

Prevalence of Pigeonpea Diseases and Associated Crop Losses in Asia, Africa and the Americas*

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Abstract. Surveys were carried out to determine the prevalence of pigeonpea diseases in the major pigeonpea growing areas of Asia, Africa and the Americas between 1975 and 1980. In India, surveys in eleven states revealed that wilt, sterility mosaic, *Phytophthora* blight, *Macrophomina* stem canker and yellow mosaic were economically important diseases. Other diseases were of minor importance. Disease problems in Bangladesh, Malaysia and Nepal were of less importance. In Africa, wilt was a serious disease in Malawi (36.3%), Tanzania (20.4%) and Kenya (15.9%). Leaf spot in Kenya and Malawi; and powdery mildew in Kenya, Tanzania and Zambia were important. Other diseases were not economically important. In the Americas witches' broom, Phoma stem canker and rust were the important diseases. Annual crop losses due to the combined effect of wilt and sterility mosaic diseases in India were estimated to be worth about US\$ 113 millions. In Africa the estimated losses from wilt disease alone were over US\$ 5 millions annually.

Introduction

Pigeonpea (*Cajanus cajan* (L.) Millsp.), an important pulse (grain legume) crop in the Indian subcontinent, is also grown in Southeast Asia, Africa and the Americas. According to FAO statistics some 2.9 million hectares of pigeonpea are grown in the world with an average yield of 684 kg/ha (Parpia, 1981). More than 88% (2.6 million hectares) of the world's pigeonpea crop is grown in India, with only 8.6% grown in Africa. It is a backyard crop in most of the American countries where it is found, except in the Dominican Republic and Puerto Rico where it is grown commercially. Pigeonpea is a perennial shrub partially cross pollinated, with a quantitative short-day photo-period response. However, it can be grown as a one-year crop if circumstances demand. It has a relatively high total biological production but a low harvest index (15-30%). Pigeonpea generally has a slow rate of growth for the first 45 days, followed by maximum growth between 45 days and flowering; this is apparently due to selection for the traditional system of intercropping for some 80% of the crops is grown this way. It is a valuable food and is consumed particularly in developing tropical countries. Green seeds and tender pods are used as a vegetable, while in the form of dhal it is used in soups or eaten with rice. It can be used as a perennial forage crop for animal feed while dried stalks are used for fuel, thatching and for making both baskets and grain stores.

More than 50 pathogens have been reported to affect pigeonpea (Nene, 1980) but only a few cause economically important diseases such as wilt (*Fusarium udum* Butler) in the Indian subcontinent and Africa; sterility mosaic (SM) (virus ?) and *Phytophthora* blight (PB) (*Phytophthora drechsleri* f.sp. *cajani* Kannaiyan *et al.*) in India; witches' broom (WB) (mycoplasma ?) and rust (*Uredo cajani* Syd.) in the Americas and leaf spot (LS) (*Mycovellosiella cajani* (P. Henn.) Rangel ex Trotter) in Africa.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India has a world mandate to improve pigeonpea. Since diseases are a major constraint to yield improvement, it was important to have some indication of the prevalence of various diseases and their economic importance in the countries of the semi-arid tropics. This was done through surveys conducted during 1975 to 1980 in Asia, Africa and the Americas

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and the results are reported in this paper. In addition, we also estimated the yield losses caused by the two important diseases, wilt (India and Africa) and SM (India). This information was useful in deciding research priorities of pigeonpea diseases at ICRISAT and elsewhere.

Methods

The survey teams consisted of pathologists from ICRISAT and other research organisations who travelled by road during the flowering and podding stage of the crop and covered the major pigeonpea growing areas. In India observations were recorded in fields at a 30–40 km distance. In Africa stops were made at 45–60 km. Stops were less frequent in areas where pigeonpea was sparsely grown. In India the data at each location were collected using the proforma given below.

PIGEONPEA DISEASE SURVEY INFORMATION SHEET

1. Route _____ 2. Date _____ 3. State _____

4. District _____ 5. Place (nearest village/
town/indicate
distance)

Total area of the field (approx.) _____

a. Sole/intercrop (describe) _____

b. Percent area under pigeonpea

7. Stage of crop growth (i) pre-flowering, (ii) flowering, (iii) podding and flowering and (iv) podding

8. Disease(s) observed

(i) _____ % calculated from 500 plants

(ii) _____ as above _____

(iii) _____ as above _____

(in case of significant leaf spot/powdery mildew incidence, indicate incidence)

9. Type of soil _____ 10. Samples collected i (), ii (),
iii ()

10. Other observations: Information given by farmer:

Was the field under pigeonpea in previous years? Is disease pattern similar in nearby fields?

For wilt, SM, PB, *Macrophomina* stem canker (MSC) (*Macrophomina phaseolina* (Tassi) Goid) and yellow mosaic (YM)(virus) disease incidence was recorded in 500 plants in random rows in a field. The incidence at each location in a district was used for calculating the district averages which were then used for calculating average incidence in that state. These averages indicate relative prevalence of pigeonpea diseases during the year of survey and can change from year to year. Also there could be an increase in disease incidence after the day of data collection. For minor diseases, depending on their severity, incidence was recorded as low, moderate or high, based on visual observations. The identification of the pathogen as *Fusarium udum* was confirmed from all locations through laboratory isolations and examinations.

In Africa the survey proforma in a simpler form was also used to collect data from each location. Wilt incidence in Africa was recorded by visual estimate in each field. The percentage incidence at each location in the African countries was used for calculating the country average. For other diseases the incidence was recorded as low, moderate or high through visual estimates.

In other countries, a visual estimate was used to indicate the relative prevalence of diseases by our colleagues who travelled in those countries.

A detailed departmental progress report, *International survey of pigeonpea diseases*, was also published (Kannaiyan *et al.*, 1981b).

Results

Asia

India

Surveys were carried out in the major pigeonpea producing states of Andhra Pradesh, Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal in co-operation with the appropriate scientists of the respective state agricultural universities. Data on the prevalence of different pigeonpea diseases in various states are summarised below and in Table 1.

TABLE 1. SUMMARY OF THE INCIDENCE OF IMPORTANT PIGEONPEA DISEASES IN VARIOUS STATES OF INDIA (1975-80)

State	Average disease incidence (%)				
	Wilt*	Sterility† mosaic	Phytophthora blight	Macrophomina stem canker	Yellow mosaic
Andhra Pradesh	5.3	1.6	0.1	0.4	0.8
Bihar	18.3	21.4	0.1	6.8	0.5
Gujarat	5.4	12.2	0.0	0.1	0.0
Karnataka	1.1	9.8	0.0	0.0	0.0
Madhya Pradesh	5.4	3.7	0.0	3.8	0.0
Maharashtra	22.6	1.1	0.0	3.7	0.0
Orissa	0.3	1.7	0.2	4.0	0.0
Rajasthan	0.1	5.4	0.0	0.1	0.6
Tamil Nadu	1.4	12.8	0.0	0.4	0.0
Uttar Pradesh	8.2	15.4	1.4	2.6	1.9
West Bengal	6.1	0.2	26.3	0.0	0.3
Average	6.8	7.8	2.6	2.0	0.4

*Range in fields = 0-97%.

†Range in fields = 0-100%.

1. Andhra Pradesh

The area under pigeonpea in the state is estimated to be 198,600 ha. The survey was carried out between December 1975 and January 1976. About 4000 km were covered with 102 stops in 19 out of 21 districts. The crop was cultivated in different soils mainly intercropped with sorghum, groundnut and pearl millet.

The diseases in this state were of relatively little importance. Wilt incidence in individual fields ranged from 0 to 92%, with a state average of 5.3%. However, average incidence was above 10% in the districts of Adilabad, Hyderabad, Medak and Nizamabad. These districts are located close to the districts in Maharashtra state where wilt was a major problem. The SM incidence ranged from 0 to 43%, with an average of 1.6%. The highest incidence (7.8%) was observed in Nalgonda district. The other less frequently observed diseases were MSC, PB, YM, LS, grey mildew (GM) (fungus not identified), powdery mildew (PM) (*Leveillula taurica* (Lév.) Arnaud), bacterial leaf spot and stem canker (BLSSC) (*Xanthomonas cajani* Kulkarni, Patel and Abhyankar), *Phyllosticta* leaf spot (PLS) (*Phyllosticta cajani* Syd.) and Alternaria blight (AB) (*Alternaria tenuissima* (Kunze ex. Pers.) Wilts).

2. Bihar

Pigeonpea is grown in 105,000 ha. The survey was carried out in March 1980. The distance travelled was about 3000 km with 68 stops in 26 out of 31 districts. The crop was mostly cultivated in loamy and red soils with crops like sorghum and maize.

Both SM and wilt were most important. SM was observed in all the 26 districts surveyed and the incidence in farmers' fields ranged from 0 to 100% (average 21.4%), the highest incidence (58.8%) was observed in Hazaribagh district. The SM incidence was also above 10% in 20 districts. Wilt incidence ranged from 0 to 87% (average 18.3%) and was observed in 19 districts with maximum incidence (50.9%) in Muzaffarpur district. Wilt incidence was also above 10% in 14 districts. MSC was the third important disease (average 6.8%) and its incidence was above 10% in seven districts. There was a low incidence of YM, PB, LS, PM, BLSSC, AB and GM. However, AB was found to be a serious problem on post-rainy (winter) season pigeonpea at certain locations.

3. Gujarat

The area under the crop is 111,400 ha. The survey was made during January–February 1980. The distance covered was above 1400 km with 42 stops in 11 out of 20 districts. The crop was cultivated mostly in black and loamy soils with sorghum, pearl millet and cotton. Winter (rabi) pigeonpea was common in the hilly district of Dangs.

SM was observed in all 11 districts surveyed and the incidence in farmers' fields ranged from 0 to 92% (average 12.2%). Its incidence was above 10% in five districts. Wilt incidence in fields ranged from 0 to 45% (average 5.4%) and was a maximum (23.2%) in Baroda district. It was also above 10% in two other districts. Incidence of MSC, LS, PM, BLSSC, PLS, AB, GM, Phoma stem canker (PSC) (*Phoma* sp.), sooty mould (*Capnodium* sp.), white root rot (fungus not identified) and phyllody (mycoplasma?) was low.

4. Karnataka

Pigeonpea is grown in 303,887 ha. The survey was carried out in December 1976. More than 2000 km were covered with 37 stops in 14 out of 19 districts. The crop was mostly cultivated in black and red soils with sorghum, pearl millet, groundnut and horsegram.

SM was the major disease and its incidence in farmers' fields ranged from 0 to 95% and the state average was 9.8%. Maximum incidence (49.7%) was observed in Bidar district. It was also above 10% in two other districts. Wilt incidence was very low in the entire state. It ranged from 0 to 17% with an average of 1.1%. In subsequent trips wilt was more common, in northern Karnataka districts, but no data were collected. A low incidence of LS and PM was observed.

5. Madhya Pradesh

The crop is cultivated in 503,100 ha. The survey was carried out in December 1977 and January–February 1978. About 5000 km were covered with 136 stops in 40 out of 45 districts. The crop was grown mostly in black and loamy soils intercropped with sorghum, cotton, pearl millet and groundnut.

The surveys revealed that wilt, SM and MSC were the major diseases. Wilt incidence ranged from 0 to 97% in individual fields (average 5.4%) and was observed in 27 districts. Its incidence was maximum in Khargone district (43.2%) while it was also above 10% in seven districts. SM incidence ranged from 0 to 100% with an average of 3.7%. Bilaspur district had the highest incidence (49.5%) and four other districts also had more than 10% SM. MSC incidence was above 10% in four districts and the overall state average was 3.8%. The incidence of other diseases was low. In addition, the crop in two districts was damaged by frost.

6. Maharashtra

Among the Indian states, Maharashtra has the maximum area (660,300 ha) under pigeonpea. Surveys were carried out in December 1975 and 1976. About 4000 km were covered with 82 stops in 19 out of 27 districts. The crop was grown mostly in black soil and was intercropped mainly with cotton or sorghum.

In this state wilt was the major disease. Incidence varied from 0 to 94% in farmers' fields (average 22.6%) and was present in 14 districts, with the highest incidence (68.8%) in Yeotmal district. The incidence was also above 10% in 11 districts. The disease was observed more frequently in black soils than in loamy soils. A wilt-MS complex was observed in Yeotmal district. SM was rare, with a range from 0 to 47% (average 1.1%). Since 1979 we have

noticed a substantial increase in SM incidence in our trips through the Marathwada region of the state. The incidence of MSC, LS, PM, BLSSC and PLS was low.

7. Orissa

The area under pigeonpea is 61,496 ha. The surveys were made between March and December 1980 and the distance covered was more than 2000 km with 37 stops in 11 out of 13 districts. The crop was cultivated in different soils intercropped with sorghum, field beans and sunnhemp.

The most important disease was MSC, with an average of 4.0%. Its incidence was above 10% only in two districts. SM and wilt were of minor importance. Average incidence of wilt, SM and PB was 0.3%, 1.7% and 0.2% respectively. The other less frequently observed diseases were LS, PM, BLSSC and GM.

8. Rajasthan

The area under pigeonpea is 33,509 ha, grown mostly in eastern Rajasthan. The survey was carried out in February 1980. The distance covered was above 1500 km with 31 stops in 12 out of 26 districts. The crop was grown in loamy soils with sorghum, pearl millet and groundnut.

The survey revealed that SM was an important disease in Rajasthan. Its incidence ranged from 0 to 68%, with an overall average of 5.4%. The disease was above 10% in two districts. There was a low incidence of wilt, MSC, YM, LS, PM, PLS and AB. Moderate frost damage occurred in four districts.

9. Tamil Nadu

In this state pigeonpea is cultivated in 101,350 ha. The survey was conducted in December 1976 and above 2000 km were covered with 46 stops in 11 out of 14 districts. The crop was grown in red and black soils intercropped with groundnut, sorghum and minor millets.

SM was confirmed as the major disease of pigeonpea in the state, incidence varying between 0 and 93% with an overall average of 12.8%. It was observed in 10 districts and the highest incidence (37.5%) was in Pudukkottai district. Its incidence was also above 10% in five districts. Ramakrishnan and Kandaswamy (1972) reported 0–100% incidence with 3–10% common in most fields. Wilt was observed in two districts only. Its incidence varied from 0 to 65% with an overall average of 1.4%. MSC, LS, PM, BLSSC and PLS were also present.

10. Uttar Pradesh

The area under pigeonpea is 504,565 ha. The survey was made in January and February 1979 and a distance of more than 3000 km was covered with 108 stops in 44 out of 54 districts. The crop was mostly cultivated in black or loamy soils intercropped with sorghum, pearl millet, groundnut, setaria and maize.

The most important disease in the state was SM, followed by wilt, MSC, PB and YM. SM was observed in 40 districts and incidence in the field varied between 0 and 93%, with an average of 15.4%. The highest overall incidence (67.3%) was recorded in Azamgarh district; over 10% was recorded in 18 districts. Nene (1972) reported the widespread occurrence of SM in this state. The disease was found in 30 of the 38 districts surveyed; 27 of these districts had 26 to 50% incidence and three districts had 76–100%.

Wilt incidence as observed in the present survey varied between 0 and 86% in individual fields, with an average of 8.2%. It was noticed in 33 districts and the maximum incidence was in Pratapgarh district (47.4%). Its incidence was also above 10% in 11 districts.

The next important disease was MSC which was observed in 18 districts. Its incidence ranged from 0 to 46%, with an average of 2.6% and was above 10% in four districts. YM was recorded in 30 districts and incidence ranged from 0 to 22%, with an average of 1.9%. Its incidence was above 10% only in Agra district. PB was observed in 17 districts and incidence varied between 0 and 18% with an average of 1.4%. In subsequent trips this disease was found to be a serious problem, particularly in Nainital, Kanpur and Varanasi districts. A low incidence of LS, GM, BLSSC and PLS was also recorded.

11. West Bengal

Pigeonpea is grown in 22,800 ha mainly in Murshidabad and Nadia districts. The survey was carried out in December 1980 and the distance covered was about 500 km with eight stops in three out of 16 districts.

PB was the most important disease of pigeonpea in West Bengal. Its incidence ranged from 0 to 100% with an average of 26.3% and it was serious in Nadia district (70%). The state average wilt incidence was 6.1% and maximum incidence (18.3%) was noticed in Murshidabad district. A very low incidence of SM (0.2%) and YM (0.3%) was also observed.

Bangladesh

A survey trip was made to Bangladesh in the last week of December 1979. Pigeonpea is not an important crop in Bangladesh and it is grown in isolated small fields. The diseases observed were blossom blight caused by *Sclerotinia fuckeliana* (de Bary) Fuckel (*Botrytis cinerea* Pers. ex. Pers.) in Mymensingh and Jamalpur districts, WB in Jamalpur and Joydebpur districts and wilt in Ishurdi and Kushtia districts. WB appeared to be a potential threat.

Malaysia

In Malaysia pigeonpea is of minor importance. It is grown for both forage and grain. The Kuala Lumpur area was surveyed for pigeonpea diseases in March 1978. The only serious disease observed was aerial blight caused by *Thanatephorus cucumeris* (Frank) Donk (*Rhizoctonia solani* Kuhn). The incidence ranged between 10 and 20%. A leaf spot and a mosaic (pathogens not identified) were minor.

Nepal

Both wilt and SM diseases on pigeonpea were recorded in Nepal in 1978 by Dr J. M. Green of ICRISAT. No systematic survey has been carried out in Nepal so far.

Africa

A survey trip was taken through the major pigeonpea growing areas of Kenya, Malawi, Tanzania and Zambia in June–July 1980 and the information obtained has been summarised below and in Table 2.

TABLE 2. SUMMARY OF PIGEONPEA DISEASE INCIDENCE IN FOUR AFRICAN COUNTRIES (1980)

Country	Total number of locations examined	Wilt		Leaf spot	Powdery mildew	Grey mildew	Macro-phomina stem canker	Rust	Phoma stem canker	Root-knot	A mosaic	A root tumor (gall)
		Average (%)	Range in fields (%)									
Kenya	25	15.9 [†]	0–90	M [†]	M	L*	–	–	–	–	L*	L*
Malawi	20	36.3* [†]	0–90	M* [†]	L	–	–	–	L*	L*	–	–
Tanzania	13	20.4 [†]	0–60	L	M [†]	L*	L*	L*	–	–	–	–
Zambia	6	–	–	L	M*	–	–	–	L*	–	–	–

– = Not observed. L = low, M = moderate.

* Reported for the first time.

† Diseases of considerable economic importance.

Kenya

The area under pigeonpea is about 115,000 ha most of which is intercropped. About 1500 km were covered in the survey with 25 stops in the Makueni, Kitui and Mombasa regions. Pigeonpea is grown in a range of soil types (sandy, loam (red and black)) and intercropped with maize, sorghum, cassava, bean, cotton or sunflower. It is also cultivated as a perennial hedge.

In the past, diseases such as wilt (Acland, 1971) and LS (Onim and Rubaihayo, 1976) have been reported. The survey revealed that wilt was an important disease and its incidence ranged from 0 to 90%, with an overall average of 15.9%. It was recorded in 20 of the 25 locations surveyed. Perennial pigeonpea was affected more with wilt. LS at higher altitudes and PM at lower altitudes were of moderate importance. The presence of a mosaic, GM and a root tumor (gall) (cause not identified) were also recorded at a few locations.

Malawi

The crop is cultivated on approximately 50,000 ha as an intercrop with maize, bean, sorghum or cassava, in red or black sandy loam or red loam soils.

About 1000 km were covered with 20 stops in the southern and a part of the central provinces. The survey revealed that wilt was the major disease of pigeonpea. Wilt incidence ranged from 0 to 90%, with an average of 36.3% and was noticed at 19 of the 20 locations surveyed. LS was the next important disease and its incidence was moderate. The incidence of PM, PSC and the damage by root-knot nematode (*Meloidogyne* sp.) was low.

Tanzania

Pigeonpea is grown on about 35,000 ha in Tanzania being the third most important pulse crop (after cowpea and bean). The crop is cultivated in black or red loamy soils mostly as intercrop with sorghum. Perennial pigeonpea was also seen in some fields. Observations for pigeonpea diseases were made over a distance of 600 km at 13 locations.

Wilt and PM were the most important diseases. Wilt incidence varied from 0 to 60%, with an overall average of 20.4%. Here again perennial pigeonpea showed more wilt incidence. PM incidence was moderate and a low incidence of LS, GM, rust and MSC was also recorded.

Zambia

The area under pigeonpea is small and its cultivation is mainly limited to the farms of resident Asians. It is mostly cultivated as a sole crop in large fields for commercial purposes.

Six locations in all were surveyed. PM was prevalent at a moderate level. The incidence of other diseases, i.e. LS and PSC was low. Wilt was not present.

Ghana

Dr D. Sharma of ICRISAT has reported the occurrence of wilt, however, its economic importance has not been studied.

The Americas

Drs Y. L. Nene and D. V. R. Reddy surveyed diseases in pigeonpea growing areas of Costa Rica, the Dominican Republic, Panama, Puerto Rico, Trinidad and Venezuela in 1976 and 1977 respectively and the observations are presented below and in Table 3.

TABLE 3. PREVALENCE OF PIGEONPEA DISEASES IN THE AMERICAS (1976-77)

Country	Disease incidence*									
	Witches' broom	Rust	Southern blight	Phytophthora blight	Phoma stem canker	Yellow mosaic	Bacterial leaf spot and stem canker	Seed/seedling rot	Pod anthracnose	Unidentified mosaic
Costa Rica	L	—			S					
Dominican Republic	M	L			L					
Panama	L	L		L	L	—	L	L	—	—
Puerto Rico	L	L		L	L	L	—	—	—	L
Trinidad	—	S		—	L	—	—	—	—	L
Venezuela	—	M								
USA (Florida)	—	—								

*L = low, M = moderate, S = severe.

Costa Rica

The diseases observed were WB and PSC, the latter being serious.

Dominican Republic

WB, rust, PB (caused by *Phytophthora parasitica* Dast.), PSC and a pod anthracnose of unknown etiology (observed by Dr W. Reed of ICRISAT) were observed. Only WB appeared to be a potential threat.

Panama

The diseases observed were seed/seedling rots, BLSSC, rust, WB, PB and PSC. None of these diseases was serious.

Puerto Rico

Rust, YM, WB, PB, PSC and an unidentified mosaic were observed, but none appeared serious.

Trinidad

Rust, PSC, collar rot or southern blight (*Corticium rolfsii* Curzi (*Sclerotium rolfsii* Sacc.)) and a mosaic similar to that in Puerto Rico were observed. Rust was most common and other diseases were frequently observed. In general disease problems were minor in farmers' backyard crops.

Venezuela

Only rust and a leaf spot disease were observed. Rust was common but not a serious problem.

USA (Florida)

Dr D. Sharma of ICRISAT visited Gainesville, Florida experimental plots in 1977 and reported the occurrence of southern blight.

Production losses due to wilt and SM in India and Africa

An assessment of the production losses from wilt and SM can be made as three parameters are known, i.e. area affected, yield reduction and actual production. Let us define several variables as follows:

L = the production loss from disease.

χ = the proportion of the area affected.

The disease incidence figures reported in this paper refer to the percentage of plants affected. For the purpose of this analysis it is assumed that the percentage of plants affected equals the crop area affected.

r = yield reduction in proportionate terms.

From field surveys the estimate yield reduction in the affected area is known.

P = actual production.

This statistic is known from production statistics. To derive the amount lost several auxiliary values are introduced as follows:

T = theoretical total production without any disease losses;

Y = yield without disease losses;

A = total area sown.

ℓ = the actual production in per cent of theoretical production.

The following equations then hold:

$$(1) \quad T = Y \cdot A$$

$$(2) \quad \ell = \frac{P}{T} \times 100 \text{ and}$$

$$(3) \quad L = Yr \cdot A\chi$$

Actual production is the difference between loss-free production and the quantity lost:

$$(4) P = T - L. \text{ Substituting equations (1) and (3) into (4) gives}$$

$$(5) P = (Y \cdot A) - (Yr \cdot A\chi). \text{ Substituting equations (5) and (1) into equation (2) and rearranging gives}$$

$$(6) \chi = \frac{Y \cdot A - Yr \cdot A\chi}{Y \cdot A}$$

$$= 1 - r\chi$$

From equations (2) and (6) the following can be derived:

$$(7) T = \frac{P}{1-r\chi}. \text{ Substituting equation (7) into equation (4) and rearranging, the amount lost (L) is derived as:}$$

$$(8) L = P \left(\frac{1}{1-r\chi} - 1 \right).$$

The wilt affected areas of pigeonpea result in approximately a 50% yield reduction (i.e. $r = 0.5$) (Kannaiyan and Nene, 1981). Substituting this into equation (8) gives the loss (L^w) equation for pigeonpea wilt as (8a):

$$(8a) L^w = P\chi/(2-\chi)$$

For SM, Reddy and Nene (1981) estimated about 100% yield loss ($r=1.0$). Hence loss L^s equation for SM is:

$$(8b) L^s = P\chi/(1-\chi).$$

The above equations were used to derive approximate quantitative estimates of production losses due to wilt and SM, the two major diseases of pigeonpea in India and Africa. Incidence levels (χ) for India were taken from Table 1 and applied to the production data for 1977-78 in 11 of the major pigeonpea producing states. The results are shown in Table 4.

TABLE 4. ESTIMATES OF PRODUCTION LOSSES FROM STERILITY MOSAIC AND WILT ON PIGEONPEA IN INDIA IN 1977-78 USING AVERAGE PREVALENCE LEVELS 1975-80

State	Production ('000t)	Prevalence (%)		Production losses ('000t)		
		Sterility mosaic	Wilt	Sterility mosaic	Wilt	Total
Andhra Pradesh	30	1.6	5.3	0	1	1
Bihar	65	21.4	18.3	18	7	25
Gujarat	44	12.2	5.4	6	1	7
Karnataka	182	9.8	1.1	20	1	21
Madhya Pradesh	363	3.7	5.4	14	10	24
Maharashtra	344	1.1	22.6	4	44	48
Orissa	26	1.7	0.3	0	0	0
Rajasthan	10	5.4	0.1	1	0	1
Tamil Nadu	44	12.8	1.4	6	0	6
Uttar Pradesh	749	15.4	8.2	136	32	168
West Bengal	21	0.2	6.1	0	1	1
Total	1878	-	-	205	97	302

Losses from SM in India appear to be about double those from wilt, the former amounting to 205,000 t annually. If these two diseases were controlled in India, pigeonpea production could rise by about 16%. At a price of Rs. 3300 t the value of these losses is about Rs. 1000 millions or US\$ 113 millions annually (US\$ 1.00 = Rs. 8.80).

Using the wilt incidence for Kenya, Malawi and Tanzania reported in Table 2 and an estimated production of 116,000 t, the losses amount to 14,000 t annually. Prices of pigeonpea vary considerably in Africa, however, valuing this at Indian prices (US\$ 375) we arrive at an estimated annual loss from wilt in these three eastern African countries of US\$ 5.2 millions annually. These values are based on 1980-81 figures. These figures are not absolute but give us an idea of the extent of loss due to these diseases.



Fig. 1. Pigeonpea field showing damage due to Fusarium wilt in Kenya.



Fig. 2. Sterility mosaic damage in susceptible pigeonpea cultivar (foreground) and resistant cultivar (background).

Summary and conclusion

The surveys carried out in eleven major pigeonpea growing states of India revealed that the wilt, SM, PB, MSC and YM were the important diseases. Wilt and SM were the most important and widespread (Figs 1 and 2). Crop losses from these two diseases in India were assessed at US\$ 113 millions annually. PB, MSC and YM were of some importance in some states. Other diseases were of minor importance. Frost damage was moderate in some parts of Madhya Pradesh and Rajasthan states. Diseases in Bangladesh, Malaysia and Nepal were of minor importance.

In Africa, wilt was the only major disease in Malawi, Tanzania and Kenya causing crop losses around US\$ 5 millions annually. Wilt was not observed in Zambia. LS in Kenya and Malawi and PM incidence in Kenya, Tanzania and Zambia were moderately important.

In the Americas, WB, PSC and rust were the most important diseases.

Based on these survey results ICRISAT has given priority to research on the three major diseases, i.e., wilt, SM and PB. Investigations are aimed at developing cultivars resistant to these diseases. At ICRISAT Center, sources of resistance to wilt have been identified (Nene and Kannaiyan, 1982), as well as to SM (Nene and Reddy, 1976) and PB (Kannaiyan *et al.*, 1981a). These sources are being used in the regions where these disease problems are serious and widespread. Seeds of resistant lines are maintained by ICRISAT's Genetic Resources Unit and are available on request.

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