STUDIES ON BACTERIAL BLIGHT OF SUNFLOWER

(*Helianthus annuus* L.)

IN NIGERIA

BY

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DEPARTMENT OF CROP PROTECTION

FACULTY OF AGRICULTURE

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11.

DECLARATION

I hereby declare that the whole work now submitted as a Thesis for the Master of Science degree (Crop Protection) of Ahmadu Bello University is the result of my investigation. It has not been presented before in any previous application for a higher degree.

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CERTIFICATION

This thesis entitled "Studies on Bacterial Blight of Sunflower (Helianthus annuus L.) in Nigeria" by Oparah, Emmanuel Umunnah meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

TO MY FAMILY

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ABSTRACT

Investigations were conducted to identify the pathogen, determine the level of seed infection by the bacterium, evaluate different seed dressing chemicals and foliar sprays for control of the disease, determine the effect of sowing date on the severity of the disease, screen for resistance to the disease and isolate and identify the causal organism of a stem canker disease of *sunflower*.

The pathogen that induces bacterial blight in Nigeria was isolated and identified as Pseudomonas syringae pv. helianthi. The seeds of eight different cultivars tested showed that the disease is seed borne.

Early sowing (June) and late sowing (August) reduced plant growth and yield without significant effect on disease severity. On the contrary, July-sown crops had better growth and higher yield, though the disease severity score was high, it did not affect plant performance adversely.

Seven seed dressing chemicals and four bactericides were used in the field and in pot respectively. Mancosan, Terrachlor and Bronocot were effective in reducing the disease in the field while Busan and Bronocot reduced the disease in pots. Out of the four fungicidal foliar sprays evaluated in the field only two, Copper oxychloride and Fungaron were able to lower the disease severity.

Eight varieties of sunflower were screened for resistance to bacterial blight. Results showed that no variety was resistant to the disease based on disease severity scores. However, varietal differences existed in terms of response to the disease and plant yield, but there was no correlation between disease severity score and yield.

The identity of the causal organism of stem canker was established. The same pathogen (Pseudomonas syringae pv helianthi) that inducees bacterial blight was also found to be responsible for stem canker of sunflower.

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1 INTRODUCTION

1.1 Botany and origin of Sunflower

Sunflower (Helianthus annuus L.) is a member of the compositae family and a dicotyledonous annual herb. Although believed to be a native of North America (Hill, 1975), sunflower is adapted to both tropical and temperate regions where rainfall is up to 3,500 mm (Weiss, 1966). Sunflower was once used in parks and gardens as ornamental plants in America and Europe. From the 19th Century it spread from Europe to Russia, Africa, India and China (Heiser, 1978).

1.2 World production statistics

As at 1980 the world production of sunflower seed was 13,174,000 metric tons from 12,374,000 ha (Atuk, 1988). The major world producers of sunflower were USSR, Rumania, United States, South and Central America (Anon, 1979).

Sunflower was brought to Nigeria in the early sixties as an oil crop that could possibly be grown on a large scale to supplement the vegetable oils from traditional sources (Ogunremi, 1979).

Though there has been no official record of hectarage in Nigeria, the crop has been cultivated widely in the semi-arid Sudan Savanna zone and is known to be tolerant to drought.

1.3 Economic Importance of Sunflower

The need for another oil seed crop to complement

groundnut and oil palm has motivated research into sunflower production (Yayock et al., 1986). Since the drought of the early seventies which affected most of the West African regions, Nigeria had relinquished her position as third largest producer of groundnut and as world's largest exporter of the crop. Also the recent ban on importation of vegetable oil, has necessitated the need for an alternative oil seed crop. Therefore, sunflower as one of the most important edible oil crops is a potential source of vegetable oil in Nigeria. Sunflower is grown primarily for production of edible oil (cooking and salad) for human consumption. The seeds may be eaten directly since it is known to contain appreciable quantities of protein (13-20%), rich in oil (41-47%) or linoleic acid (Sackston, 1981). Sunflower is also used in shortening. Industrially, it is used in the manufacture of margarine, soaps and paints. The cake is used mainly as livestock feeds but some may be used as fertilizers in crop production. Apart from its industrial and domestic uses the sunflower seed oil is also medicinal. It can also be used as alternative source of fuel for diesel engine (Benvenuli and Vannozzi 1984; Sackston, 1981).

1.4 Pests of Sunflower

Although sunflower is attacked by about 30 species of insect pests, only a few can be regarded as serious pests. The major ones are : the coreid bug (Leptoglossus membranaceous), cotton stainer (Dysdercus spp), some hymnoptera and homoptera including Nysius and Hallododapus

spp. Others are Poophilus costalis, Macropteris and Aphis spp (Misari and Apagu, 1988; Misari and Dike, 1989; Misari, 1990).

1.5 Fungal Diseases of Sunflower

The fungal diseases associated with sunflower in Nigeria include: Alternaria leaf spot which is the wide spread disease caused by Alternaria helianthi (Hanf) Tubaki and Nishihara, leave spots caused by Helminthosporium sp and Cercospora sp, fungal rot and fungal wilt caused by Fusarium spp and Macrophomina phaseolina (Tassi) Goid. Sunflower has also been reported to be attacked by Puccinia helianthi Schiv causing leaf spot. Verticillium dahliae Kleb, inducing wilt disease and Sclerotinia sclerotium (Lib) de Bary which causes head rot (Ado, 1988; Okoli et al., 1989).

1.6 Occurrence of Bacterial Blight in Nigeria

Bacterial blight of sunflower is widespread in the Northern Guinea Savanna zone. The first report of its occurrence was made by Erinle (personal communication) in 1981 at Kadawa farm in Kano State. Since then the disease has been seen in all sunflower fields in the Guinea Savanna. Although the yield loss due to the disease has not been quantified, it would appear from the severity of the disease that it results in crop loss and will be a disease of potential importance in the 90s. Although much has been done on the agronomy of sunflower production in Nigeria comparatively much less has been done on the

associated diseases so far. There is therefore the need to study the associated diseases of this crop and if the potential of this crop as oil crop is not to be threatened.

In Nigeria, the list of work done on bacterial blight diseases include those of cassava, cotton, cowpea, jute, rice, sesame, soyabean and tomato. Apart from bacterial blight of soyabean that is induced by Pseudomonas spp, all other bacterial blights are induced by Xanthomonas spp (Erinle, 1981).

1.7 Objectives of the Research

The following are the main objectives of this research:

1. Isolation and characterization of the causal organism of bacterial blight of sunflower.
2. Investigation into the seed borne nature of the disease.
3. Preliminary investigation into the effect of various sowing dates on the severity of the disease.
4. Investigation into the effect of seed dressing chemicals as well as foliar chemical sprays on control of the disease.
5. Screening for resistance to bacterial blight disease; and
6. Isolation and characterization of the causal organism of stem canker of sunflower.

2 LITERATURE REVIEW

2.1 DISEASES OF SUNFLOWER

Sunflower (Helianthus annuus L.), an important oil seed crop in many parts of the world, is attacked by a number of diseases. The most important of these are fungal and bacterial diseases.

2.1.1 Fungal Diseases

Rust disease induced by Puccinia helianthi occurs in sunflower fields and severe losses have been reported in many countries of the world (Sackston, 1962; 1981). Verticilliun wilt induced by Verticillium dahliae and V albo - atrum is now world-wide in distribution. The pathogen is both seed borne and soil borne and persistent once introduced (Zimmer and Hoes, 1978). Downy mildew caused by Plasmopara haltstedii (Farl) Berlet et de Toni is reported to be destructive on sunflower crops especially where there is adequate moisture (Zimmer and Hoes 1978). Sclerotium rot of basal stem and head induced by Sclerotium rolfsii, also stem and head rots caused by Botrytis cinerea and Rhizopus spp have been reported (Bailey, 1966; Okoli et al., 1991; Sackston, 1981).

Charcoal rot is induced by Macrophomina phaseolina and causes premature ripening which results in small heads, poorly filled seeds and reduced yield. It is one of the important diseases affecting sunflower crop world-wide and reduces yield by 20-30% (Tikhonov et al., 1976; Sackston, 1981).



Plate 1

Diseased Sunflower plants at harvest showing a combination of Bacterial and Alternaria Blights in the field

Fungal leaf-spots constitute one of the major groups of diseases of sunflower. Fungi that induce leaf-spots include Septoria helianthi and Alternaria helianthi. Alternaria leaf-spot was first reported in 1969 in Uganda (Anukumar et al., 1974); since then, it has been found to be important in all sunflower-growing areas of the World causing severe stem, foliar and head spotting diseases and thus appears to be most threatening (Anukumar et al., 1974, Herr and Lipps, 1981; Shane et al., 1981). In Nigeria for instance Alternaria leaf-spot caused by A. helianthi is considered as an important fungal disease in the northern Guinea Savanna (Okoli et al., 1989: Emechebe, 1980).

2.1.2 Bacterial Diseases

Bacterial diseases though not as numerous as fungal diseases have been shown to be as important on sunflower crop. Green et al., (1984) reported attacks by Erwinia carotovora var atroseptica causing the Erwinia stalk rot which is characterized by rapid plant wilting and leaf destruction distal to the infection point. They also reported that Agrobacterium tumefaciens induced crown gall which inhibited normal inflorescence development. Pseudomonas solanacearum caused a characteristic wilt and pith discolouration in affected sunflower plants.

Gulya et al. (1982) and Styer and Durbin (1982) implicated P. syringae pv. tagetis as the pathogen causing apical chlorosis of sunflower. They also found that infected seed served as the primary source of inoculum.



Plate 2

Typical symptoms of bacterial blight in the field

2.2 Distribution and identity of Bacterial Blight Pathogen World wide

Bacterial blight of sunflower has been reported in Canada, Mexico, Brazil (Kimura et al., 1974, Robbs et al., 1981), United States of America (Hellmers, 1955; Styer et al., 1980), Canada (Piening, 1976), Japan (Kawamura, 1934), Australia (Trimboli et al. 1978), Europe (Arsenijevic and Masirevic, 1989; Duran and Sobrino, 1987).

The first report of bacterial blight of sunflower was made by Kawamura (1934). He identified the pathogen as Pseudomonas helianthi. Piening (1976) reported the occurrence of bacterial blight of sunflower in Canada and the causal organism was identified as P. syringae pv helianthi. However, Robbs and Almeira (1981) identified two different organisms; one of which was P. cichorii and the other as P. syringae pv. tagetis. Styer et al., (1980) and Gulya et al., (1982) named the pathogen that induces bacterial blight as Pseudomonas syringae pv. tagetis. In Spain (Duran and Sobrino, 1987) and in Yugoslavia (Arsenijevic and Masirevic 1989) the incitant of the disease is reported to be P. syringae pv helianthi.

2.3 Symptoms of Bacterial blight

The primary symptom of bacterial blight of sunflower resembles those of other bacterial blights of plants (Erinle, 1981). It starts as water soaked spots on the lower surface of the leaves of young seedlings; this

further develops into angular brown to black spot (about 1-3 mm) on the plants. The lesions sometimes enlarge and coalesce to form irregular areas of dead tissues. Lesions also occur on petioles, stems and heads (Piening, 1976; Arsenijevic, and Masirevic, 1989). If the disease attacks at germination stage the cotyledons are damaged and the seedlings die off. In older plants, the leaf lamina becomes distorted and rolls inwards (plates), extensive yellowing around lesions occur. There is tendency for the affected leaves to tear off especially during rainstorms. Completely killed leaves may still remain attached to the plant (Duran and Sobrino, 1987).

2.4 Characteristics of the Pathogen

2.4.1. Cultural and Biochemical Characteristics

The bacterium forms large white, glistening colonies on nutrient sucrose agar and a water soluble, green fluorescent pigment on King's medium B (Pseudomonas F agar (DIFCO)) (Lelliot, et al., 1966). It is a Gram negative rod, oxidase negative, able to induce a hypersensitive reaction in tobacco, negative for soft rot of potato and catalase positive, nonpathogenic to either bean or peach. Based on these characteristics the pathogen was identified as Pseudomonas syringae pv. helianthi (Kawamura, 1934; Hellmers, 1955; Duran and Sorbrino, 1987; Asenijevic and Masirevic, 1989).

2.4.2 Seed Transmission

Gulya et al. (1982) obtained up to 63% seed transmission from bacterial blight-infected sunflower. Other workers (Styer and Durbin, 1982, Piening, 1976) also reported seed transmission but did not indicate the level.

2.4.3 Host Range Test

Work done by Styer and Durbin (1982) showed that Pseudomonas syringae pv tagetis can attack sunflower as well as the natural host marigold (Tagetes erecta). Robbs and Almeira (1981) showed that P. s. cichorii and P. syringae pv helianthi can attack sunflower. However, Robbs (1990 personal communication) indicated one distinguishing feature of P. syringae pv. helianthi; its inability to attack any other host other than sunflower while P. cichorii can attack both sunflower and Cichorii and P. syringae pv tagetis attacks both sunflower and marigold.

2.4.4 Resistance to Bacterial Blight

All the cultivars tested for resistance to bacterial blight were susceptible, though a few showed some degrees of resistance in the glasshouse, but not in the field, (Gulya, et al., 1982).



Plate 3

Diseased head, stem and leaves from which the pathogen that induces bacterial blight was isolated

3 ISOLATION, IDENTIFICATION OF THE PATHOGEN AND DETERMINATION OF THE SEED BORNE NATURE OF THE DISEASE

3.1 ISOLATION AND IDENTIFICATION OF THE PATHOGEN.

3.1.1 Introduction

It is necessary to isolate and characterize the causal organism of bacterial blight of sunflower in Nigeria as there seems to be a controversy regarding the causal organism in some countries where the disease had earlier been reported. In Brazil, it was reported that bacterial blight of sunflower is caused by Pseudomonas cichorii (Robbs and Almeira 1981). In the United States of America, Styer and Durbin, (1982) and Gulya et al. (1982) reported that the disease is induced by P. syringae pv tagetis. In Europe and Canada many workers reported that the same disease is incited by P. syringae pv helianthi (Piening 1976, Duran and Sobrino, 1987, Arsenijevic and Masirevic, 1989). In view of the above controversy, the present investigation aims at establishing the causal agent in Nigeria in order to pave the way for further research especially towards control of the disease.

3.1.2 Materials and Methods

3.1.2.1 Isolation

The standard bacteriological technique of dilution plating (Bradbury, 1970) was used in the isolation of the bacterium from diseased tissue. Small pieces of the diseased leaf, petiole or stem was cut from the advancing margin of the lesion with a sterile scapel. The tissue was washed thoroughly in two exchanges of sterile distilled water and placed in a sterile Petri-dish with a drop of sterile water, teased apart with two sterile needles and allowed to stay for 15 minutes, after which the suspension was examined microscopically to detect bacterial cells released from the tissues. A loopful of the suspension was then streaked on an appropriate medium, e.g. Nutrient agar, sucrose peptone agar (SPA) or King's medium B. The streaked media were placed in an incubator with Petri-dish placed upside down and the temperature maintained at 27°C (±2°C) for a period of 24 - 48h. A pure culture was obtained by sub-culturing two or more times well separated single colonies that were more in abundance.

3.1.2.2 Biochemical Tests

Preliminary investigation into the characteristics and taxonomic position of the isolated pathogen was based on some physiological and cultural tests as contained in the standard laboratory guide (Schaad, 1980). These included Gram-staining, oxidase and catalase tests, indole and

arginine-dehydrolase tests, carbohydrate utilization and florescence tests.

3.1.2.4 Hypersenstive Reaction (H.R)

Hypersentivity test was one of the tests done to prove the pathogenicity of the pathogen isolated. The method employed was that of Klement (1975). The inoculum suspension from a 24h old culture containing about 10^7 - 10^8 colony forming unit per ml (cfu/ml) was injected into the lower surface of a leaf of tobacco seedling (Nicotianum tabacum var White Burley). The effect was observed within 24h at 25-28°C in the laboratory.

3.1.2.5 Pathogenicity tests

Inoculation of young sunflower seedlings was carried out using 4-8 week-old potted seedlings in the laboratory by spraying the bacterial suspension from a 24 hour old culture with a spray gun or an atomizer. The control was also sprayed but with sterile distilled water. The plants were examined regularly for up to two weeks after inoculation.

3.1.2.6 Host Range tests

Various workers have reported the pathogen, Pseudomonas syringae pv. helianthi to be host-specific (Duran and Sorbino, 1987; Asenijecic and Masirevic, 1989) while in Brazil P. syringae pv. tagetis and P.s. cichorii are pathogens of surflower and marigold and cichorii respectively. Thus the inability of P. syringae pv.

helianthi to attack any other host other than sunflower is an important taxonomic feature. In this investigation the pathogen of sunflower bacterial blight was inoculated into Phaseolus bean, tomato and marigold seedlings to test the host range status. The method used was the same as in pathogenicity test outlined above.



Plate 4: Hypersenstive Reaction (arrowed) induced by the pathogen

3.1.2.7 Incubation of the inoculated seedlings

The seedlings were partially covered with transparent polythene bags for 48h in the laboratory in order to increase humidity, while at the same time allowing for adequate aeration. Symptoms and disease incidence were recorded on weekly basis for a period of 8-10 weeks after inoculations.

3.1.2.8 Identification of the Re-isolated Pathogen

Identification of the pathogen re-isolated from the inoculated seedlings was based on two methods: biochemical and cultural tests and by sending cultures to the International Mycological Institute IMI, Kew, London.

3.1.3 RESULTS AND DISCUSSION

Bacterial growth was observed during 2 days of incubation after streaking nutrient media with suspension from infected tissue. Colonies on Sucrose Peptone Agar (SPA) or Nutrient agar (NA) were creamy, slimy, convex and glistering. Some biochemical tests performed showed that the pathogen of sunflower is gram-negative and oxidase negative. The pathogen is also able to produce acid from various carbon sources.

When the bacterial suspension was injected into tobacco leaves, it induced hypersensitive reaction in less than 24h (Plate 4). When plated on King's medium B, the pathogen formed a mass of green pigments which fluoresced under ultra violet light.



Plate 5A: Control experiment



Plate 5B: 7 days after inoculatior



Plate 5C: 21 days after inoculation

Plate 5: Typical bacterial blight symptoms induced by the pathogen in the laboratory.

This result is similar to those obtained by other workers (Kimura et al.1974; Duran and Sorbrino, 1987; Arsenijevic and Masirevic, 1989).

The pathogen was also able to induce typical bacterial blight symptoms on young sunflower seedlings after 7 days, and by 21 days after inoculation the lesions had coalesced leading to advanced necrosis and distortion of the inoculated leaves (plates 5A - 5C). However, when the pathogen was inoculated on bean, tomato or (Marigold) Tagetes spp seedlings it was unable to induce any symptoms showing that the pathogen is host specific. This agrees with results obtained by some other workers (Kawamura, 1934; Hellmers, 1955; Duran and Sorbrino, 1987; Arsenijevic and Maserevic, 1989).

When the pathogen was re-isolated from the inoculated seedlings, it produced colonies similar to the original culture. As a further proof of pathogenicity of the organism the re-inoculated seedlings also showed typical blight symptoms after three weeks.

The identification of the pathogen was established by the International Mycological Institue (IMI - 350936) although not up to the pathovar level. But based on all the identification and charaterization results obtained which were similar to those reported by other workers in other countries the pathogen was proven to be Pseudomonas syringae pv helianthi (Kawamura, 1934; Hellmers, 1955; Lelliot et al., 1966, Kimura et al., 1974; Duran and Sorbrino 1987; Arsenijevic and Maserevic, 1989).

3.2 DETERMINATION OF THE SEED BORNE NATURE OF THE PATHOGEN

3.2.1 Introduction

Some workers reported that the bacterial blight pathogen of sunflower is seed borne and thus serves as the primary source of inoculum (Gulya et al., 1982; Styer and Durbin, 1982).

3.2.2 Materials and Methods

This investigation was carried out over 1990 and 1991 growing seasons. One hundred seeds from each of the eight varieties were surface sterilized by immersing them in 0.5% aqueous solution of sodium hypochlorite for three minutes, and rinsed in three exchanges in sterile distilled water. The seeds were filter dried and twenty seeds were asceptically removed and plated on SPA so that there were five plates for each variety. The seeds were examined for infection after 24 - 48 hours. The percentage seed infection was recorded.

For identification of the pathogen(s) responsible for the seed infection, the bacteria from the infected seeds were purified and used to inoculate young sunflower seedlings as outlined in the pathogenicity test earlier. Symptoms on the head, stem and leaves were compared with those found in the field.



Plate 6: Typical bacterial blight symptom induced by pathogen isolated from infected seeds (similar to those of leaf)

3.2.3 RESULTS AND DISCUSSION

Table 3.1 Incidence of bacterial infection on sunflower seed for 1990/91 wet seasons.

Variety	Percentage seed infection	
	1990	1991
Cherneanka	47	50
Isaanka	47	26
Saturn	57	60
VNIIMK8883	36	46
Smena	60	50
Cakinskij 268	49	53
Funtua	53	55
Record	54	50

The result in Table 3.1 showed that all the varieties were infected with the bacterial blight pathogen. The incidence ranged from 36-60% and 26-60% for 1990 and 1991 growing seasons respectively. Varieties Smena and Saturn had the highest percentage seed infection in 1990 and 1991 respectively while UNIIMK and Isaanka had the lowest for the two years.

When the colonies were subcultured, the bacterial growths observed were similar to those obtained from the field. Furthermore, pathogenicity test proved that the pathogen was the same as that isolated from the field. Furthermore, identification carried out through biochemical tests conducted confirmed that the pathogen was the same as those that induce bacterial blight in the field. This result corresponds with the work done earlier by other workers showing that the disease is seed borne (Gulya et al., 1982; Styer and Durbin, 1982).

4 EFFECT OF SOWING DATES ON SEVERITY OF THE DISEASE

4.1 Introduction

The effect of sowing date on the incidence and severity of bacterial blight of sunflower was investigated in order to ascertain the optimum date for sowing of the seeds to escape or reduce the incidence and severity of the disease. The effect of various dates on the yield and yield components of the crop were also assessed both in field and in pots experiments.

4.2 Materials and Methods

4.2.1 Pot Trials

Pot experiments were carried out to assess the effect of four different sowing dates on the incidence and severity of the disease. This experiment was conducted during the 1990 and 1991 wet seasons.

During the 1990 growing season the four sowing dates were as follows: 11th and 25th June, 9th and 23rd July designated as D_1, D_2, D_3 and D_4 respectively.
During the 1991 growing season the sowing dates were as follows: 25th June, 9th July, 23rd July and 6th August designated as D_1, D_2, D_3 and D_4 respectively.

The experiments were carried out in clay pots containing heat sterilized soil supplemented with single super phosphate and calcium nitrate fertilizers. The experiment was a Randomized complete block design with three replicates.

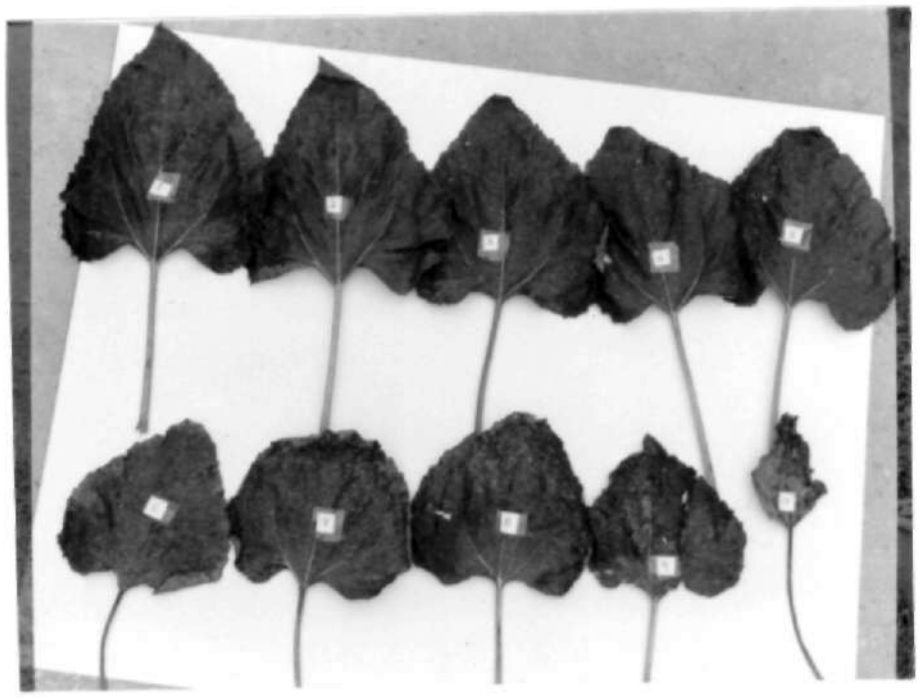

Plate 7: Visual display of the scale (1 - 10) used in assessing the severity of the disease.

The sunflower (cv. Isaanka) seeds were sown at the rate of five per pot. The seedlings were thinned down to three per pot two weeks after germination.

The disease incidence was recorded within the first 3-4 weeks after germination and thereafter at forth nightly intervals. The disease was assessed using scale of 1-10, a modified scale of Bird and Hadley (1958) as follows:

1. No symptoms on either side of the leaf and petiole.
2. Few small, necrotic and angular lesions barely visible on upper surface but readily visible on lower surface; no lesion on petiole.
3. Large number of small necrotic lesions covering about 50% of leaf area, no coalescence; few small scattered lesions on petiole.
4. Entire leaf surface covered mostly by small lesions but lesions begining to coalesce especially towards the tip of the lamina; few scattered lesions on petiole.
5. Entire leaf surface covered by lesions many of which have coalesced; yellowing around lesions, few scattered lesions on the petioles.
6. Entire leaf surface covered by lesions with coalescence in about 33% of area affected; few lesions on petiole and some of them about 0.5cm long.
7. Similar to above but coalesced area more extensive and darker on both lamina and petiole, leaf becoming distorted as a result of concentration of advanced necrosis towards the tip of lamina.

8. Leaf lamina badly necrosed and appears dark with area of dead tissue end rolled downwards; extensive yellowing around lesions; petioles carry lesions.
9. About half of the leaf lamina dead and appear very dark, distorted and surrounding area chlorotic; tendency for leaf to tear; petioles may or may not have prominent lesions.
10. Leaf completely killed but may remain attached to the plant.

Other parameters used in the assessment of the effect of the four sowing dates on the severity of the disease include measurement of plant height, head diameter, head weight and seed weight at harvest for the 1990 and 1991 growing seasons.

4.2.2 Field Trials

A field experiment was also carried out to test the effect of various sowing dates on the incidence and severity of bacterial blight disease of sunflower during the 1990 and 1991 wet seasons. The trial was also laid out in a Randomized complete block design with 3 replications The field was divided into 12 plots each consisting of 6 ridges, 6 metres long and 0.75 meters apart with a spacing of 25cm within rows.

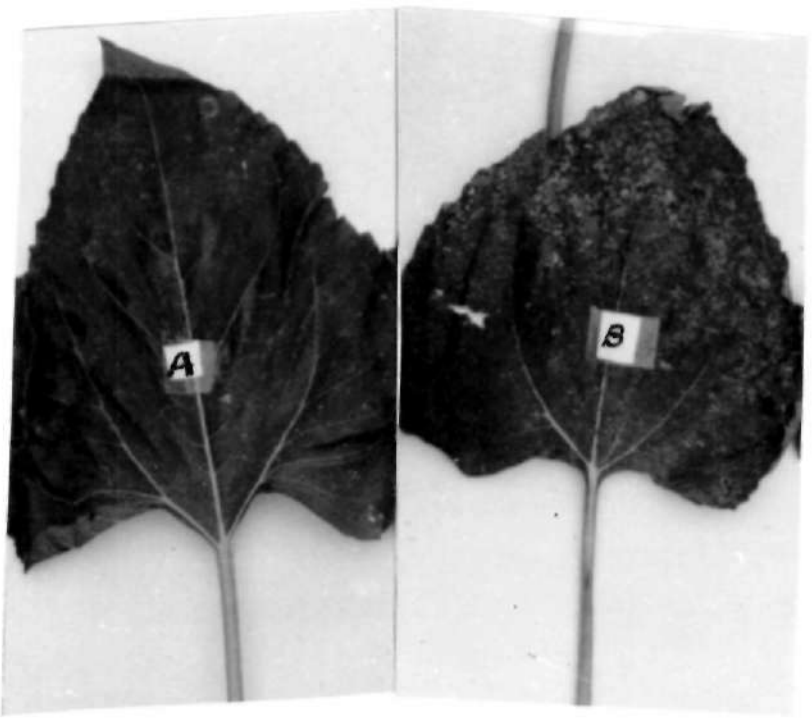

Plate 8 A: Healthy leaf B: Infected leaf

The four sowing dates for both 1990 and 1991 wet seasons were the same as follows; 25th June as D_1, 9th July as D_2, 23th July as D_3 and 6th August as D_4.

The variety of seeds used were the same as those used in the pot trial (Isaanka) and were planted five per hole and later thinned down to two per stand two weeks after germination. To support the growth of the plants, there was NPK fertilizer application, at ratio of 100.50.30 so that the field received 225 kg/ha.

The first disease severity score was recorded within the first three to four weeks after seedling emergence and subsequently at weekly intervals. The method of disease assessent was as indicated in the pot trial i.e. using a scale 1-10. However, in the field, sixty plants were randomly selected from the net-plots for scoring. At the time of the assessment the first four leaves from the youngest open foliage leaf were tagged on each of the selected plants.

At harvest records of yield and yield attributes were obtained from the selected plants and net plots by recording the plant height, head diameter, head weight, seed weight per plot and weight of 1000 seeds. All data collected were analysed statistically and the treatment means were separated using either the Duncan's Multiple Range Test (DMRT) or the Least Significant Difference (LSD).

4.3 RESULTS AND DISCUSSION

4.3.1 Pot Trials

The effect of the different sowing dates on severity of bacterial blight of sunflower obtained during the 1990 and 1991 pot trials is shown in Tables 4.1 and 4.2 along with the yield data at harvest.

The second sowing date (D_2) planted late June 1990 had the highest mean disease severity of 3.16. It was, however, not significantly different from those of D_1 D_3 and D_4. In 1991 the third sowing date (D_3) planted late July had the highest disease severity score but was not stastically different from D_1 and D_2 though highly significantly different from D_4 which was planted early August.

In 1990 the rainfall was heavier than in 1991, the total amount of rainfall being 887.70mm and 506.20mm for 1990 and 1991 respectively (Table 4.3). Although, the rainy season began early in 1991 there was a slight break in early June which delayed sowing till the end of the month. In contrast, however, the rainfall pattern in 1990 made early June planting possible.

From the 1990 investigation it was found that crops planted late June and early July, had higher disease severity score than plants sowed early June or early August. This could be explained by the fact that rainfall was at the peak at August so that the crop was heavily attacked by the disease prior to maturity.

Early August-sown crops (D_4) for 1991 and late July sown

Table 4.1 Effect of sowing Date on the severity of Bacterial blight of sunflower and plant parameters in the 1990 Pot Trial.

Sowing Date	Disease Score	Plant Height (m)	Head Diameter (cm)	Head weight (g)	Seed weight (g)	1000 seed weight (g)
11th June	3.00	1.33^{b}	17.80^{b}	34.48^{c}	4.60^{b}	52.00
25th June	3.16	1.34^{b}	19.40^{ab}	45.77^{b}	6.00^{a}	53.00
9th July	3.04	1.56^{a}	21.36^{a}	57.10^{a}	7.36^{a}	56.49
23th July	3.01	1.27^{b}	14.87^{c}	32.38^{c}	3.06^{b}	49.70
LSD (P=0.05)	N.S	0.189*	1.910**	2.110**	0.918**	N.S

Legend: Values followed by the same superscripts are not significantly different (p=0.05 using DMRT)
N.S = Not significant (p = 0.05)
* = significant (p = 0.05)
** = Highly significant (p = 0.01)

Table 4.2 Effect of sowing Date on the severity of Bacterial blight of sunflower and plant parameters in the 1991 Pot Trial.

Sowing Date	Disease Score	Plant Height (m)	Head diameter (cm)	Head weight (g)	Seed weight (g)	1000 seed weight (g)
25th June	3.05^{a}	1.41	17.63^{ab}	51.20^{b}	8.72^{b}	54.17
9th July	3.15^{a}	1.42	18.43^{a}	55.50^{a}	10.72^{a}	53.15^{a}
23rd July	3.32^{a}	1.36	15.92^{2}	42.99^{c}	6.30^{c}	50.30^{b}
6th Aug.	2.45^{b}	1.37	13.62^{c}	33.00^{d}	5.36^{c}	49.13^{b}
LSD (p=0.05)	0.317**	N.S	1.942**	2.55**	1.190**	2.19**

Legend: As in Table 4.1

crops (D_4) for 1990 had the least disease. The crops approached maturity during September when the rains were almost gone so that enviromental conditions did not favour the spread of the disease.

It was found from the comparison of the two years work that the 1990 crops had a higher disease severity score (grand mean of 3.055) than that of 1991 (Grand mean of 2.993). This is because there was a higher rainfall in 1990 (887.70mm) than in 1991 (506.20mm) (Table 4.3).

The growth performance of the crops at the various sowing dates for both 1990 and 1991 was also analysed. For both years crops sown early July (D_3 for 1990 and D_2 for 1991) had the best growth (which was statistically significant from other sowing dates) in relation to plant height, head diameter and head weight.

Yield data followed the same trend as growth perfomance. In relation to seed weight the early July-sown crops had the highest yield (7.36g for 1990 and 10.72g for 1991) which was highly significantly different from others. Although the weight of 1000 seed showed no significant difference in 1990, there was significant difference between late June or early July sown crops and late July or early August-sown crops in 1991.

These results showed that crop yields are better if crops are sown either in late June or early July. Furthermore the results have further established that yield is a complex parameter determined by several factors; nature of plant, disease, environmental conditions, etc. The same observtion was made in studies of bacterial blight of sesame (Akpa, 1985).



Plate 9

1991 Field Trial

D_2 - Second sowing date showing the degree of bacterial blight severity but with increased growth and big heads.

Table 4.3 Weather Records in Samaru During the Field Experimental Periods 1990 and 1991

MONTH	MEAN RAINFALL (MM)		MEAN TEMP. (°C)		SUN-SHINE (HRS)		% RELATIVE HUMIDITY. A.M.		% RELATIVE HUMIDITY. P.M		WIND SPEED (KM)	
	1990	1991	1990	1991	1990	1991	1990	1991	1990	1991	1990	1991
MARCH	-	44.70	25.80	35.20	7.80	7.60	9.10	27.40	9.10	17.70	227.82	140.28
APRIL	-	47.80	30.10	35.40	8.40	8.20	45.90	54.30	23.0	33.40	213.63	195.44
MAY	123.30	243.0	27.20	30.80	7.50	6.40	68.50	76.80	50.50	60.50	221.91	151.58
JUNE	155.70	87.0	25.90	30.10	7.30	6.90	75.80	78.40	60.70	64.30	220.36	165.90
JULY	221.90	189.60	24.20	28.10	6.40	5.70	80.40	80.30	65.50	69.90	167.08	145.75
AUGUST	255.30	32.90	24.20	27.90	6.80	5.00	81.40	84.40	66.60	72.50	112.42	117.20
SEPT.	131.50	51.20	25.10	31.30	7.40	8.10	75.90	72.80	62.20	58.80	107.89	94.58
OCT.	-	28.70	25.70	32.0	8.40	8.50	58.80	66.0	48.80	40.40	90.78	76.91
TOTAL	887.70	506.20	-	-	-	-	-	-	-	-	-	-
MEAN	110.96	63.28	26.03	31.35	7.50	7.05	61.98	67.55	48.30	52.19	170.23	135.96

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4.3.2 Field Trials

The effect of the different sowing dates on severity of bacterial blight of sunflower obtained during the 1990 and 1991 field trials are shown in Tables 4.4 and 4.5. The results showed that sowing date has a significant effect on the disease severity score.

There were significant differences between the means of the disease severity scores of the second sowing (D_2) and the third sowing (D_3) dates. However, there was no

significant difference between the means of first sowing (D_1) and the fourth sowing (D_4) dates.

The result from head diameter in the 1990 wet season showed that the means of the four different sowing dates are not significantly different among themselves. However, in 1991, the means of the four sowing dates were significantly different ($p = 0.05$) with D_2 having the largest head diameter and D_4 having the least.

The mean plant height was also affected by the sowing date. In the 1990 wet season both D_1 and D_2 had the same mean height which was not significantly different from D_3 but was significantly different from D_4. In the 1991 growing season, the mean plant height was also highest with second sowing (D_2) but not statistically differerent from D_1 and D_4 which were not significantly different from each other.

When the mean head weight was analysed statistically, it was found that sowing date had a significant effect on this parameter in the 1990 wet season. The mean head weight at D_2 was highest and was significanlty different from D_3 and D_4 but not from D_1. Similar trend was observed in the 1991 trial. The mean head weight had the highest at D_2 weight followed by D_1, but these are not different statistically but were highly significantly different from D_3 and D_4.

The differences between the four sowing dates in relation to mean seed weight per plant were not significant in the 1990 trial. In the 1991 wet season, however, the differences between the four dates were statistically

significant, the highest mean seed weight was produced by D_2 followed by D_1 though their values were not statistically significant but there were significant difference between D_2 and D_3, and D_4 on one hand and between D_1 and D_4 on the other hand.

The data for the seed weight per plot followed the same pattern as that of seed weight per plant. In 1990 wet season D_2 produced the highest weight followed by D_1 with no significant difference. The result further showed that there were no significant difference between D_2 and D_1 on one hand but D_4 plants significantly yielded less than both D_2 and D_3. Values of seed weight per plot between D_1 and D_4 were, however, not significant statistically. In the 1991 growing season D_2 also produced the highest seed weight per plot with significant difference from the other dates while plants sown on other dates did not differ statistically from each other.

In relation to the weight of 1000 seed there was no significant difference among the sowing dates.

From this investigation, it can be seen that though D_2 had the highest disease severity for the two years trials, this had no significant effect on plant yield as the best yield was produced by plants sown at this date.

The high disease severity of the second sowing date (D_2) could be explained in terms of the total and the distribution of rainfall during the life of the crop (Table 4.3). July - August recorded the highest rainfall for both years compared to other months. This factor favoured the spread and severity of the disease.

It is also clear from this investigation that yield is controlled by many factors besides disease; such factors include soil type, the environmental conditions, nutrient status, pests, nature and variety of the crop. Therefore, the high or reduced yield obtained at each date cannot be attributed to any single factor.

Table 4.4 Effect of sowing date on the severity of bacterial blight of Sunflower; 1990 Field trial

Sowing Date	Disease Score	Head diameter (cm)	Plant height (m)	Head weight (g)	Seed Weight/ plant (g)	Seed-weight/ plot (g)	1000 seed weight (g)
25th June	3.77[b]	17.43	1.41[a]	45.50[ab]	34.84	1137[ab]	52.27
9th July	6.61[a]	17.39	1.41[a]	50.50[a]	41.96	1349[a]	51.62
23rd July	5.84[a]	16.18	1.38[ab]	31.50[b]	25.64	656[b]	48.17
6th August	2.91[b]	14.65	1.36[b]	25.30[b]	23.04	576[c]	49.52
LSD(P=0.05)	0.739	N.S	0.0422*	114.794**	4.647**	4.647**	N.S

Legend: As in Table 4.1

Table 4.5 Effect of sowing date on the severity of Bacterial blight of Sunflower; 1991 Field Trial

Sowing Date	Disease Score	Head diameter	Plant height	Head weight	Seed-weight/ plant	Seed weight/ plot	1000 seed weight
25thJune	3.85[b]	17.91[ab]	1.19[b]	57.50[a]	32.0[ab]	641[b]	56.9[a]
9th July	4.75[a]	20.64[a]	1.56[a]	59.40[a]	34.20[a]	1261[a]	52.0[ab]
23rdJune	4.23[ab]	16.67[b]	1.23[ab]	36.0[b]	19.20[bc]	596[b]	47.0[ab]
6th Aug.	3.29[b]	12.33[c]	1.02[b]	12.90[c]	8.20[c]	215[b]	41.7[b]
LSD(P=0.05)	0.894*	3.472**	0.299*	15.969**	12.104**	500.984*	9.473*

Legend: As in Table 4.1

Statistical analysis of the other yield attributes like head diameter, plant height and head weight produced similar results as the yield. The early July sown crops (D_2) consistently produced the best result in these parameters. Late June sown crops (D_1) usually followed D_2 in terms of performance which was inturn better than late July (D_3) and early August (D_4) sown crops. August sown crops were found consistenly stunted with smaller heads which could be responsible for the reduced yield rather than disease severity as plants sown at this date recorded the least disease score.

From the two years' results, it can be seen that 1990 had higher disease severity than 1991. This could be explained from the fact that although the rainy season began early in 1991, there was a slight break in early June which delayed sowing till the end of the month. In contrast, however, the rainfall pattern in 1990 made early June sowing possible. This promoted greater disease severity than during the following season.

Similarly, the result showed that growth performance and crop yield were better in 1990 than in 1991 wet season. Poor weather condition could also be responsible for the reduced growth and yield of the 1991 wet season.

5 CONTROL OF BACTERIAL BLIGHT OF SUNFLOWER BY CHEMICAL TREATMENT.

5.1 Introduction

In this investigation, different chemical treatments were employed in both pot and field trials to determine the possibility of chemical control of bacterial blight of sunflower. The main chemical treatments tested include seed dressing chemicals and foliar spray.

5.2 MATERIALS AND METHODS

5.2.1 Pot Trials (Seed dressing chemicals)

A small scale trial based on a pot experiment was conducted to test the efficacy of some seed dressing chemicals in controlling bacterial blight of sunflower. The bactericides used as dressing chemicals were Busan, Bronocot, Streptomycin and Terrachlor (see Appendix 20). The trials were conducted during the 1990 and 1991 wet seasons.

Busan, a liquid emusifiable concentrate was used as slurry treatment at the rate of 1.1ml of the product per 300g of seed and streptomycin as 1% solution. Bronocot and Terrachlor are dust formulations and were applied at the rate of 0.2g a.i per kg seed. The control treatment received no chemical dressing.

The trial was a randomized complete block design (RCBD) with three replicates. The seeds (Isaanka) were

planted five per pot containing heat sterilized soil supplemented with Super Phosphate and Calcium Ammonium Nitrate fertilizers. Disease incidence and severity were assessed 4-5 weeks after sowing using a 1-10 disease severity scale. The treatment means were calculated.

Growth performance and yield data were also obtained. All data collected were analysed statistically and the significant differences between the means interpreted by use of the Least significant difference (LSD) or Duncan's Multiple Range Test (DMRT).

5.2.2 Field Trial (Seed dressing chemicals)

During the 1991 growing season a field trial was conducted at Samaru, Zaria using various seed dressing chemicals to evaluate their efficacy for the control of bacterial blight disease of sunflower. Seven dressing chemicals were used as follows: benomyl (Benlate), metaxyl + caboxin + furathiocarb (Apron plus), Streptomycin sulphate, PNCB (Terrachlor), carbendazim + iproidione (Rovral T.S.), mancozeb (Mancosan) and bronopol (Bronocot) (see Appendix 20 for details). Apart from streptomycin, all other chemicals used were dust formulation and were applied at the rate of 2g a.i. per kg of seeds (variety Isaanka) while streptomycin was applied at 1% solution. The seeds were divided into seven batches, each batch received one of the seven chemicals and the eigth batch of seeds which received no chemical treatment and served as the control.

This investigation was conducted only in 1991 wet season and the seed variety used was Isaanka collected

from the IAR 1990 seed harvest (the only variety with enough supply). The seeds were planted 23rd July 1991 and the trial was a Randomized complete block design (RCBD) with three replications. The trial had 24 plots, each consisting of five 6m ridges and 75 cm wide. Each ridge gave a total of about 50 plants at an intra row spacing of 25cm within rows. All treatments were randomly allocated within each replication using Tippet's random numbers.

The seeds were sown five per hole and later thinned down to two seedlings per stand two weeks after seed germination. Disease assessment was conducted 4-5 weeks after sowing. Twenty seedlings from the net plots were randomly selected out of which the first four leaves from the youngest open foliage were tagged for disease severity score based on a scale of 1-10 as outlined in Section 4. Growth performance as part of yield attribute was obtained by recording height of plant, head diameter and head weight per plant (mean of 20 plants), while grain yield was determined by recording seed weight per plant, per plot and 1000 seed weight per plot. All data collected were analysed statistically and their differences separated with the aid of Duncan's Multiple Range Test (DMRT) or Least Significant Difference (LSD).

5.2.3 Effect of Foliar Fungicide Spray on the Severity of Bcterial Blight of Sunflower

Another field trial was conducted during the 1991 wet season to determine the effectiveness of four different

fungicides as foliar sprays for the control of bacterial blight of sunflower. The use of fungicides to control bacterial diseases is justified due to the scarcity of bactericides and also coupled with the fact that some fungicides have been shown to be effective in controlling bacterial diseases (Beer and Sherf, 1975). The chemicals employed in this trial were as follows: Rovral T.S., Copper oxychloride, Copper hydroxide (Fungaron) and Terrachlor. Copper oxychloride and Fungaron are both wettable powders containing 60% and 70% copper respectively. Rovral T.S and Terrachlor are dust formulations based on iprodione and PCNB respectively.

Each fungicide was applied at the rate of 2g a.i. every seven days beginning from the period of infection (about three weeks after seedling emergence), up to 10-14 days before harvest. The fungicides were sprayed using a knapsack (CP15) sprayer with a yellow nozzle. The crops were sprayed until there was a run-off to ensure complete coverage of the leaves.

The field layout was a RCBD with three replications. There were five treatments including four different chemical treatments and an untreated control. Disease severity score was also based on a scale of 1-10. Data yield and yield components were obtained and data statistically analysed as outlined in the seed-dressing chemical trial (Section 5.2.1).

5.3 RESULTS AND DISCUSION

5.3.1 Pot Trials

The results relating to the influence of the four bactericides on disease severity, growth performance and grain yield at harvest are presented in Tables 5.1 and 5.2 for the 1990 and 1991 wet seasons respectively. Generally each of the bactericide achieved a measure of disease control when compared with the untreated control experiment during the 1990 trials. Though their mean values (ranging from 2.18-2.80) had no significant difference from that of the untreated it can be seen that the untreated plants had the highest disease score (2.87). It was found that Busan was more effective than the other three in reducing the disease severity. Terrachlor was next to Busan and was better than Bronocot and Streptomycin which was the least effective during the 1990 trial.

In the 1991 trial, however, Terrachlor was the most effective chemical and was followed by Bronocot, Busan came third this time while Streptomycin was still the least effective and was only slightly better than the control. From the two years results it was found that Busan was the most effective (Tables 5.1 and 5.2). Terrachlor was next, followed by Bronocot and Streptomycin in the third and fourth positions respectively.

Table 5.1 Effect of chemical seed treatment on the severity of Bacterial Blight of Sunflower under pot condition during the 1990 trial.

Chemical Treatment	Disease Score	Plant Height (m)	Head diameter (cm)	Head weight (g)	Seed weight (g)	1000 seed wt
Busan	2.18	1.27	16.43	28.0	18.0	56.70
Bronocot	2.60	1.36	14.17	31.30	20.20	57.0
Streptomycin	2.80	1.31	14.52	20.80	18.30	54.80
Terrachlor	2.49	1.19	14.67	27.40	14.60	53.90
Control	2.87	1.25	14.10	25.10	13.60	54.30
LSD (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S

Table 5.2 Effect of chemical seed treatment on the severity of Bacterial Blight of Sunflower under pot condition during the 1991 trial.

Chemical Treatment	Disease Score	Plant Height (m)	Head diameter (cm	Head weight (g)	Seed weight (g)	1000 seed wt
Busan	2.59	1.23	11.33	29.80	19.80	53.70
Bronocot	2.44	1.31	13.50	28.00	18.70	58.60
Streptomycin	2.80	1.18	10.00	23.50	15.50	49.50
Terrachlor	2.43	1.21	11.67	23.30	15.70	48.30
Control	3.19	1.19	10.93	20.50	13.10	44.90
LSD (p=0.05)	N.S	N.S	N.S	N.S	N.S	N.S



Plate 10

Plants treated with four different bactericides; From left to right: Busan, Bronocot, Terrachor and Streptomycin.

In the control of bacterial blight of cotton, Busan was also found to be the most effective bateriicide (Poswal 1981).

The growth performances of plants from the five different treatments were also compared for both years. Generally, it was found that plants treated with Bronocot had the best growth for the two years trials in terms of plant height, head diameter and weight. The least growth performance was recorded with plants treated with Terrachlor. From these results it does seem that disease severity had no significant effect on growth performance as plants treated with Terrachlor had lowest disease but growth was less than others.

In relation to the effect of the disease severity on yield the results of the five different treatments including the control was compared. Bronocot treated plants had the highest yield in terms of seed weight per plant and 1000 seed weight. This was followed by Busan treated plants for the two years trials. Streptomycin treated plants performed better than Terrachlor treated plants when their two years grain yield were combined. In all the parameters assessed, the untreated plants performed poorest even though the results showed that the differences among the treatments were not statistically significant. It does seem however, that there is some wisdom in the use of seed dressing chemicals. It is also true in this aspect that disease severity can not be directly correlated with yield performance as Terrachlor treated plants consistently performed poorly though with the least disease grade.

5.3.2 FIELD TRIAL (SEED DRESSING CHEMICAL TREATMENTS)

The results of the 1991 field trial are shown in Table 5.3. Out of the seven seed dressing chemicals used, Terrachlor proved most superior by achieving the best control; this was followed by Mancosan and Benlate with mean score of 3.08 and 3.19 respectively. When the values were analysed statistically it was found that the difference between Terrachlor and other treatments (except Mancosan) was highly significant. Apron plus and Rovral T.S had the highest disease severity score of 3.45 and 3.44 respectively and their differences were highly significant from other treatments. In addition when their values were compared with that of the untreated plants, the untreated plants had less disease severity (3.28) than Apron plus and Rovral T.S. It could be that several factors such as pest attack, high or low elevation, water logging and other unaccountable factors combined to lead to poor performance of these two chemicals.

In relation to growth performance as one of the attributes of plant yield, there was no significant difference among the eight treatments. However, plants treated with Benlate had the largest head diameter followed by Rovral T.S, Mancosan and Apron plus trated plants. Bronocot-treated plants gave the smallest heads.

In terms of plant height Rovral T.S. and Bronocot treated plants had the tallest plants. Streptomycin-treated plants had the least plant height. The reduced growth and yellowing of leaves of plants treated with streptomycin could be that the application rate (1%) was

toxic to the plants as the level of phytotoxity of these chemicals to the plant was not evaluated. From the result it can be seen that the untreated plants were taller than plants treated with streptomycin.

When the results of seed weight per plant was carefully analysed there was no significant difference among the treatments. The results showed that the differences among the seed weight per plot were highly significant. Mancosan gave highest seed yield per plot (646.10g) which was not significantly different from that of Terrachlor (596.30g) and Bronocot (586.60g) but was statistically different from that obtained from others. The yields obtained from plants treated with Bronocot (583.60g) was not significantly different from that obtained from Apron plus (568.80g) and Rovral T.S (529.90g) but significant differences existed between them and other treatments. From the same result, it was found that streptomycin treated plots scored the least yield (369.80g). It is important to note that even the control performed better than streptomycin-treated plants.

Regarding seed weight of 1000 seeds, Bronocot and Apron plus performed best but their differences were not statistically significant from others. Streptomycin also had the least seed weight of 1000 seeds.

From the above results, it can be seen that yield is a parameter not controlled by disease alone but by several factors. However, all the plants treated with chemicals had improved yield (apart from streptomycin) when compared with the control (untreated) plants. Thus there seems to

be no correlation between disease severity and grain yield in this investigation. Terrachlor treated plants had the least disease severity score (2.99) and in terms of seed yield per plot terrachlor treated plants came second. However, in case of Mancosan treated plants had less disease severity (3.08) than other chemical (except streptomycin) treated plants and produced the highest grain yield per plot. Apron plus, Rovral T.S and Bronocot resulted in high yield despite high disease severity score. For such treatments their high yields cannot be attributed to less disease but to other factors related to promotion of yield such as environmental conditions, disease tolerance, nutrient status, type of crop and soil nature.

5.3.3 Effect of Foliar Fungicide Sprays on the severity of Bacterial Blight of Sunflower in the Field

The results relating to the effect of the four chemicals used as foliar sprays are presented in Tabe 5.4 for the 1991 planting season. The least disease severity score was attained by plants sprayed with Copper oxychloride with mean of 2.74. This was followed closely by Fungaron (Copper hydroxide) with the mean of 2.78. When their means were compared with those of Rovral T.S (3.13) and Terrachlor (3.53) their differences were highly significant. Terrachlor performed poorly in controlling the disease.

It is significant to note that though Terrachlor proved ineffective as foliar spray it however proved effective as a seed-dressing chemical as was demonstrated earlier under seed dressing trial. On the other hand Rovral T.S performed fairly well as a foliar spray but performed poorly as seed dressing chemical in control of bacterial blight of sunflower. This shows that Rovral T.S can serve as effective foliar spray while Terrachlor could be used as a seed dressing chemical.

The effect of these foliar sprays on growth performance was also determined. Rovral T.S had the highest mean value in relation to head diameter and plant height. This was followed by Copper oxychloride. The analysis of the mean head weight showed that there was no significant difference among all the treatments. However, the highest head weight was recorded by Copper oxychloride

while the least head weight was from untreated plants. The means of seed weight per plant followed the same trend as head weight. Rovral T.S treated plants still performed better than the others while the untreated had the least seed weight per plant. Analysis of seed weight per plot showed that there were highly significant differences among the five treatments. The highest yield was produced by Rovral T.S. treated plants. There was a highly significant difference between Rovral T.S. treated plants and the untreated and between those of Terrachlor treated plants.

From this investigation it can be seen that the most effective chemical in terms of disease control was Copper oxychloride but in terms of yield, however, the most effective is Rovral T.S. In this investigation the efficiency of a chemical is not based on yield alone as yield has been shown to be controlled by complex parameters. Therefore for the control of bacterial blight of sunflower Copper oxychloride and Fungaron are effective as foliar sprays. However, the effectiveness of these foliar sprays and their economics need to be evaluated properly.

Table 5.3 Effect of Chemical seed treatment on the severity of Bacterial Blight of sunflower under field conditions during 1991.

Chemical Treatment	Disease Score	Head Diameter (cm)	Plant Weight (g)	Head Height (m)	Seed Weight (g)	Seed wt /plot (g)	1000 Seed Weight
Benlate	3.19^{bc}	17.53	33.50	1.30	90.70	516.80^{cd}	46.60
Apron Plus	3.45^{a}	16.60	31.10	1.31	77.00	568.80^{bc}	47.90
Streptomycin	3.25^{ab}	15.74	30.20	1.26	62.20	369.80^{e}	43.40
Terrachlor	2.99^{c}	15.59	35.20	1.34	91.70	596.30^{ab}	46.50
Rovral T.S	3.44^{a}	16.73	34.90	1.39	84.30	529.90^{bcd}	44.50
Maconsan	3.08^{bc}	16.67	39.40	1.35	108.90	646.10^{a}	44.70
Bronocot	3.16^{b}	14.93	49.00	1.39	101.00	583.60^{abc}	47.30
Control	3.28^{a}	15.87	30.00	1.39	74.60	493.10^{de}**	44.50
LSD (p=0.05)	0.224	N.S	N.S	N.S	N.S	61.821	N.S

Legend: As in Table 4.1

Table 5.4 Effect of chemical foliar fungicide spray on the severity of Bacterial Blight of Sunflower under field conditions during 1991.

Chemical Treatment	Disease Score	Head Diameter (cm)	Plant Height (m)	Head Weight (g)	Seed wt Plant (g)	Seed wt /Plot (g)	1000 Seed (g)
Rovial T.S	3.13^{bc}	19.40	1.49	53.80	20.70	571.70^{a}	58.60
Copper Oxychloride	2.74^{c}	19.07	1.47	56.00	16.70	517.50^{ab}	53.70
Fungaron	2.78^{c}	18.00	1.46	42.80	16.30	509.20^{ab}	48.30
Terrachlor	3.53^{a}	16.80	1.45	41.40	12.50	441.10^{c}	50.10
Control	3.28^{ab}	16.93	1.43	40.00	10.30	484.40^{bc}	48.00
LSD (p=0.05)	0.375**	N.S	N.S	N.S	N.S	91.668**	N.S

Legend: As in Table 4.1

6 SCREENING SUNFLOWER VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT DISEASE.

6.1 Introduction

There are no reports so far on varietal resistance to bacterial blight disease in Nigeria. In this investigation therefore, an attempt was made to assess the degrees of susceptibility or resistance of some of the varieties of sunflower in the IAR collection. Eight varieties were tested both in pots and in the field. The trials were conducted for two years in the 1990 and 1991 growing seasons.

6.2 MATERIALS AND METHODS

6.2.1 Pot Trials

The eight varieties tested were as follows: Cherneanka 66(V_1), Isaanka (V_2),Saturn (V_3), UNIIMK 8883 (V_4), Smena (V_5), Cakinskij (V_6), Funtua (V_7), Record (V_8).

The experiment was carried out for two years (1990 and 1991) and the design was a Randomized complete block design with three replicates. The clay pots were filled with heat sterilized soil. Before the seeds were planted, thrash from infected sunflower plants were incorporated superficially into the sterile soil to the depth of about 5cm as a source of initial inoculum. The seeds were planted five to ten per pot and thinned to two two weeks after seedling emergence. The disease severity score was recorded at 30 days after germination and thereafter, once

every week. The disease assessment was based on a scale of 1-10. Data yield and yield components were obtained and analysed statistically.

6.2.2 Field Trials

The field trial was also carried out for two years, i.e 1990 and 1991 growing seasons. The layout of the field was a Randomized Complete Block Design with three replicates. The method of inoculation was both by artificial and by natural infection. Artificial infection was attained by planting sunflower seeds by May. These plants when infected served as initial inoculum and were planted along the ridge and when fully infected were incorporated into the soil along the ridges so that each plot received equal treatment.

The eight varieties used were the same as in the pot trial. The seeds were sown 23rd July at five seeds per stand and seedlings reduced to two per stand two weeks after seed germination. Method of disease severity score was based on a scale of 1-10. Yield data were collected in relation to plant height, head diameter, head weight, seed weight per plant and per plot and weight of 1000 seeds. The data were analysed statistically using Duncan's Multiple Range Test or Least Significant Difference.



Plate 11

One of the varietal trials in pots

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6.3 RESULTS AND DISCUSSION

6.3.1 Pot Trials

The results (Tables 6.1 and 6.2) showed that in general all the eight varieties were susceptible based on disease severity score. During the 1990 trial Cherneanka had the lowest disease grade (3.32) followed by Isaanka (3.95) but their differences were not statistically significant from those of Record, Smena; VNIIMK and Saturn. However, there was a significant difference from those of Funtua and Cakinskij which had the highest score but their differences were not statistically significant among themselves. From this result the most susceptible was Funtua (5.68) followed by Cakinskij (4.89).

When the trial was repeated in 1991, it was found that the result of the disease severity score followed the same trend as in 1990. Funtua still had the highest disease score with 5.07 and the differences were highly significant when compared with the other 7 varieties. The least susceptible variety that year was Isaanka (2.98) followed by Cherneanka (3.07).

When the two years results were compared it was found that Cherneanka was least susceptible and this was followed by Isaanka (see apendix 16). Smena and VNIIMK can be regarded as moderately susceptible others apart from Funtua can be classified simply as susceptible while Funtua can be regarded as very susceptible; based on the two years pot trials.

Table 6.1 Susceptibility of Sunflower varieties to bacterial blight at Samaru during the pot trial in 1990.

Variety	Disease Score	Plant Height (m)	Head Diameter (cm)	Head Weight (g)	Seed Weight (g)	1000 Seed Weight
Cherneanka 66	3.32^{c}	1.39	15.40	26.00^{d}	21.00^{c}	50.70^{b}
Issanka	3.95^{c}	1.29	16.80	36.00^{c}	20.00^{c}	50.90^{b}
Saturn	4.60^{b}	1.47	16.20	40.00^{b}	24.00^{bc}	52.00^{b}
VNIIMK 8883	4.38^{b}	1.26	16.00	48.00^{a}	30.00^{b}	51.00^{b}
Smena	4.35^{b}	1.40	15.60	33.00^{c}	27.20^{b}	52.37^{b}
Cakinskij 268	4.89^{b}	1.54	16.00	39.00^{b}	24.00^{bc}	50.90^{b}
Funtua	5.68^{a}	1.27	16.60	35.70^{c}	21.80^{c}	50.94^{b}
Record	4.00^{b}	1.50	17.00	48.00^{a}	36.40^{a}	60.33^{a}
LSD (p=0.05)	1.145*	N.S	N.S	1.335**	6.639**	3.93**

Legend: As in 4.1

Table 6.2 Susceptibility of Sunflower varieties to bacterial blight at Samaru during the 1991 trial.

Variety	Disease Score	Plant Height (m)	Head Diameter (cm)	Head Weight (g)	Seed Weight (g)	1000 Seed Weight
Cherneanka 66	3.07^{c}	1.36	15.40^{bcd}	25.36^{d}	14.60^{c}	51.73
Issanka	2.98^{c}	1.64	17.60^{a}	45.98^{a}	25.40^{a}	58.00^{a}
Saturn	3.55^{b}	1.41	16.60^{ab}	33.60^{bc}	16.80^{b}	46.20
VNIIMK 8883	3.32^{b}	1.42	15.80^{bc}	33.27^{bc}	17.20^{b}	47.4
Smena	3.27^{bc}	1.40	14.00^{dc}	30.84^{c}	19.96^{c}	42.20^{d}
Cakinskij 268	3.80^{b}	1.33	14.80^{cde}	26.70^{d}	11.94^{d}	40.40
Funtua	5.07^{a}	1.39	13.60^{e}	25.43^{d}	12.58^{d}	40.80^{d}
Record	3.65^{b}	1.47	15.60^{bcd}	35.09^{b}	24.80^{a}	56.83^{a}
LSD (p=0.05)	0.53**	N.S	1.51**	3.62**	1.47**	3.0**

Legend: As in table 4.1

In relation to plant weight there was no significant difference among the eight varieties for the two years work. Although Record had the highest mean when the results were combined, Isaanka came second while the least mean height was recorded by Funtua. The result of the 1990 trial showed that in relation to head diameter the highest mean was by Record though the value was not significantly different from the other 7 varieties. During 1991 however, Isaanka had the highest head diameter and the difference was statistically different from the others except Saturn. The combined results for the two years proved that Isaanka had the best performance in terms of head diameter; the difference was also statistically significant.

Variety Record had the highest head weight as shown by the result of the analysis and this was not significantly different from that of Isaanka and Saturn but significant differences existed with the rest of the varieties. When the grain yield in terms of seed weight per plant was added together for the two years the results showed that Record was the highest yielder while Saturn and Isaanka came second and third respectively and the means were statistically significant from that of other varieties. The lowest yielder in this aspect was Funtua followed by Cakinskij. The highest values in terms of seed weight of 1000 seeds for the two years was also Record followed by Isaanka which differred significantly from the other varieties. Funtua had the least 1000 seed weight.

From the foregoing it can be seen that Record and Issanka proved to be superior varieties in terms of yield though susceptible to bacterial blight, while Funtua and Cakinskij are poor varieties.



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Plate 12

Varietal trial at Samaru during the 1991 wet season

6.3.2 Field Trials

The results of the field trials during the 1990 and 1991 wet seasons respectively are presented in Tables 6.3 and 6.4 respectively. In general all the varieties were susceptible but Record was most susceptible with highest disease grade of 6.07 in 1990, the difference was statistically significant when compared with other varieties whose means were not different among themselves. The least score was recorded with Cakinskij. On the contrary during the 1991 trial, disease severity score values were significant among all the eight varieties. The reasons for the variability in the disease severity for the two years (field trials) are not known but it could be attributed to the different weather conditions in which the trials were conducted. A variety may respond to disease differently at different weather. However, it is important to note that the fairly consistent result in relation to disease severity obtained with the pot experiments for the two years would possibly be that the trials were conducted in the same location for those two years under the same weather conditions.

All the disease scores obtained in 1991 were comparatively lower than those obtained in 1990. Saturn had the least score while the scores for Record and Cakinskij 268 were not statistically different. The remaining varieties were intermediate in reaction between Saturn and Cakinskij 268.

Table 6.3 Sussceptibility of Sunflower varieties to bacterial blight at Samaru during the field trial in 1990.

Variety	Disease Score	Head Diameter (cm)	Plant Height (m)	Head Weight (g)	Seed wt/ Plant (g)	Seed wt/ Plot (g)	1000 Seed
Cherneanka 66	4.07[b]	16.73	1.293	30.70	21.00	509	50.34
Issanka	4.32[b]	17.13	1.303	31.60	22.70	522	51.47
Saturn	4.27[b]	15.60	1.440	24.30	23.10	409	51.30
VNIIMK 8883	4.05[b]	16.20	1.350	29.30	27.10	403	51.32
Smena	4.80[b]	16.87	1.317	32.30	25.50	543	51.22
Cakinskij 268	3.98[b]	16.47	1.433	24.00	20.90	435	61.3
Funtua	4.55[b]	17.13	1.337	33.30	22.10	511	61.13
Record	6.07[a]	16.53	1.337	42.30	30.60	544	61.33
LSD (p=0.05)	1.00*	N.S	N.S	N.S	N.S	N.S	1.3**

Legend: As in Table 4.1

Table 6.4 Susceptibility of Sunflower varieties to bacterial blight at Samaru during the field trial in 1991.

Variety	Disease Score	Head Diameter (cm)	Plant Height (m)	Head Weight (g)	Seed wt/ Plant (g)	Seed wt/ Plot (g)	1000 Seed
Cherneanka 66	3.04^{b}	16.40	1.438	38.20	71.00	541.20^{ab}	46.6
Issanka	3.21^{ab}	14.60	1.433	27.30	85.60	601.50^{a}	47.90
Saturn	2.94^{c}	15.13	1.350	26.80	85.80	485.80^{b}	43.40
VNIIMK 8883	3.17^{b}	15.80	1.310	32.00	76.90	515.50^{b}	46.5
Smena	3.12^{b}	16.07	1.420	32.20	81.40	600.10^{a}	44.50
Cakinskij 268	3.50^{a}	14.80	1.220	25.70	62.60	418.50^{c}	44.
Funtua	3.29^{ab}	15.80	1.470	33.90	83.90	612.90^{a}	47.5
Record	3.19^{ab}	15.20	1.430	30.40	96.40	610.20^{a}	44.50
LSD (p=0.05)	0.27*	N.S	N.S	N.S	N.S	54.88**	N.S

Legend: As in Table 4.1

All the disease scores were comparatively lower than those obtained in 1990. Saturn had the least score while the scores for Redord and Cakinskij 268 were not statistically different. The remaining varieties were intermediate in reaction between Saturn and Cakinskij 268.

In relation to head diameter the 1990 trials result showed that there was no significant difference among the eight varieties, but Isaanka and Funtua had the highest head diameter with mean of 17.13cm while Saturn had the least head diameter with 15.6cm. The 1991 trials result showed that Funtua also had the highest head diameter along with VNIIMK but their values were significantly different from other varieties. Furthermore, during the wet season of 1990, the result showed that both the mean plant height and head weight were not statiscally significant. Saturn had the highest plant height while Cherneanka had the least. In terms of head weight, Record scored the highest with 42.30g while Funtua followed (33.30g); the least head weight was in Cakinskij with 24.00g (for the 1990 field trial). In the 1991 trial the values of the mean plant heights and head weights were also not significantly different. Funtua, however, had the highest mean plant height while Cakinskij had the least. In terms of head weight for the 1991 wet season, Cherneanka had highest, Funtua followed while Cakinskij also had the least head weight.

From the foregoing results it seems that the mean plant height, head diameter and head weight were different during the two years trials for the same varieties used;

similar results were obtained by Ado (1992) while assessing the agronomic performance of the eight sunflower varieties. Thus disease severity seems not to have significant effect on these parameters just analysed as the varieties with least disease grade did not produce the best plant height, head diameter or head weight. Similar observation were recorded for the pot trials.

In the two years trials, seed yield based on seed weight per plant, seed weight per plot and weight of 1000 seeds per plot were also analysed statistically to determine the overall effect of the disease severity on yields of the different varieties. For the 1990 trial, cultivar Record had the highest yield in relation to seed weight per plant though the mean was not statistically different from other varieties VNIIMK followed while Cakinskij scored the lowest yield per plant. For seed weight per plot Record was also the highest yielder; its mean was not significantly different from the rest of the varieties. The least yielder in terms of seed per plot was VNIIMK. During the same year (1990), the results of 1000 seed weight indicated that there was highly significant difference among the eight varieties. Variety Cakinskij had the highest along with Record and Funtua. The least weight in this aspect was with Cherneanka.

When the same yield parameters were analysed in the 1991 trial the result in terms of seed weight per plant indicated that Record had the highest, the mean not being statistically different from the rest. The minimum seed weight per plants was recorded by Cherneanka.

The comparison of the seed yield per plot showed Record, Funtua, Isaanka and Smena to have the highest ranging from 600.10g-612.90g. The least yielder was Cakinskij (418.50g). The result of 1000 seed weight showed that Isaanka had the highest, Funtua followed while the least weight of 1000 seeds was recorded by Saturn.

When the two years work was combined (see Appendix 17) Record was still the highest yielder; this was followed by Funtua. The least yielder for the two years was Cakinskij.

From the results of the two years obtained both for pot and field trials there seemed to be no correlation betweeen disease severity and yield as Record which was most susceptible (with high disease severity) had the highest yield in terms of seed weight, the observation was also true of Funtua variety. Yield performance therefore could be controlled by several factors such as the nature or agronomic qualities of the variety, the environmental conditions, soil type, nutritional status and level of disease tolerance of the variety. A plant variety may be susceptible to a disease and still be a high yielder while on the other hand a plant may be less susceptible or moderately resistant and low yielding. The pot and field trials both showed that Record is the highest yielding variety, though susceptible.



13 A



13 B

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Plate 13

Infected sunflower plant showing stem canker disease (A) and blight on head and leaves (B).

7 IDENTIFICATION OF THE CAUSAL ORGANISM OF STEM CANKER OF SUNFLOWER

7.1 Introduction

It has also been observed that along with bacterial blight disease is a stem canker which in itself may also lead to a reduction in yield. The causal organism is hitherto unknown and in this investigation, an attempt was made to isolate and identify the causal agent.

Materials and Methods

Areas with canker symptoms on stems and capitullum from the field were collected during the wet seasons of 1990 and 1991. The method used in isolating the pathogen from the diseased stem is the standard bacteriological technique of dilution plating (Bradbury, 1970). This involved cutting out a small piece of the diseased stem from the advancing margin of the lesion with a sterile scapel. This was followed by washing of the tissue in two exchanges of sterile water. The infected pieces were teased apart with sterile needles and allowed to stay for 20-30 minutes in a drop of sterile water. This enabled the release of bacterial cells out of the tissue.

The suspension was streaked on sucrose peptone agar and Pseudomonas-F-agar (Kings medium B). This was then incubated at 27°C for 24 hours. A preliminary investigation into the identity of the pathogen was based on biochemical and cultural tests as outlined in Schaad (1980). Pathogenicity test was also conducted using young seedlings.

However, final confirmation of the identity of the pathogen was based on Koch's postulate by inoculating young sunflower seedlings (3-4 weeks old) with the pathogen isolated from infected stems from the field. The plants were assessed for typical canker symptoms and the pathogen re-isolated and cultured on the appropriate medium. The bacterial growth was compared with the one from the field, and the bacterium from the final culture used again to inoculate young seedlings in the laboratory to see if that would lead to the canker symptoms. In addition to the above the culture of the isolate was sent to IMI Kew, London for identification.

7.3 RESULTS AND DISCUSSION

From the microscopic observation it was found that the bacterium consistently isolated from the affected tissues (stem and capitullum) resembled that isolated from tissue affected by bacterial blight. The bacterium formed large white glistering colonies on sucrose peptone agar and a water soluble, green flourescent pigment on Pseudomonas F agar (King's medium B). This was similar to the cultural characteristics of the pathogen associated with bacterial blight. The result of the biochemical test further showed that the pathogen that induces stem canker of sunflower is a gram-negative and oxidase negative bacterium and has the ability to liberate acid from various carbon sources. This result is also similar to those obtained earlier with the pathogen from bacterial blight of sunflower.

When the pathogenicity test was conducted by inoculating the pathogen into stems and leaves, symptoms typical of stem canker and leaf blight were obtained. By two weeks after inoculation some of the seedlings lodged or broke from the base or along the stem due to the severity of the disease (Plate 14).

The re-isolated pathogen induced similar canker symptoms when used to re-inoculate young seedlings. Further proof of the identity of the pathogen was based on the identification made by IMI London, (IMI number 350926). Therefore the pathogen that induces stem canker is Pseudomonas syringae pv. helianthi the same pathogen as the one that induces bacterial blight of sunflower (Kawamura, 1934, Hellmers, 1955; Duran and Sorbrino, 1987).



Plate 14: Sunflower plant showing stem canker symptoms in the laboratory:

(Note lodging as a result of the severity of the stem canker disease 3 weeks after inoculation)

SUMMARY AND CONCLUSIONS

The identity, characteristics and taxonomic position of the causal organism of bacterial blight of sunflower in Nigeria were studied. It was shown that the causal agent of the disease is Pseudomonas syringae pv. helianthi. The seed-borne nature of the pathogen was also studied and it was found that the pathogen is seed borne. This agrees with reports from other countries (Styer and Durbin, 1982; Piening, 1976).

In order to determine the effect of various sowing dates on the severity of the disease so as to determine how to manage the disease by sowing at a particular date(s), two years trials were conducted in 1990 and 1991 wet seasons, both in pots and in the field. Sowing the seeds in June or in August reduced plant growth and yield, while plants sown in July grew well and although they had higher disease severity, this did not adversely affect the growth and grain yield significantly. Plants raised in July consistently had the best growth and grain yield.

Four bactericides namely, Busan, Bronocot, Streptomycin and Terrachlor were tested for their efficacy in the control of bacterial blight in pots. Busan and Bronocot effectively reduced the disease. Considering the health hazard posed by dust formulation, Busan (an emusifiable concentrate) was preferred to Bronocot.

Seven seed dressing chemicals were evaluated in the field for their effectiveness in reducing the severity of bacterial blight. Of these only three namely, Mancosan, Terrachlor and Bronocot were effective in reducing the

disease with significant increase in grain yield.

In 1991 wet season, four foliar spray chemicals; Rovral T.S., Copper oxychloride, Fungaron and Terrachlor were further assessed for their efficacy for blight control in the field. The result of disease severity score showed that Copper oxychloride and Fungaron were significantly better than Rovral T.S. and Terrachlor. The failure of Terrachlor to serve as an effective foliar spray suggest that it is more suitable as seed dressing chemicals where it proved to be effective.

In a varietal trial conducted for the two years (1990 and 1991) eight sunflower cultivars were screened for resistance to bacterial blight in pots and in the field both by artificial and natural inoculations. Although all the varieties were susceptible, differences and variability in susceptibility existed. Because of the comparatively high yields of Record and Funtua despite the high disease scores, they can be regarded as tolerant to bacterial blight, while Cakinskij was very susceptible and very low yielding; others were intermediate. From the investigations it was found that there was no definite correlation between disease severity and plant growth or yield.

The identity of the causal organism of the stem canker was also investigated, and it was found that the pathogen inducing the stem canker was the same one causing bacterial blight of sunflower. Through microscopic, cultural, biochemical and pathogenicity tests the organism was confirmed to be Pseudomonas syringae pv.helianthi.

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APPENDIX 1

ANALYSIS OF VARIANCE (ANOVA) For Effect of sowing date on the severity of Bacterial blight of sunflower in 1990, Pot trial.

1.1 Disease Severity Score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.00380	0.00190	$0.047^{N.S}$
Treatment	3	0.04883	0.01628	$0.400^{N.S}$
Error	6	0.24440	0.03258	
Total	11	0.29703		

1.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.
Replication	2	1.7668	0.8834	$4.184^{N.S}$
Treatment	3	30.6993	10.2331	48.462**
Error	6	1.2669	0.21128	
Total	11	33.7331		

N.S - not significant (p=0.05)

** - Highly significant (p=0.01)

APPPENDIX 2

Analysis of Variance (ANOVA) for effect of sowing date on the severity of Bacterial blight of Sunflower in 1991 pot trial.

2.1 Disease severity score

Source of Variation	DF	SS	M.S	F.
Replication	2	0.06065	0.30320	1.205$^{N.S}$
Treatments	3	1.28903	0.42968	17.079**
Error	6	0.15095	0.02516	
Total	11	1.50062		

2.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.0938	0.0469	0.139$^{N.S}$
Treatment	3	52.7217	17.5739	49.512**
Error	6	2.1296	0.3549	
Total	11	54.9451		

N.S - not significant (p=0.05)

** - Highly significant (p=0.05)

APPPENDIX 3

Analysis of Variance (ANOVA) for effect of sowing date on the severity of Bacterial blight of Sunflower in 1990 pot trial.

3.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.2455	0.1228	0.898$^{N.S}$
Treatment	3	26.9879	8.9960	65.801**
Error	6	0.8203	0.1367	
Total	11	28.0537		

3.2 Mean seed weight per plant

Source of Variation	DF	SS	MS	F
Replication	2	185991	92996	1.448$^{N.S}$
Treatment	3	1256.981	418994	6.525*
Error	6	385283	64214	
Total	11	1828255		

N.S - not significant (p=0.05)

* - Highly significant (p=0.05)

APPENDIX 4

ANALYSIS OF VARIANCE (ANOVA) For Effect of sowing *date on the severity of Bacterial blight of sunflower in* 1991, Field trial.

4.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.1338	0.0669	$0.334^{N.S}$
Treatment	3	3.4449	1.1483	5.731*
Error	6	1.2022	0.2004	
Total	11	4.7810		

N.S - not significant (p=0.05)

* - Highly significant (p=0.05)

4.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.
Replication	2	177630	88815	$1.413^{N.S}$
Treatment	3	1687587	562529	8.947*
Error	6	377243	62874	
Total	11	2242460		

N.S - not significant (p=0.05)

* - Highly significant (p=0.01)

APPENDIX 5

ANALYSIS OF VARIANCE (ANOVA) For the assessing Effect of Chemical seed treatment (Bactericides) on the severity of Bacterial blight disease of sunflower under pot condition, 1990 trial.

5.1 Disease severity score

Source of Variation	D.F	SS	MS	F.
Replication	2	1.1453	0.5726	$1.800^{N.S}$
Treatment	4	0.9072	0.2268	$0.713^{N.S}$
Error	8	2.5454	0.3182	
Total	14	4.5980		

5.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.
Replication	2	35.25	17.62	$0.306^{N.S}$
Treatment	4	91.30	22.82	$0.396^{N.S}$
Error	8	461.28	57.66	
Total	14	587.83		

N.S - not significant (p=0.05)

APPENDIX 6

ANALYSIS OF VARIANCE (ANOVA) for assessing the Effect of Chemical seed treatment (Bactericides) on the severity of Bacterialblight disease of sunflower under pot condition, 1991 trial.

6.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.7763	0.3881	$0.868^{N.S}$
Treatments	4	1.2171	0.3043	$0.680^{N.S}$
Error	8	3.5779	0.4472	
Total	14	5.5712		

6.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.
Replication	2	36.32	18.16	$1.172^{N.S}$
Treatments	4	86.31	21.58	$1.392^{N.S}$
Error	8	124.00	15.50	
Total	14	246.63	17.53	

N.S - not significant (p=0.05)

APPENDIX 7

ANALYSIS OF VARIANCE (ANOVA) for assessing the Effect of seed dressing Chemicals on the severity of Bacterial blight of sunflower for 1991 Field Trial.

7.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.09911	0.04955	3.022*
Treatment	7	0.53152	0.07593	4.631**
Error	14	0.22956	0.01640	
Total	23	0.76107		

* - significant (p=0.05)

** - not significant (p=0.01)

481911

7.2 Mean seed weight per plot

Source of Variation	D.F	S.S	M.S	F.
Replication	2	1433.00	717.00	0.575N.S
Treatment	7	146854.00	20979.00	16.843**
Error	14	17438.00	1246.00	
Total	23	165725.00		

N.S - not significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 8

ANALYSIS OF VARIANCE FOR ASSESSMENT EFFECT OF FOLIAR CHEMICAL SPRAYS ON THE SEVERITY OF BACTERIAL BLIGHT OF SUNFLOWER FOR 1991 FIELD TRIAL.

8.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.08297	0.04149	1.584 N.S
Treatments	4	1.36471	0.34118	13.029**
Error	8	0.20949	0.02619	
Total	14	1.65717		

8.2 Mean seed weight per plot

Source of Variation	D.F	S.S	M.S	F.
Replication	2	3896.30	1948.10	2.279 N.S
Treatments	4	27395.20	6848.80	8.012 **
Error	8	6838.10	854.80	
Total	14	38129.60		

N.S - not significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 9

ANALYSIS OF VARIANCE (ANOVA) FOR SCREENING SUNFLOWER VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT DURING 1990 POT TRIAL.

9.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	2.7491	1.3745	3.218*
Treatment	7	10.3721	1.4817	3.467*
Error	14	5.9828	0.4273	
Total	23	19.1040		

9.2 Mean seed weight per plot

Source of Variation	D.F	S.S	M.S	F.
Replication	2	23.41	11.70	0.815 N.S
Treatments	7	631.86	90.27	6.282 **
Error	14	201.15	14.37	
Total	23	856.42		

* - significant (p=0.05)

APPENDIX 10

ANALYSIS OF VARIANCE (ANOVA) FOR SCREENING SUNFLOWER VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT 1991 POT TRIAL.

10.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.27930	0.13965	1.520$^{N.S}$
Treatments	7	9.89696	1.41385	15.391**
Error	14	1.28610	0.09186	
Total	23	11.46236		

10.2 Mean seed weight per plot

Source of Variation	D.F	S.S	M.S	F.
Replication	2	7.7889	3.8944	5.514 *
Treatments	7	574.2504	82.0358	116.147**
Error	14	9.8883	0.7063	
Total	23	591.9276	27.8161	

* - significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 11

ANALYSIS OF VARIANCE (ANOVA) FOR SCREENING SUNFLOWER VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT DURING THE 1990 FIELD TRIAL.

11.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	9.2106	4.6055	14.039**
Treatment	7	9.8729	1.4104	4.299*
Error	14	4.5927	0.3281	
Total	23	23.6763		

11.2 Mean seed weight per plot

Source of Variation	D.F	S.S	M.S	F.
Replication	2	8988	4494	0.507 N.S
Treatment	7	57790	8256	0.931 N.S
Error	14	124187	8871	
Total	23	190965	8666	

* - significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 12

ANALYSIS OF VARIANCE (ANOVA) FOR SCREENING SUNFLOWER VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT DURING THE 1991 FIELD TRIAL.

12.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.03182	0.01591	0.685 N.S
Treatment	7	0.59632	0.8519	3.668*
Error	14	0.32511	0.02322	
Total	23	0.95325	0.04388	

12.2 Mean seed weight per plot

Source of Variation	D.F	S.S	M.S	F.
Replication	2	1449.70	724.90	0.738 N.S
Treatments	7	106160.00	15165.70	15.446**
Error	14	13746.30	981.90	
Total	23	121356.10		

N.S - not significant (p=0.05)

* - Significant (p=0.05)

APPENDIX 13

COMBINED ANALYSIS OF VARIANCE OF BOTH 1990 AND 1991 POT SOWING DATES USED TO DETERMINE THE EFFECT OF SOWING DATE ON SEVERITY OF BACTERIAL BLIGHT OF SUNFLOWER.

13.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.4727	0.02364	$0.717^{N.S}$
Years	1	0.02160	0.02160	$2.515^{N.S}$
Error a	2	0.01717	0.00859	$0.261^{N.S}$
Date	3	0.76755	0.25585	7.766 **
Years x Date	3	0.57030	0.19010	5.770 *
Error b	12	0.39535	0.03295	
Total	23	1.81925		

13.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.
Replication	2	1.1422	0.5711	$2.018^{N.S}$
Years	1	38.1024	38.102	106.072**
Error a	2	0.7184	0.3592	$1.269^{N.S}$
Years x Date	3	53.0238	17.6746	35.797*
Error b	12	3.3966	0.2830	
Total	23	126.7806		

N.S - not significant (p=0.05)

* - Significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 14

COMBINED ANALYSIS OF VARIANCE OF 1990 AND 1991 FIELD TRIAL USED FOR DETERMINATION OF EFFECT OF SOWING DATE ON SEVERITY OF BACTERIAL BLIGHT OF SUNFLOWER.

14.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.3203	0.1602	$0.593^{N.S}$
Years	1	2.0592	2.0592	7.798*
Error a	2	0.5287	0.2641	$0.978^{N.S}$
Date	3	19.9132	6.6377	24.595**
Years x Date	3	4.1655	1.3885	5.145*
Error b	12	3.2386	0.2699	
Total	23	30.2250		

14.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.
Replication	2	284805	0.5711	$2.018^{N.S}$
Years	1	378322	38.102	106.072**
Error a	2	78805	0.3592	$1.269^{N.S}$
Date	3	2741307	17.6746	62.443**
Years x Date	3	203287	10.1324	35.797*
Error b	12	762509	0.2830	
Total	23	4449635		

N.S - not significant (p=0.05)

* - Significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 15

COMBINED ANALYSIS OF VARIANCE OF 1990 AND 1991 USED FOR ASSESSING SEED DRESSING CHEMICALS ON THE SEVERITY OF BACTERIAL BLIGHT DISEASE OF SUNFLOWER UNDER POT CONDITION.

15.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	0.0488	0.0244	$0.064^{N.S}$
Years	1	2.0801	0.0801	$0.086^{N.S}$
Error a	2	1.8727	18.27	$2.447^{N.S}$
Chemical	4	1.7389	0.4347	$1.136^{N.S}$
Years x Chem	4	0.3855	0.0964	$0.252^{N.S}$
Error b	16	6.1233	0.3827	
Total	29	10.2493		

15.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.
Replication	2	54.94	27.47	$0.751^{N.S}$
Years	1	1.15	1.15	$0.139^{N.S}$
Error a	2	16.62	8.31	$0.227^{N.S}$
Chemical	4	157.74	39.06	$1.068^{N.S}$
Years x Chem	4	21.37	5.34	$0.146^{N.S}$
Error b	16	585.29	36.58	
Total	29	835.62		

N.S - not significant (p=0.05)

* - Significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 16

COMBINED ANALYSIS OF VARIANCE OF 1990 AND 1991 USED FOR SCREENING SUNFLOWER VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT UNDER POT CONDITION .

16.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.	
Replication	2	0.6834	0.3417	1.316	N.S
Years	1	9.3369	9.3369	7.963	*
Error a	2	2.3449	1.1725	4.516	*
Variety	7	19.3205	2.7601	10.632	**
Years x Var	7	0.9486	0.1355	0.522	N.S
Error b	28	7.2689	0.2596		
Total	47	39.9032			

16.2 Mean seed weight per plant

Source of Variation	D.F	S.S	M.S	F.	
Replication	2	28.577	14.288	1.896	N.S
Years	1	844.705	844.705	644.948	**
Error a	2	2.619	1.310	0.174	N.S
Variety	7	811.651	115.950	15.384	**
Years x Var	7	394.459	56.351	7.476	*
Error b	28	211.041	7.537		
Total	47	2293.053			

N.S - not significant (p=0.05)

* - Significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 17

COMBINED ANALYSIS OF VARIANCE OF 1990 AND 1991 USED FOR SCREENING SUNFLOWER VARIETIES FOR RESISTANCE TO BACTERIAL BLIGHT UNDER FIELD CONDITION .

17.1 Disease severity score

Source of Variation	D.F	S.S	M.S	F.
Replication	2	5.5030	2.7515	14.218 **
Years	1	23.9701	23.9761	12.403 **
Error a	2	3.8653	7.9326	9.987 *
Variety	7	6.0599	0.8657	4.473 *
Years x Var	7	5.4660	0.7809	4.035 *
Error b	28	5.4187	0.4034	
Total	47	50.2830		

17.2 Mean seed weight per plot

Source of Variation	D.F	S.S	M.S	F.
Replication	2	1729	865	0.176 N.S
Years	1	39533	39533	9.079 **
Error a	2	8708	4354	0.884 N.S
Variety	7	145060	20723	4.207 *
Years x Var	7	18890	2699	0.548 N.S
Error b	28	137934	4926	
Total	47	351855		

N.S - not significant (p=0.05)

* - Significant (p=0.05)

** - Highly significant (p=0.01)

APPENDIX 18 Correlation Analysis of Pairs of Parameters obtained during 1990 and 1991 Field Trials.

18.1 SOWING DATE

Pairs of Parameters	1990 Corr. Coeff.	1990 Coeff. det.(r^2)	1991 Corr. Coeff.(r)	1991 Coeff. of Det.(r^2)
Disease severity score and Head diameter	$+0.345^{NS}$	0.119	0.691^{NS}	0.477
Disease severity score and Plant Height	$+0.351^{NS}$	0.123	0.577^{NS}	0.333
Disease severity score and Head Weight	$+0.204^{NS}$	0.042	0.532^{NS}	0.283
Disease severity score and Seed weight/Plant	$+0.192^{NS}$	0.037	0.544^{NS}	0.296
Disease severity score and seed weight/Plot	$+0.241^{NS}$	0.058	0.640^{NS}	0.409
Disease severity score and 1000 seed wt.	-0.233^{NS}	0.054	0.258^{NS}	0.067

Note: N.S. = not significant (p=0.05)

18.2 Screening Different Varieties For Bacterial Blight resistance during 1990 and 1991 wet season

Pairs of Parameters	1990 Corr. Coeff.	1990 Coeff. det.(r^2)	1991 Corr. Coeff.(r)	1991 Coeff. of Det.(r^2)
Disease severity score and Head diameter	$+0.297^{NS}$	0.088	-0.262^{NS}	0.068
Disease severity score and Plant Height	-0.361^{NS}	0.130	-0.311^{NS}	0.096
Disease severity score and Head Weight	$+0.008^{NS}$	0.000	-0.212^{NS}	0.212
Disease severity score and Seed weight/Plant	$+0.338^{NS}$	0.114	$+0.028^{NS}$	0.000
Disease severity score and seed weight/Plot	$+0.283^{NS}$	0.080	-0.145^{NS}	0.021
Disease severity score and 1000 seed wt.	-0.271^{NS}	0.073	-0.037^{NS}	0.001

Note: N.S. = not significant (p=0.05)

APPENDIX 19: Effect of three concentrations of seed dressing chemicals on the severity of Bacterial Blight during the 1990 observation trials, used to determine the rate of application in 1991 field trial.

Chemical	Concentration	Disease severity score
Benlate	2×	2.80^{bc}
	×	3.07^{b}
	0.5×	3.45^{ab}
Apron plus	2×	3.10^{bc}
	×	3.40^{b}
	0.5×	3.44^{ab}
Streptomycin	2×	3.28^{a}
	×	3.55^{a}
	0.5×	3.75^{a}
Terrachlor	2×	3.10^{b}
	×	3.10^{b}
	0.5×	3.40^{a}
Rovral T.S.	2×	3.27^{bc}
	×	3.40^{ab}
	0.5×	3.66^{ab}
Mancosan	2×	3.05^{bc}
	×	3.00^{bc}
	0.5×	3.35^{a}
Bronocot	2×	3.08^{b}
	×	3.20^{b}
	0.5×	3.40^{a}
Busan	2×	3.19^{bc}
	×	3.10^{bc}
	0.5×	3.50^{a}
Fungaron	2×	2.80^{bc}
	×	2.78^{c}
	0.5×	2.99^{bc}
Copper oxychloride	2×	2.73^{c}
	×	2.84^{bc}
	0.5×	2.91^{bc}

Note: × = recommended quantity for treating a given weight of seed.

APPENDIX 20: Trade Names, Common Names and Chemical Nature of different Chemicals evaluated in the pots and in the field for their efficacy against Bacterial Blight of sunflower.

Trade Name	Common Name	Chemical Nature of a.i.
Benlate	Benomyl	Methyl 1- (butyl carbamoyl) benzimidazote-2yl carbomate
Apron plus	Metalaxyl + Carboxin	
Rovral T.S.	Carbendazim + Iproidione	3(3,5-0 ichlorophynyl-1-isopropyl) carbamoyl Hydanton
Mancosan	mancozeb	Mn-Zn ethylene bisdithiocarbamate
Bronopol	Bronocot	Bronopol (2- bromo -2 nitro -1,3 propanadiol
Busan	TCMB	2(-thiocyanomethyothio) benzothiazole
Terrachlor	PNCB	6-pentachloro Nitrobenzene
Streptomycin	Streptomycin sulphate	
Fungaron	Copper Hydroxide	
Copper oxychloride	Copper oxychloride	

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