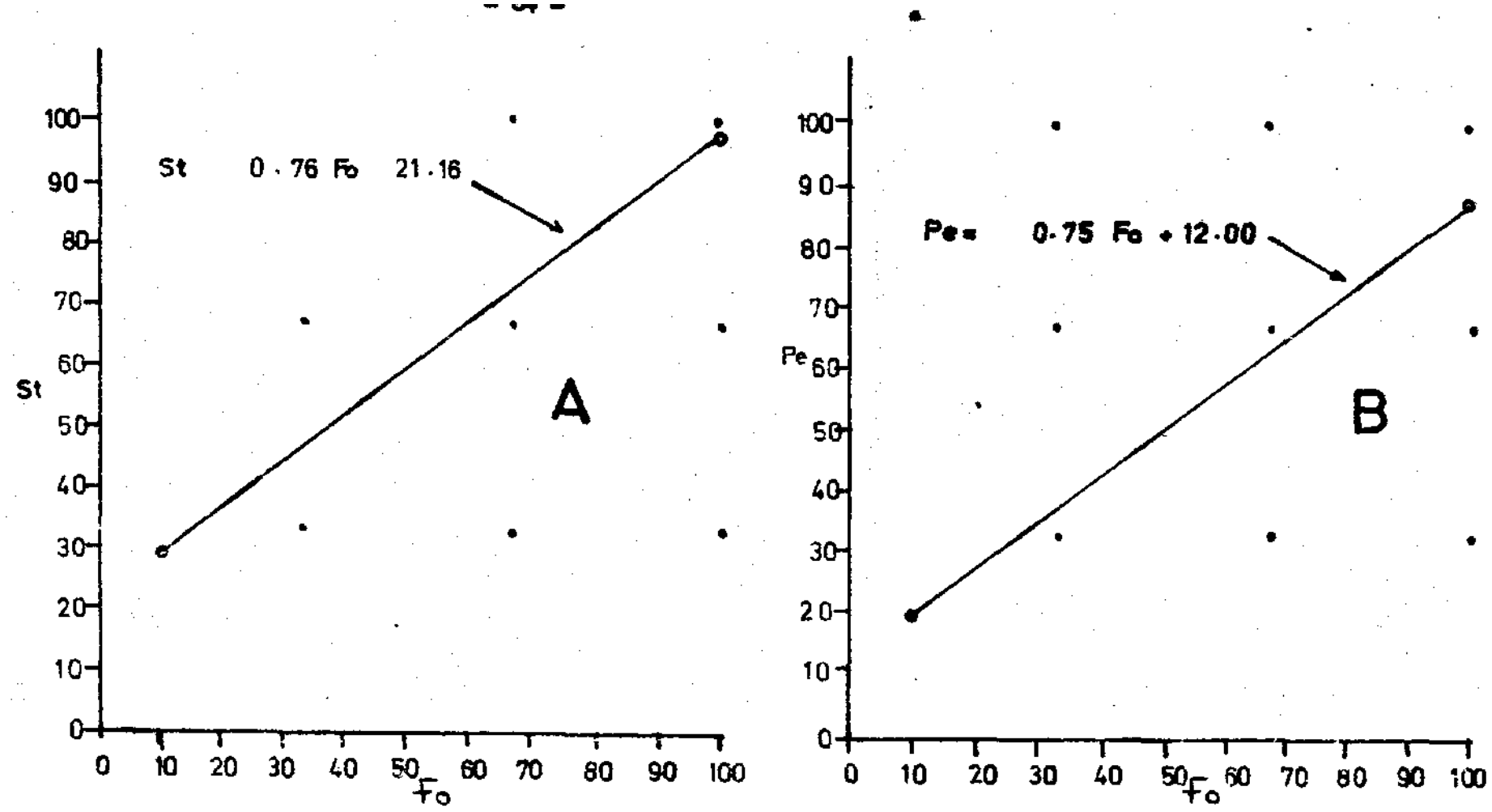


Fig. 13: Linear regression of:

A: Stem scab incidence (St) on folia scab incidence (Fo)

B: Peduncle scab incidence (Pe) on foliar scab incidence (Fo)

O: Mathematically determined points used in fitting regression line

,= Points obtained by plotting actual experimental data

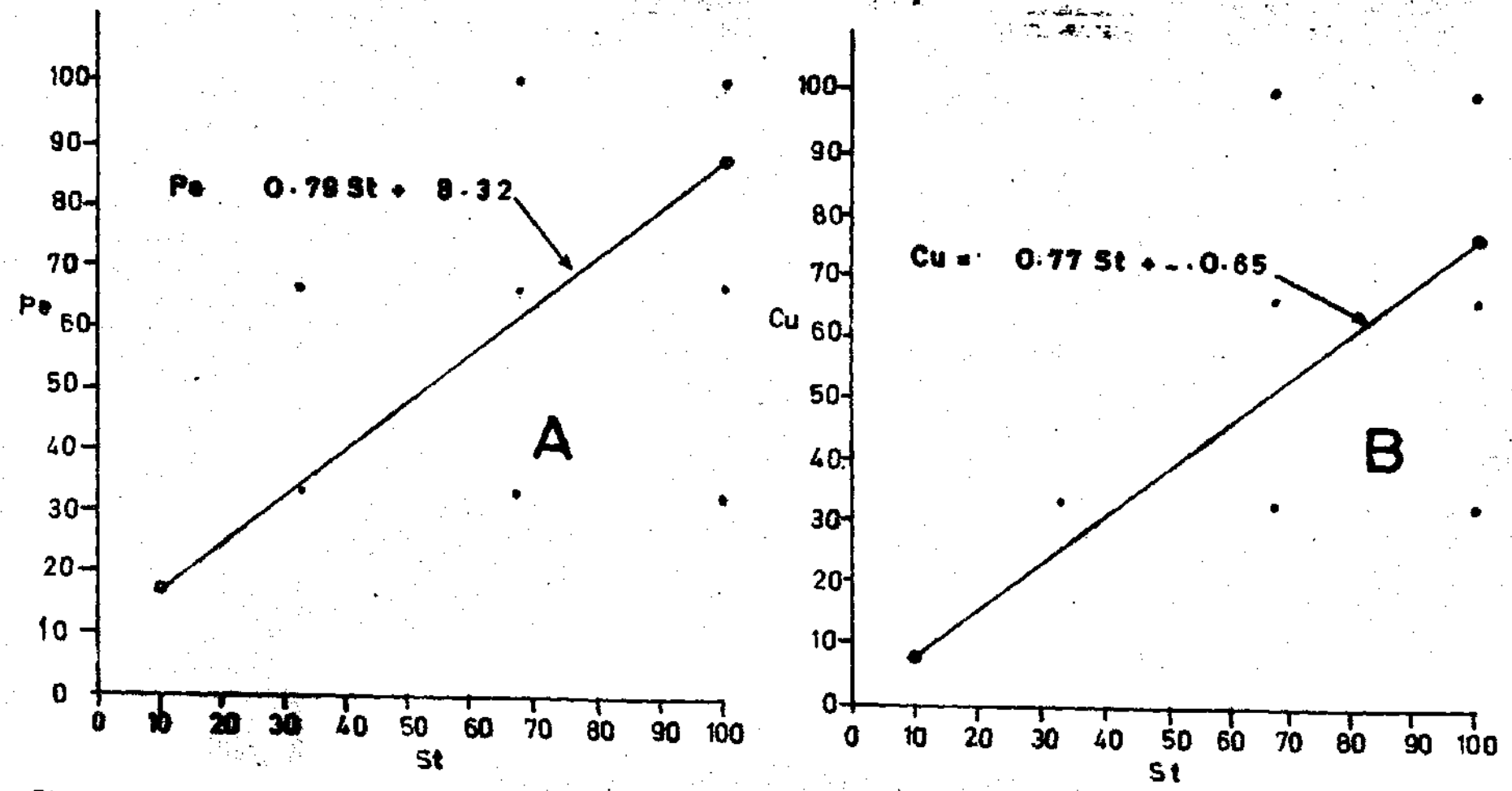


Fig. 14: Linear regression of:

A: Peduncle scab incidence (Pe) on stem scab incidence (St)

B: Flowering cushion incidence (Cu) on stem scab incidence (St)

O: Mathematically determined points used in fitting regression

'.= Points obtained by plotting actual experimental data

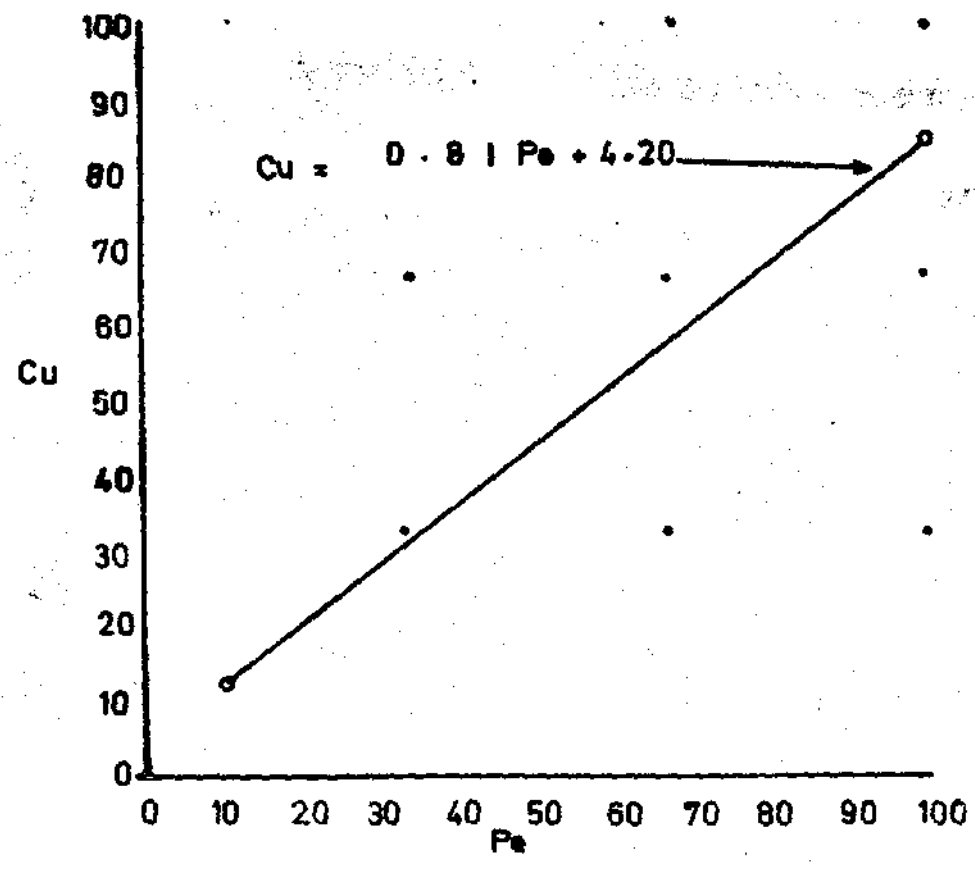


Fig. 15: Linear regression of

Flowering cushion scab incidence (Cu) on peduncle scab incidence (Pe)

0: Mathematically determined points used in fitting regression line

•= Points obtained by plotting actual experimental data

V. DISCUSSION

In the host range studies, the four cowpea varieties/lines included were severely attacked by scab. Yardlong beans (Vigna sesquipedalis) showed mild scab symptoms. These findings agree with those of Emechebe (1980) who showed that the most susceptible hosts of cowpea isolate of Sphaceloma sp. belong to the genus Vigna. However, other legumes, namely, hyacinth beans (Lablab niger), bambara nut (Voandzeia subterranea) and a leguminous weed, Casia tora were infected by the pathogen. Whereas Emechebe's (1980) work showed that hyacinth bean is a host, he did not include Casia tora in his tests, nor did he find bambara nut susceptible to the cowpea scab pathogen. On all these hosts, the fungus produced symptoms similar to those it produced on cowpea.

To the writer's best knowledge, this is the first report of a Sphaceloma sp. infecting bambara nut and Casia tora; the latter is a common wild legume which is infected in nature by a disease that produces scab-like lesions. Infact, C. tora was specifically included in these studies because of the close resemblance between its disease and scab. Attempts by the author to isolate the pathogen of this disease on C. tora were not successful. However, given the difficulty encountered in isolating the cowpea scab pathogen (Emechebe, 1980), it is suggested that more attempts should be made to determine if the disease is induced by Sphaceloma and if that isolate of Sphaceloma is pathogenic to cowpea. The author's personal observations indicate that C. tora is apparently not utilized as food by grazing animals and

consequently its trash is available throughout the dry season. This trash probably acts as a source of primary inoculum because infection of young seedlings occurs early in the rainy season when cowpea is yet unplanted. By the time the cowpea is planted C. tora is already severely infected by the scab like disease. Should the pathogen of this disease be the same that induces cowpea scab, then C. tora would assume considerable importance in the epidemiology of cowpea scab.

In the host range studies, it was found that groundnut, green gram, black gram, sword bean and pigeon pea were not affected by cowpea scab pathogen. The author's findings agree with those of Emechebe (1980) who showed that groundnut, green gram, black gram, sword beans and pigeon pea were unaffected when artificially inoculated with the fungus.

Other plants found to be unaffected in this study included tomato, sweet pepper, bird chilli, maize, sorghum, millet, wheat and spinach. It appears that, as suggested by Emechebe (1980), the fungus infected only a limited number of leguminous plants.

The studies on the survival of the pathogen on infected plant materials suggest that the pathogen's survival is probably determined by three factors, namely, soil moisture, the type of affected plant materials and whether or not the soil is sterilized. The exact role of soil moisture on survival was not investigated in these studies, but it appears that soil moisture enhanced the decay of the plant materials and

the concomitant reduction of the period of surival of the pathogen on such materials. For example, Table 12 showed that the longest survival period of 39 weeks (the duration of the experiment) occurred on infected materials placed on the surface of, or buried in, dry soil (natural or sterilized) inside the glasshouse while the shortest survival periods (20 weeks) occurred on plant materials buried in moist soil.

Secondly, moist soil provides a suitable environment for microbial activity; this results in competition amongst these organisms for the nutrients provided by cowpea trash. Apart from competition, antibiosis by microbial antagonists on the decaying trash may contribute to the disappearance of the pathogen. Both these forms of antagonism (competition and antibiosis) are known to influence the survival of plant pathogens on infected material (Ckark, 1965; Jackson, 1965). However, their exact role in survival of Sphaceloma sp. on cowpea trash was not investigated in the present studies.

The importance of moisture on survival of the pathogen is also reflected in Table 12 which showed that the pathogen survived for a shorter period on infected materials in dry soil outside the glasshouse than inside the glasshouse e.g. 32 and 28 weeks on stems and pod shells buried inside dry soil outside the glasshouse and 39 weeks (experimental duration) for such

materials treated in a similar way inside the glasshouse. This is because with the onset of rains in the 16th week of the experiment the soil which had been kept dry outside the glasshouse became moist, thereby encouraging decomposition of the plant materials through enhancing microbial activity which led to antagonistic interactions amongst soil microorganisms as explained above. These findings that survival is shorter in moist than in dry soil agree with the findings of Fellows (1941) and Garrett (1970) who investigated the survival of Gaeumannomyces graminis in soil and reported that under warm conditions, survival of G. graminis was longer in dry soil than in moist soil. Similar results were reported by Okpala (1981) who investigated the survival of C. capsici in cowpea trash and found that this fungus survived longer on infected tissues in dry than in moist soil.

It has also been shown in these studies (Table 12) that the survival of the pathogen outside the glasshouse was shorter in dry natural soil than in sterilized soil. This finding is in consonance with the above suggestion that enhanced competition and antibiosis in moist soil probably contributed to shorter survival period in moist soil than in dry soil. It seems fair to assume that the population of microorganisms in sterilized soil was, at least initially, less than that in natural soil. As a result, with the onset of rains in the 16th week of the experiment, decomposition of plant materials started but the process was probably slower in sterilized than

in natural soil. These results agree very closely with those of Okpala (1981) who showed that the cowpea brown blotch pathogen (C. capsici) survived longer in infected stems and pods shells buried in sterilized soil than in those buried in natural soil.

Table 12 shows that while the longest survival period outside the glasshouse on pod shells was 33 weeks, that on stem was 35 weeks. The survival on these materials is probably related to their thickness, the stem being more bulky than the pod shells. Apparently it would take a longer period for the stem to be decomposed relative to the pod shells. This finding again agrees with that of Okpala (1981) who found that C. capsici survived longer on infected cowpea stems than on pod shells.

The results of the survival studies showed that Sphaceloma sp. survived up to August, 23 and July, 15 respectively on pieces of infected stems and pod shells placed on the surface of natural soil kept dry outside the glasshouse until the rainy season; the rains started on April 10th of the same year (1982). The fungus also survived up to August 16 and July 15 on infected stems and pod shells, respectively, buried in dry natural soil and exposed to environmental conditions outside the glasshouse. These results agree with the report of McCubbin (1933) that Elsinoe canavaliae survived the dry season between two successive crops on undisturbed Lima bean trash. These findings were considered important because in Northern Nigeria, cowpea is sown between middle of June and first week of August. Consequently, by the time cowpea is planted, the pathogen's primary inoculum from

infected trash would still be available.

Although these results suggest that infected cowpea trash of a particular year is a potential source of primary inoculum for infection of the crop of the following year, the pathogen is apparently unable to survive in such trash for more than one rainy season since it did not survive more than 17 weeks after the commencement of the rains. This means that after a crop of cowpea, the pathogen would probably disappear from the soil in the absence of the host during the subsequent rainy season, provided that it does not survive on a weed host such as Cassia tora.

On the basis of their reactions to different phases of scab in the field and glasshouse, over 100 lines of cowpea have been grouped into four classes, namely, high resistant, moderately resistant, susceptible and highly susceptible. It was shown that generally some lines which were highly resistant to one phase of the disease were moderately resistant or even susceptible to another phase of the disease. Of the 107 lines tested under the field conditions, for example, 12, 14, 10 and 11 lines were found to be resistant to the leaf, stem peduncle and flowering cushion phases of scab, respectively. In addition, all the 11 lines that were resistant to the flowering cushion scab plus another 8 lines were resistant to the pod phase of the disease. The results obtained in the glasshouse showed that out of the 124 lines, 16 lines were resistant to foliar, peduncle and flowering cushion phases of scab while 15 lines were resistant to the stem phase of the disease.

Of the original 107 lines tested in the field and the glasshouse (Table 23), 8 and 12 lines were resistant to the foliar and stem phases of the disease, while 9 lines each were resistant to the peduncle and flowering cushion phases of the disease.

These results show that the number of lines found to be resistant to these phases of scab in the glasshouse was less than that detected in the field (Table 26). These differences are probably attributable to the fact that in the glasshouse experiment, a conidial inoculum was sprayed on to the plants which were then kept under humid conditions. The effectiveness of infected trash as a source of inoculum in the field, while convenient depended on availability of several days of humid weather conditions for sporulation on infected tissues from where conidia were

Table 26 Number of varieties resistant to the different phases of scab in the field and glasshouse

Environment	Foliar Scab	Stem Scab	Peduncle Scab	Flowering Cushion scab
Field	12	14	10	11
Glasshouse	8	12	9	9

dispersed to susceptible parts of the plants which would become infected only if humid conditions persist. Thus the conditions for successful infection were apparently better in the glasshouse than in the field. It will thus seem that a better indication of resistance of the lines was provided by the results obtained in the glasshouse than by those obtained in the field. However, in the

long run, the field data would probably be more meaningful than those obtained in the glasshouse since cowpea is not grown in the glasshouse in Nigeria. However, Table 26 shows that results obtained in both environments compare favourably with each other.

Five lines have been found in the present studies to be truly resistant to all phases of scab in both environments. These are TVU 1486, TVU 1890, TVU 1404, 35 - 4 and TVU 851.

The most destructive phase of scab is the scab of the flowering cushion which leads to the abscission and/or shrivelling of pods (Emechebe, 1980). In the present studies, some lines were considered to be resistant to scab because they were relatively free of the flowering cushion and/or pod phases of scab although they flowered and podded during the wet periods that encourage infection and disease development. These lines are TVU 1486, TVU 1404, 35 - 4, TVU 1890, 200, 45, TVU 851 and TVU 625. TVU 625 flowered late in the field but had already flowered at the time of inoculation in the glasshouse and so it did not merely escape the disease. On the other hand some lines appeared to escape decreasing levels of the disease by flowering and/or podding towards the end of the rains, i.e. from about middle of September to early October. These lines, their dates of flowering and podding and the final disease scores on them are given in Table 27. Even though the seven late flowering varieties succumbed to the leaf and stem phases of the disease in the field, they were rated as resistant to the flowering cushion and/or pod phases of the disease. As suggested earlier, such lines merely

Table 27: Flowering and podding dates of, and scab scores on, 7 late and 2 early maturing varieties

	Varieties	Date of: Flowering	Podding	Scab Intensity on [a]: Leaf	Stem	Peduncle	Flowering cushion	Pod
1	1696	30/09	7/10	10	8	4	2	2
2	162	9/09	17/09	10	8	6	4	4
3	20	9/09	17/09	10	8	6	6	2
4	83	07/09	16/09	8	8	8	6	2
5	34 - 77	9/09	17/09	10	8	66	6	2
6	B - 7	16/09	23/09	10	8	4	4	2
7	Sokoto	10/09	17/09	10	8	6	6	2
8	353	13/09	20/09	10	10	10	10	10
9	Ife Brown	13/09	20/09	10	10	10	10	10

a: Date obtained on October 26, 1981

escaped damage by flowering and/or podding late in the season when humid conditions necessary for sporulation, inoculum dispersal, infection and disease development have become erratic or completely ceased. Thus, when these lines were inoculated after flowering in the glasshouse, they were severely affected by all phases of the disease.

Some lines that were found to be resistant to scab in the present studies have also been found to be resistant to other important diseases of cowpea. For example, Emechebe (1982) found TVU 1404, TVU 1486, TVU 1890 and TVU 851 resistant to brown blotch while TVU 1486, TVU 1404 and TVU 1890 were resistant to bacterial blight.

Correlation and regression analyses have been used to indicate the relationship (not necessarily cause and effect one) between one phase of scab and some of the other phases, both in the glasshouse and in the field. In the glasshouse, for example, there was a highly significant ($P = 0.01$) positive correlation ($r = 0.82$) between the severity of flowering cushion scab and peduncle scab. Furthermore, in the field there was a highly significant ($P = 0.01$) positive correlation ($r = 0.86$) between pod scab severity and flowering cushion scab severity. These high positive correlations are probably expected since it is reasonable to suppose that the peduncle scab lesions generate inoculum for infection of flowering cushion, whose lesions generate inoculum for pod infection.

The correlations between the peduncle/flowering cushion and pod scab severity, on the one hand, and foliar scab on the other, were invariably low. This is probably because by the time the varieties flowered, the leaves had already matured and the lesions had become so old that they had ceased to be infectious. Also the lesions on the leaves often fall off to produce shot hole spots prior to flowering. The fact that the correlations even in these cases were highly significant (P - 0.01) is not particularly surprising because the detection of significance was obviously related to the large error degrees of freedom (854) used in the calculations.

However, the regression equations are potentially useful in predicting the severity and/or incidence of a particular phase of scab given the corresponding values for other phases. For example, the regression equation of severity of the stem scab on leaf scab severity was St - 0.66Fo + 1.44. This means that for every unit change in the foliar phase of scab there was 0.66 unit change in the stem scab.

From the results of the present work, certain control measures can be suggested. One possible control measure would be the destruction of debris before the land is prepared. This could be done by collecting cowpea trash in a heap and burning before the onset of rains. Important also would be the destruction of weed hosts such as Cassia tora.

Another possible control measure would be the use of crop rotation. This is based on the fact that in the absence of its susceptible hosts, the pathogen does not survive after the rainy season immediately following an infected cowpea crop (Table 12). The rotation should be done in such a way that cowpea is followed at least once by a non-host like groundnut, maize, pearl millet, wheat or sorghum. This sort of rotation has been used to control bean anthracnose in Australia (Anonymous, 1966b).

An important and relatively cheap (as far as the farmer is concerned) control measure against scab would be the use of resistant varieties. Five resistant varieites have been identified in this work (Table 23). These could be utilized in developing resistant and agronomically acceptable varieties of cowpea because none of these possesses desirable seed characteristics i.e. medium to large, brown or white seeds with porous testa. In cotrast, lines like 1696 (yield - 1150gm/30 plants) and B - 7 (yield - 800gms/30 plants) not only gave relatively high yields of grain with acceptable seed quality but also escaped damaging levels of scab. These lines can be used as commercial varieties in areas where rains continue up to October. In developing resistant varieties however, care must be taken to study the inheritance of the resistance so that varieties with horizontal resistance (sensu Van der Plank, 1963) are produced in preference to those with

race specific resistance (sensu Nelson, 1973; 1978) to avoid the appearance of races of the pathogen with mutating virulent genes to specific resistance.

SUMMARY

The host range and survival in infected trash of cowpea isolate of Sphaceloma sp. (the fungus that causes scab in cowpea) were studied. Its interactions with cowpea lines in northern Nigeria were also investigated.

In the host range studies, conidial suspension was used as inoculum. Apart from cowpea, four other plant species were infected, namely, bambara nut, hyacinth bean, yardlong bean and Cassia tora (a weed). Of these, bambara nut was the most severely affected. Yardlong bean and hyacinth bean had mild lesions on their leaves and stems while C. tora suffered only from mild stem scab. This is the first report of this fungus infecting bambara nut and C. tora.

The survival of Sphaceloma sp. on infected stem and pod shells was studied both inside and outside the glasshouse. In both environments, the materials were either buried in soil or placed on soil surface. Survival periods in dry or moistened natural or sterilised soils were studied. The longest survival period was 39 weeks (the experimental period) which occurred on stems and pod shells placed on the surface of, or buried in, soil that was dry throughout the experimental period. Survival periods of the pathogen in soils that were exposed to natural rain and sunshine outside the glasshouse were 39 and 28 weeks, respectively for stems

and pod shells placed on soil surface and 32 and 28 weeks, respectively for stems and pod shells buried in soil. These shorter survival period outside the glasshouse were associated with rains that began 16 weeks after commencement of the experiment. However, the pathogen survived for a further period of 17 and 12 weeks after the start of the rains on stems and pod shells, respectively. This suggested that the infected trash on a particular piece of land could act as a source of primary inoculum for the infection of cowpea in the year immediately following that in which an infected cowpea crop was grown.

The interaction of the pathogen with different varieties of cowpea was studied and the severity and incidence of different phases of scab were used to assess the resistance of 107 and 124 lines of cowpea in the field and glasshouse, respectively. The lines were then grouped into four reaction classes. The results showed that some lines that were highly resistant to one phase of scab succumbed to one or more phases of the disease. However, more lines were shown to be more resistant to scab in the field than in the glasshouse, probably because in the glasshouse, a conidial inoculum was used to inoculate plants that were immediately enclosed in a fitened polythene bags while in the field, infected plant materials, placed in axils of upper leaves, were used as source of inoculum.

Linear regression analyses were also done to show the relationship between one phase of scab and some other phases of the disease.

The present studies identified five lines resistant to scab. It also identified seven lines that escape damaging levels to the flowering cushion and/or pod phases of the disease.

From the above results, the following control measures for cowpea scab were proposed.

a. Destruction of infected trash, i.e. collecting in a heap and burning
b. Crop rotation in which cowpea is followed by unrelated non-host crop.
c. The development and use of scab resistant varieties.

VII REFERENCES

Anonymous (1957). Annual Report of the Dept. of Agric. Kenya for 1955, Vol. II, pp. 237.

Anonymous (1966a). Jaarverslag 1965 Med Lid.g Landbouw Proefstation Suriname, No. 40, pp. 89.

Anonymous (1966b). Some Plant Diseases: Bulletin P.D. 41C. pp. 100.

Anthonio, Q.B.O. (1979). General Agriculture for West Africa. London, George Allen and Unwin.

Arruda, S.C. (1957). Read in: Jenkins, A.E. and Bitancourt, A.A. (1960). Notes on the spot Anthracnose A-Spot anthracnose of Sugar cane. Biologico 26(6): 111-113.

Bates, G.R. (1955). News from Southern Rhodesia. Commonwealth Phytopathological News 1, : 43 - 44.

Bitancourt, A.A. and Jenkins, A.E. (1936). Perfect Stage of sweet orange scab fungus. Mycologia 28(5): 489 - 492.

Bitancourt, A.A. and Jenkins, A.E. (1939). New species, host and distribution records of Elsinoe and Sphaceloma. Chron. Bot. 4(4 - 5): 388 - 389.

Bitencourt, A.A. and Jenkins, A.E. (1940). New species of Elsinoe and Sphaceloma on hosts of economic importance. Argentina Institute of Biology, Sao Paulo. 9: 45 - 48.

Bitencourt, A.A. and Jenkins, A.E. (1950). Studies on the Myriangiales I. Ten new species of Elsinoe discovered in Brazil. Argentina Institute of Biology, Sao Paulo, 19, (7): 93 - 109.

Bitencourt, A.A. and Jenkins, A.E. (1951). Studies on the Myriangiales II. Twenty new species of neotropical Elsinoaceae. Argentina Institute of Biology, Sao Paulo, 20 (1): 1 - 28.

Brooks, N.E. (1955). Annual Report of the Secretary to the Federal Ministry of Agric., Rhodesia and Nyasaland for the year ended 30th September, 1954. pp. 115

Brooks, N.E. (1956). Botany and Plant Pathology Reports for Ministry of Agric., Rhodesia and Nyasaland for the year ended 30th September, 1955, pp. 60 - 70

Bruner, S.C. and Jenkins, A.E. (1933). Identity and host relations of Elsinoe of lima beans. Journal of Agric. Res. 47: 783 - 789.

Clark, E.F. (1965). The concept of competition in microbial ecology. pp. 339 - 347 In: Baker, K.F. and Snyder, W.C. (Eds). Ecology of Soil Borne Plant Pathogens. London, John Murray

Ebong, U.U. (1965). Cowpea Production in Nigeria. Memorandum, No. 8, pp. 9. Federal Dept. of Agric. Res. Ibadan.

Emechebe, A.M. (1979). Brown blotch of cowpea in northern Nigeria. Samaru Journal of Agricultured Research 1 (1) 21 - 26.

Emechebe, A.M. (1980) Scab disease of cowpea (Vigna unguiculata) caused by a species of the fungus, Sphaceloma. Annals of Applied Biology, 96: 11 - 16.

Emechebe, A.M. (1982). Screening cowpea lines for multiple disease resistance. I.A.R Cropping Scheme Meeting, 1982: pp. 30 - 31.

Emechebe, A.M. and MacDonald, D. (1979). Seed borne pathogenic fungi and bacteria of cowpea in northern Nigeria. PANS 25 (4): 401 - 404.

Ezedinma, F.O.C. (1961). Research on cowpea, (Vigna sp.) in Nigeria before 1960. Memorandum No. 68, pp. 49. Federal Dept. of Agric. Res., Ibadan.

Fellows, H. (1941). Effect of certain environmental conditions on the prevalence of Ophiolobus graminis in the soil. Journal of Agric. Res., 63: 715 - 726

Garrett, S.D. (1970). Pathogenic Root Infecting Fungi pp. 294. London, Cambridge University Press.

Hansford, C.G. (1933). Annual Report of the Mycologist, pp. 55 - 56. In: Annual Rept. Dept. of Agric., Uganda, for the year ended 31st December, 1932 (Part II).

Hansford, C.G. (1934). Annual Report of the Mycologist, pp. 48 - 51. In: Annual Rept. Dept. of Agric., Uganda, for the year ended 31st December, 1933 (Part II).

Jackson, R.M. (1965). Antibiosis and fungistasis of soil microorganisms. pp. 363 - 373. In Baker, K.F. and Snyder, W.C. (Eds). Ecology of Soil Borne Plant Pathogens. London, John Murray

Jenkins, A.E. (1930). A scab disease of Lima beans in Cuba and Porto Rico. Plant Disease Reporter, 9 (11): 96 - 97.

Jenkins, A.E. (1938). Further studies of Lima bean scab. Phytopathology 23 (8): 662 - 666.

Jenkins, A.E. (1936). Present generic status of the citrus scab organism. Phytopathology 26 (I): 68 - 70.

Jenkins, A.E. and Whitncomb, A.A. (1936). Plant disease caused by fungus belonging to the genera Elsinoe and Sphaceloma. Rodriguesia 2: 305 - 315.

Jenkins, A.E. and Viegas, A.P. (1943). Stem and foliar scab of sweet potato. J. Wash. Acad. Sci 33 (8): 244 - 249.

Jenkins, A.E. and Whitncomb, A.A. (1960). Notes on the Spot Anthracnose, X-Spot anthracnose of sugar cane. Biologico 26(6) 111 - 113.

Klages, K.H.W. (1954). Ecological Crop Geography pp. 615. (5th ed.). London, MacMillan.

Kurata, H. and Kuribayashi, K. (1954) Soybean scab caused by Sphaceloma glycines. Ann. Plant Pathology Soc. Japan 18(3-4):119-121.

Marchionatto, J.B. (1934). Argentine Republic: Plant diseases observed in the country. International Bulletin of Plant Protection, 8(11): 241.

McCubbin, W.A. (1933). The Lima bean scab situation. Journ. Econ. Entomology 26(3): 625 - 630.

Nelson, R.R. (1973). The meaning of disease resistance in plants, pp. 13 - 25. In: Nelson R.R. (ed.) Breeding Plants For Disease Resistance. Pennsylvania State, University Press.

Nelson, R.R. (1978). Genetics of horizontal resistance to plant diseases. Annual Review of Phytopathology 16: 359 - 378.

Ojomo, O.A. (1967). Cowpea: Production and Research in Western State of Nigeria. Min. of Agric. and National Res., Research Division, Moor Plantation, Ibadan. pp. 30.

Okpala, R.O. (1981). Host Range and Survival of Collectrotrichum capsici and its Interaction with Cowpea Lines in Northern Nigeria. M.Sc. Thesis, Ahmadu Bello University, Zaria. pp. 148.

Oyenuga, V.A. (1959). Nigerian Feeding Stuffs: Their Composition And Nutritive Value. (2nd ed.) Ibadan University Press.

Purseglove, J.W. (1974) Tropical Crops: Dicotyledons. London, Longman. pp. 719.

Kochie, K.O. and Roberts, L.M. (1974). Grain Legumes in the Lowland and humid tropics. Advance in Agronomy, 26: 1 - 132.

Kochie, K.O. and Rawal, K.M. (1976). Integrated Approaches to Improving Cowpeas Vigna unguiculate (L) walp. Ibadan: International Institute of Tropical Agriculture. pp. 36.

Koheja, A.K. (1976). Assessment of losses caused by insect pests to cowpeas in northern Nigeria. PANS 22 (2): 229 - 233.

Koheja, A.K. and Apeji, S.A. (1979). Insect pests management in cowpea. Nigerian Journal of Entomology, 3 (2): 59 - 82.

Singh, S.R. and Allen, D.J. (1979). Cowpea Pests and Disease. Ibadan: International Institute for Tropical Agriculture. pp. 113.

Staples, R.R. (1958). Reports of the Dept. of Research and Specialists Services (Southern Rhodesia) for the year ended 30th September, 1957. Report Ministry of Agric., Rhodesia Nyasaland, 1956 - 57. Pp. 7 - 86.

Steele, W.M. (1965). The Cowpea, Vigna unguiculata (L) walp, the bambara nut, Voandzia subterranea L(DC) Lima bean, Phaseolus lunatus L.

in Northern Nigeria. Paper read at FAO Technical Meeting on Improvement of Vegetable and Grain Legume Production in Africa, Dakar 18 - 24th January, 1965.

Van der Plank, J.E. (1963). Plant Diseases: Epidemics and Control. London, Academic Press. pp. 349.

Wallace, G.B. and Wallace, M.M. (1953). Tanzania fungus list: Recent records No. 18. Mycol. Circ. Dept. of Agric., Tanzania 36: 7.

Williams, R.J. (1975). Disease of Cowpea (Vigna unguiculata (L.) Walp. in Nigeria PANS, 21: 253 - 267.

VIII APPENDIX

Appendix 1: Regression Analysis of Variance for:

Regression of Stem Scab severity on foliar scab severity

Source of Variation	DF	SS	MS	F
Regression	1	2417	2416.66	1632.88**
Error	854	1262	1.477	
Total	855	3679		

Coefficient of Variability = 65.7%

Correlation coefficient = + 0.81**

Appendix 2: Regression Analysis of Variance for:

Regression of Pedundle Scab Severity on Stem Scab Severity

Source of Variation	DF	SS	MS	F
Regression	1	1898	1898.20	294.75**
Error	854	5496	6.44	
Total	855	7394		

Coefficient of Variability = 25.6%

Correlation coefficient = + 0.51**

Appendix 3: Regression Analysis of Variance for:

Regression of flowering cushion scab severity on peduncle scab severity

Source of Variation	DF	SS	MS	F
Regression	1	8962	8962.15	4092.31**
Error	854	1871	2.191	
Total	855	10833		

Coefficient of Variability = 82.79
Correlation coefficient = +0.91**

Regression on pod scab severity on peduncle scab severity

Source of Variation	DF	SS	MS	F
Regression	1	8527	8526.68	1303.77**
Error	854	5587	6.54	
Total	855	14114		

Coefficient of Variability = 60.49
Correlation coefficient = + 0.78**

Appendix 4: Regression Analysis of Variance for:

Regression of pod scab severity on flowering cushion scab severity

Source of Variation	DF	SS	MS	F
Regression	1	10531	10531.29	2513.43**
Error	854	3582	4.19	
Total	855	14113		

Coefficient of Variability = 74.69
Correlation coefficient = + 0.86 **

Appendix 5: Regression Analysis of Variance for:

a. Regression of stem scab incidence on foliar scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	620544.34	620544.34	1335.35**
Error	854	396856.77	464.70	
Total	855	1017401.11		

Coefficient of Variability = 33.7%
Correlation coefficient = +0.78 **

b. Regression of pe dundle scab incidence on foliar scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	787759.92	787759.92	924.28**
Error	854	727859.15	852.29	
Total	855	1515619.07		

Coefficient of Variability = 46.6%
Correlation coefficient = + 0.72**

c. Regresion of flowering cushion scab incidence on foliar scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	771951.07	771951.07	896.17**
Error	854	735628.82	861.39	
Total	855	1507579.89		

Coefficient of variability = 47%
Correlation coefficient = . 0.71**

d. Regression of pod scab incidence on foliar scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	615544.27	615544.26	516.11**
Error	854	1018532.26	1192.66	

Coefficient of Variability = 64.1%
Correlation coefficient = + 0.61**

Appendix 6: Regression Analysis of Variance for:

a. Regression of peduncle scab incidence on stem scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	896880.32	896880.32	1237.89**
Error	854	618738.76	724.52	
Total	855	1515619.08		

Coefficient of variability = 43.0%
Correlation coefficient = 0.77**

b. Regression of flowering cushion scab incidence on stem scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	882339.40	882339.40	1205.16**
Error	854	625240.48	732.13	
Total	855			

Coefficient of variability = 43.3%
Correlation coefficient = + 0.76

c. Regression of pod scab incidence on stem scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	787715.95	787715.95	794.83**
Error	854	846360.57	991.05	
Total	855	1634076.52		

Coefficient of Variability = 58.4%
Correlation coefficient = + 0.69 **

Appendix 7: Regression Analysis of Variance for:

a. Regression of flowering cushion scab incidence on peduncle scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	1464652.39	1464652.39	29137.81**
Error	854	42927.49	50.27	
Total	855	1507579.88		

Coefficient of variability = 11.3%
Correlation coefficient = + 0.99**

b. Regression of pod scab incidence on peduncle scab incidence

Source of Variations	DF	SS	MS	F
Regression	1	1404283.42	1404283.42	5218.86**
Error	854	229793.10	269.08	

Coefficient of variability = 30.4%
Correlation of coefficient = + 0.93**

Appendix 8: Regression Analysis of Variance for:

Regression of pod scab incidence on flowering cushion incidence

Source of Variation	DF	SS	MS	F
Regression	1	1299658.21	1299658.21	5338.11**
Error	854	207921.67	243.47	

Coefficient of variability = 25.0%
Correlation coefficient = +0.93**

Appendix 9: Regression Analysis Variance for:

a. Regression of severity of stem scab on foliar scab severity

Source of Variation	DF	SS	MS	F
Regression	1	3829.26	3829.26	1901.63**
Error	1486	2992.32	2.01	
Total	1487	6821.58		

Coefficient of variability = 23.2%
Correlation coefficient = ± 0.75**

b. Regression of severity of peduncle scab on foliar scab severity

Source of Variation	DF	SS	MS	F
Regression	1	3336.49	3336.49	943.50 **
Error	1486	5254.92	3.54	
Total	1487	8591.41		

Coefficient of variability = 30.1%
Correlation coefficient = ± 0.62**

c. Regression of severity of flowering cushion scab on foliar scab severity

Source of Variation	DF	SS	MS	F
Regression	1	3691.74	3691.74	761.90**
Error	1486	7200.30	4.85	
Total	1487	10892.04		

Coefficient of variability = 38.0%
Correlation coefficient = +, 0.58 **

Appendix 10: Regression Analysis of Variance for:

a. Regression of severity of peduncle scab on stem scab severity

Source of Variation	DF	SS	MS	F
Regression	1	3551.30	3551.30	1047.05**
Error	1486	5040.12	3.39	
Total	1487	8591.42		

Coefficient of variability = 29.5%
Correlation coefficient = + 0.64 **

b. Regression of severity of flowering cushion scab on stem scab severity

Source of Variation	DF	SS	MS	F
Regression	1	3780.68	3780.68	790.02**
Error	1486	7111.36	4.79	
Total	1487	10892.04		

Coefficient of variability = 37.8%
Correlation coefficient + 0.59 **

Appendix 11: Regression Analysis of Variance for:

a. Regression of severity of flowering cushion scab on peduncle scab severity

Sources of Variation	DF	SS	MS	F
Regression	1	7423.52	7423.52	3186.42**
Error	1486	3468.52	2.33	
Total	1487	10892.04		

Coefficient of variability = 26.4%
Correlation coefficient = +0.82 **

Appendix 12: Regression Analysis of Variance for:

a. Regression of stem scab incidence on foliar scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	427544.21	427544.21	1801.22**
Error	1486	352721.62	237.36	
Total	1487	780265.83		

Coefficient of variability = 17.1%
Correlation coefficient = + 0.74**

b. Regression of peduncle scab incidence on foliar scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	417868.57	417868.57	561.04**
Error	1486	1106786.01	744.80	
Total	1487	1524654.58		

Coefficient of Variability = 34.0%
Correlation coefficient = +0.52**

Appendix 13: Regression Analysis of Variance for:

a. Regression of peduncle scab incidence on stem scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	496537.40	496537.40	717.68**
Error	1486	1028117.18	691.87	
Total	1487	1524654.58		

Coefficient of variability = 32.7%
Correlation coefficient = + 0.52**

b. Regression of flowering cushion scab incidence on stem scab incidence

Source of Variation	DF	SS	MS	F
Regression	1	466068.64	466068.64	556.92**
Error	1486	1243467.83	836.79	
Total	1487	1709536.47		

Coefficient of Variability = 41.8%
Correlation coefficient = +0.53**

Appendix 14: Regression Analysis of Variance for:

Regression of flowering cushion scab incidence on pudunde scab incidence

Source of Variation	DF	SS	MS	F
Regressionn	1	995529.81	995529.81	2071.91**
Error	1486	714006.67		
Total	1487	1609535.48		

Coefficient of variability = 31.7%
Correlation coefficient = + 0.76**