



Jute Diseases

Diagnosis and Management

Rajib Kumar De



ICAR-Central Research Institute for Jute and Allied Fibres
ISO 9001 : 2015 Certified Institute
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केन्द्रीय पटसन एवं समवर्गीय रेशा अनुसंधान संस्थान
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Foreword

Jute is one of the most important natural fibre crop. With every passing year, its importance has been growing by leaps and bounds for its eco-friendliness, on the reverse side, its facing stiff competition from synthetic lobby. Productivity of this golden fibre jute is facing several constraints. Biotic stress, mainly, diseases are the prime ones often threatening the crop. The diseases of jute crop has been gaining importance season after season and of course with no economically viable remedy at sight. All stake holders including farmers and researchers often face difficulty to save the crop from the damages caused by diseases.

I am delighted to know that the author has come forward with brilliant idea of writing a very informative bulletin on “**Jute Diseases: Diagnosis and Management**”. All the information available on this topic is meticulously written and neatly put together to make it very useful and interesting to the readers across the society. The wide coverage of topic in a single bulletin makes it a much sought after and valued publication. The publication will be of immense use to policy makers, farmers, researchers, scientists, students and the general public. I hope, this bulletin will be widely used as a reference book for information on various aspects of diseases of jute crop.

I am sure that this bulletin will be appreciated for its up-to-date coverage and brilliant display of photographs. At the same time, I also congratulate **Dr. Rajib Kumar De** of ICAR- CRIJAF, Barrackpore for his sincere efforts in bringing out this publication.

Place: Barrackpore
Date: 19 August, 2019


(Jiban Mitra)
Director

Preface

Jute is one the most important commercial crops of India. It is grown mostly in eastern region with an area of 0.77 million hectares and production of 10 million bales (one bale = 180 kgs) and dry fibres productivity of 2329 kg per hectare. It is cultivated as pre-*kharif* crop mainly in the states of West Bengal, Bihar and Assam with percentage contributions to National production jute fibres are 81.29, 11.63 and 6.25%, respectively. In spite of declining popularity among farmers due to availability of cheap synthetic substitutes, recently jute has emerged with stronger attributes due to its eco-friendliness with more oxygen producing, carbon dioxide absorbing and higher fuel wood producing capabilities, apart from its biodegradable diversified products. Recently due to need for finer quality fibre and globalization of diversified products, the disease management is becoming more and more important.

Ever since first disease of jute was reported in 1917 from undivided Bengal province of India by Finlow, damages caused by diseases are increasing at a rapid pace season after season, year after year due to changing climate, cropping pattern and faulty agricultural practices and at the end poor, small and marginal farmers suffer the monetary loss. Challenges posed by dreaded diseases continue unabated. This issue of the publication has been enriched with latest available information on jute diseases.

It is expected that this bulletin will positively contribute in providing up to date knowledge to those who have interest in perusing research on jute crop and create awareness among development workers and jute growers.

I gratefully acknowledge the contribution of all jute pathologists whose research work has been cited in this bulletin.

I sincerely express my gratefulness to the Director, ICAR- CRIJAF, Barrackpore and Head of Crop Protection Division for their encouragement, inspiration and guidance in preparing this publication. I also record my gratitude to the all Scientists, officers and staff members of ICAR-CRIJAF, Barrackpore, my friends at ICAR and other institutes all over India for their cooperation and help in my efforts in bringing out this bulletin. I also take this opportunity to look forward to comments and suggestions for any improvement of it.

Place: Barrackpore
Date: 19 August, 2019

Rajib Kumar De
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Jute Diseases: Diagnosis and Management

Summary

Among all diseases of jute, stem rot incited by *Macrophomina phaseolina* is economically the most important. Although commonly known as stem rot, but any part of the plant may be infected by the stem rot pathogen at any stage of growth right from germination to harvest producing various symptoms, like, damping-off, seedling blight, leaf blight at seedling stage, stem rot, collar rot, stem break, root rot at adult plant stage and brown spot on pods especially in seed crop. Other important diseases of jute are anthracnose, black band, soft rot, jute mosaic and root knot nematode. In Hooghly wilt, *Ralstonia solanacearum* is the actual pathogen, whereas stem rot fungus and root knot nematode help in facilitating the entry of the original pathogen. With changing climate and introduction of new varieties, minor diseases, like, tip blight, stem gall, powdery mildew, sooty mould, die back, etc. are also slowly gaining importance. The diseases are seed, soil as well as air borne. Management of fungal diseases of jute crop involves management of soil condition for soil borne diseases, treatment of seed with fungicide, namely, carbendazim 50 WP, for seed borne diseases and application of fungicides to check the air borne spores, or judicious combination of both. Rouging of infected plants and spraying of insecticides to check vectors could prevent the spread of the viral diseases. In biological control, fungal antagonists and plant growth promoting rhizobacteria with *Trichoderma viride*, *Aspergillus niger* AN 27 and fluorescent *Pseudomonas* as seed inoculation or PGPR alone or in combinations were promising against stem rot. Integrated management strategies involves utilization of all good agricultural practices from sowing to harvesting to keep the pathogen population below economic threshold level causing minimum damage to crop ecosystem.

Jute crop diseases

Introduction

Jute (*Corchorus olitorius* L. and *C. capsularis* L.) is one of the bast fibre crops which is the source of cheapest bast fibre. It is also known as 'golden fibre' crop. Jute are grown in pre-kharif season having high rainfall with hot temperature and high relative humidity and that allows the crop to produce huge volume of green biomass and simultaneously make them more vulnerable to various diseases. Recently, due to need for more and finer quality fibre and globalization of diversified products, the disease management becomes more important.

Jute diseases

Among diseases caused by fungi, stem rot incited by *Macrophomina phaseolina* is economically the most important. Diseases of jute are listed below:

Crop: Jute (<i>Corchorus olitorius</i> L. and <i>C. capsularis</i> L.)			
SN	Name of disease	Nature	Causal organism
1	Stem rot	Fungal	<i>Macrophomina phaseolina</i> (Tassi) Goid.
2	Hooghly wilt	Bacterial	<i>Ralstonia</i> (= <i>Pseudomonas</i>) <i>solanacearum</i> (Smith) Smith (<i>Macrophomina phaseolina</i> , <i>Meloidogyne incognita</i> may facilitate entry of bacteria by making injury).
3	Anthraco nose	Fungal	<i>Colletotrichum corchorum</i> Ikata & Tanaka; <i>C. gloeosporioides</i> (Penz.) Penz. and Sacc.
4	Black band	Fungal	<i>Botryodiplodia theobromae</i> (Pat.) Griff. and Maubl.
5	Soft rot	Fungal	<i>Sclerotium rolfsii</i> Sacc. (= <i>Athelia rolfsii</i>)
6	Tip blight	Fungal	<i>Curvularia subulata</i> (Nees ex Fr.) Boedijn
7	Stem gall	Fungal	<i>Physoderma corchori</i> Lingapa
8	Powdery mildew	Fungal	<i>Oidium</i> sp.
9	Sooty mould of pods	Fungal	<i>Cercospora corchori</i> Sawada, <i>Corynespora cassicola</i> (Berk. & M. A. Curtis), <i>Alternaria</i> spp.
10	Die back	Fungal	<i>Diplodia corchori</i> Syd. & P. Syd.
11	Root gall nematode	Nematode	<i>Meloidogyne incognita</i> (Kofoid and White) Chitwood, <i>M. javanica</i> (Treub) Chitwood
12	Jute mosaic	Viral	A Begomovirus under family Geminiviridae, vector: <i>Bemisia tabaci</i> Genn. (whitefly).
13	Jute Chlorosis	Viral	A member of Tobravirusgenus
14	Yellow vein disease	Viral	A bipartite Begomovirus, vector: whitefly (<i>Bemisia tabaci</i> Genn.)

Fungal diseases

Fungal pathogens cause damage to jute crop infecting all plant parts including root, stem, leaf and pods. In the farmers' field, no single disease comes alone. Often it appears in very small proportion, gradually increases the intensity causing more and more damage to the growing crop, depending upon the prevailing meteorological factors and this phase may also go unnoticed by the growers. It is the grave mistake committed by the farmers. With time, as the crop grows, other diseases, few major ones and of course minor ones, join the team of disease causing more and more damage to the growing crop. The situation becomes terrible when simultaneous attack of three diseases, namely, stem rot caused by *Macrophomina phaseolina*, bacterial Hooghly wilt caused by *Ralstonia solanacearum* and root knot nematode (*Meloidogyne incognita*) combined with conducive weather conditions takes place killing the crop entirely, generally, harvesting of crop is not needed in extreme cases leading to complete crop failure.

1. Stem rot of jute

Economic Importance

Among biotic constraint of raw jute production, stem rot is economically the most serious disease in both cultivated species. Yield of jute fibre declines both quantitatively and qualitatively due to this stem rot and diseased seed crop produces infected seeds. The crop continues to suffer from this disease during the full crop duration from germination to maturity. Although it is commonly known as stem rot, but any part of the jute plant may be attacked by the pathogen at any stage of growth right from germination to harvest producing various symptoms, like, damping-off, seedling blight, leaf blight at seedling stage, stem rot, collar rot, stem break, root rot at adult plant stage and brown spot on pods especially in seed crop. The disease is seed, soil as well as air borne. It damages the crop beginning from germination to maturity in both seed and fibre crops wherever it is grown in India and other countries. Two cultivated species, *i.e.*, *Corchorus olitorius* and *C. capsularis* are equally susceptible to this disease.

Symptoms

In **damping off**, newly emerged seedlings rot above and below the soil level. In **seedling blight**, cotyledons become brown to black, later and young seedlings die. During high humidity and rainfall, leaf becomes brown causing **leaf blight**. As a result of **stem rot** infection during June – August, leaves become brown in colour due to prevailing high humidity. Dark brown lesion on green stem may extend vertically or horizontally, 10 - 15 cm or higher. Plants **wilt** and leaves droop or stems break in high speed wind. Infected plant dries up and slowly becomes dark brown to black and stand distinctly visible in the field. **Collar rot** symptom consists of brown rot in the

collar region. In **root rot** symptom, plants wilt, defoliate, become brown to black later and stand as naked stem and finally die (Figures 1, 2 and 3). Roots are rotten and brown, rootlets absent (Figures 4). When only the branch roots are attacked, the plants may grow and remain alive with reduced vigour showing rusty brown branch roots, but if the tap root is infected and damaged the plant generally dies. In seed crop of jute, it also produces dark **brown and black** coloured **spots on pods** and cause seed infection. High incidence of stem rot with very high plant mortality of jute often encountered in some pockets during favourable meteorological parameters.



Figure 1. Seedling blight, damping off and leaf blight symptoms of jute stem rot



Figure 2. Pathogen moves from infected leaf to stem, initial of stem rot, enlarging of rot and stem rot symptom in jute.



Figure 3. Drooping of leaves and stem rot symptom of stem rot disease in jute



Figure 4. Large stem rotting, stem break, field and root rot symptoms and sporulation on infected seeds with dark brown pycnidia with apical ostiole for release of conidia of *Macrophomina phaseolina* in jute stem rot

Causal organism: *Macrophomina phaseolina* (Tassi) Goid

Macrophomina phaseolina (Tassi) Goid is a notorious plant pathogen worldwide causing enormous loss to crop production. Its management is becoming more difficult due to its versatility in three different forms, namely, *Rhizoctonia bataticola* as sclerotial stage, *Orbilina obscura* as teleomorph (not observed in jute) and most common and damaging phase in jute being *M. phaseolina* as pycnidial stage. The pycnidial and sclerotial stage are mainly responsible for the disease and perfect stage is hardly seen. The fungus may infect wide range of hosts.

- a. Morphology:** Sclerotia within roots, stems, leaves and fruits, black, smooth, hard 100 μm –1 mm diameter (in culture 50 -300 μm). Pycnidia dark brown, solitary or gregarious on leaves and stems, immersed becoming erumpent, 100 – 200 μm diameter, opening by apical ostioles; pycnidial wall multicellular with heavily pigmented thick-walled cells on the outermost side. Conidiophores (phialides) hyaline, short obpyriform to cylindrical, 5-13 x 4-6 μm . Conidia hyaline, ellipsoid to obovoid, 14 -30 x 5 -10 μm (Figure 5).

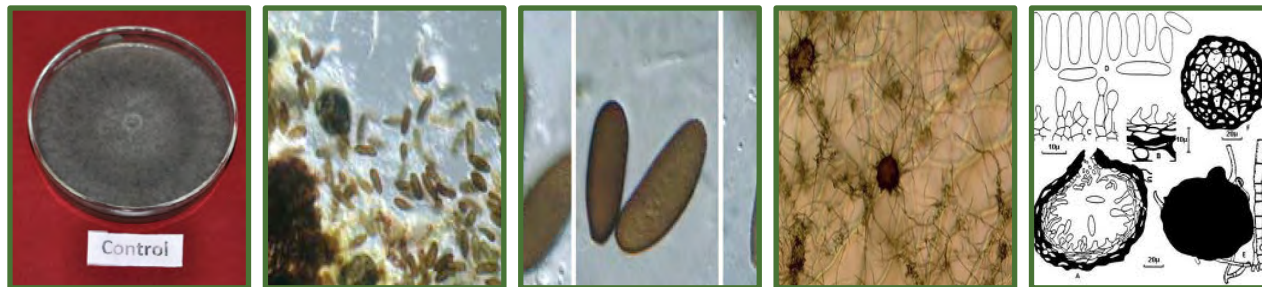


Figure 5. *Macrophomina phaseolina*. 48 hr old culture on PDA; Conidia and sclerotia; Brown, mature conidia; Sclerotia on PDA; Pycnidium, Hyaline conidia, Sclerotium.

b. Pathogenic variation: Wide range of variation was observed in *M. phaseolina* isolated from different hosts from different regions of the globe in their morphological shape and size and their sclerotial range was from less than 100 to above 400 μm . Based on the sclerotial size, *M. phaseolina* was grouped into four classes, viz., A, B, C and D. Isolates from jute collected from various jute growing places in India belonged to group C. But within such group also there are morphological and pathological variations and they have been further divided into four sub-groups based on their sclerotial morphology and pathogenicity (Mandal *et al.*, 1998). The growth rate of these four sub-groups in initial phase (5 days) was analyzed with their virulence. The most favourable temperature and pH were $34 \pm 1^\circ\text{C}$ and 6.8, respectively.

Among 13 isolates of from Assam, Bihar, Odisha and West Bengal, the isolate from Sorbhog (Assam) showed maximum virulence and it was followed by Barpeta (Assam) isolate (Mandal *et al.*, 1998).

c. Detection of *M. Phaseolina*: Detection of the pathogen from field samples by simple method of direct PCR (dPCR) without DNA extraction involved leaf bits lysis buffer, incubation and the lysate was used as PCR template (Biswas *et al.*, 2014). A miniprep yielding enough amount of quality DNA in comparison to other processes and a standard PCR method was reported (Biswas *et al.*, 2012).

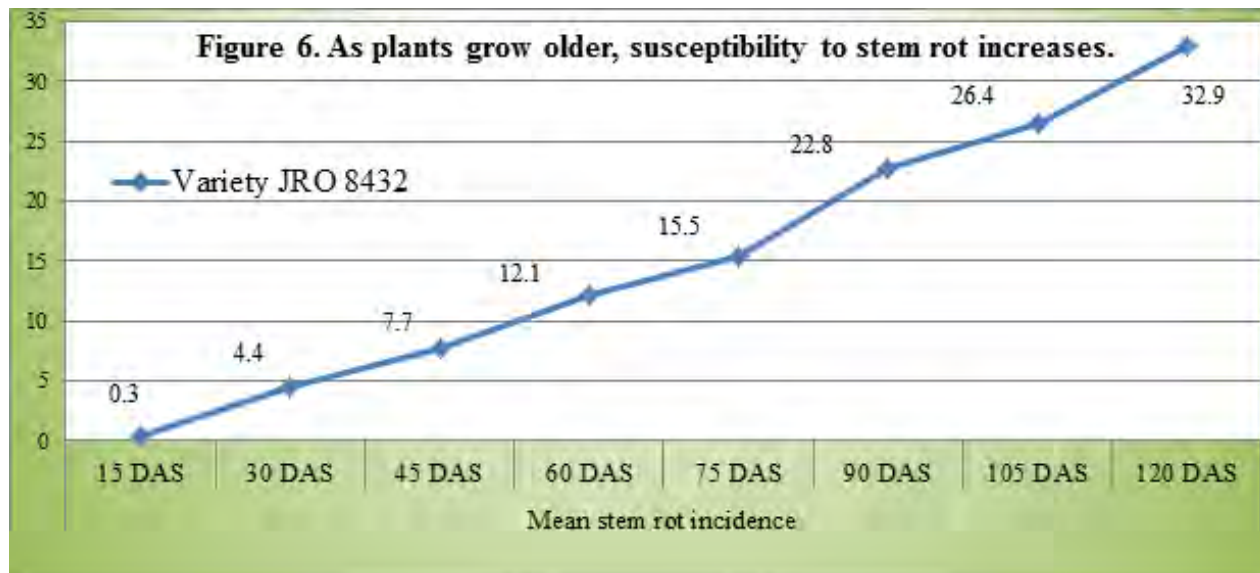
d. Pathogenesis: Pectinolytic and cellulolytic enzymes play an important part in the process of pathogenesis of blight of seedlings of jute caused by *M. phaseolina*. These two enzymes were made constitutively and inducibly. They were isolated from diseased and surrounding tissues. Distinct infected spots were found in 14 day old jute seedlings kept in enzyme solution at 21°C for 48 hours. Of the pectic enzymes contained in three variants of *M. phaseolina*, MP-C was observed to be more virulent in causing infection and retting jute indicating a relationship of pectic enzyme with stem rot disease of jute and retting.

Epidemiology and forecasting of stem rot

Soil moisture, air temperature, rainfall and relative humidity influence the progress of stem rot of jute. Host and pathogen factor has also profound effect on disease progress and development. Susceptibility of jute plants to stem rot increased with age irrespective of varieties and disease reached peak or maximum during harvesting time. Early sown crop during March is more susceptible to *M. phaseolina* causing more stem rot. Heavy rainfall with overcast cloudy condition resulting in near field capacity soil moisture, high atmospheric humidity, air temperature below 32°C and soil temperature below 30°C favour infection of jute stem rot. High nitrogen and plant density increase stem rot and P and K reduce it. No forecasting model is available.

Plant age and susceptibility

Stem rot start attacking jute plant right after germination. As the plants and grow older, susceptibility to stem rot increases and infected plants becomes visible in the field from a distance. Incidence of stem rot reaches its peak at the time of harvesting irrespective of varieties and location (Figure 6).



Varietal resistance

True resistant variety against jute stem rot is not available among either of two cultivated species, at least at farmers' level. The most ruling variety, JRO 524 and JRO 632 of *C. olitorius* and JRC 212 and JRC 321 of *C. capsularis* showed differential reactions at different places and in the same place with pathogen isolates form different places also (Mandal *et al.*, 1998; 2000). Out of 196 *C. capsularis* germplasm were assessed against the pathogen first at Barrackpore and Budbud and

later at Sorbhog, only six accessions (CIM 036, CIM 064, CIN 109, CIN 360, CIN 362 and CIN 386) confirmed resistant (Mandal *et al.*, 2000). Some accessions of wild species of *Corchorus*, like, *C. aestuans*, *C. fascicularis*, *C. pseudo-olitorius*, *C. tridens* and *C. trilocularis* showed very high degree of tolerance against the disease at Barrackpore (Palve *et al.*, 2004). Out of 293 *C. olitorius* accessions evaluated at Ramie Research Station, Sorbhog, also called as hot spot over three years, De and Mandal (2012a) reported only four accessions, namely, OIN 125, OIN 154, OIN 651 and OIN 853 showed moderately resistant reaction based on mean PDI 5.0 or below. The reaction of these 4 entries was also confirmed later in pot tests (De, 2016).

Among thirteen lines of jute, six lines, namely, OEX-27, OIN-125, OIN-154, OIN- 467, OIN- 651 and OIN-853 were moderately resistant at Barrackpore and Bahraich location (Meena *et al.*, 2015). Interestingly, all the four accessions of De and Mandal (2012a) confirmed their resistant reaction in separate studies of Meena *et al.*, 2015.

Jute stem rot scoring methodology

For precise evaluation of germplasm lines for resistance to stem rot considering all the types of symptoms produced, a rating scale was developed (De and Mandal, 2012a) in jute. The stem rot disease was scored observing (1) size of lesion (1 – 4), (2) position of lesion on the stem (1- 4) and (3) lesion type (1 – 8) with maximum value of 16 (= 4+4+8) and minimum of 3 (= 1+1+1), (4) number of stem rot infected plants (Number x score value) and (5) dead plants by root rot infection (Number x 16), as shown with example in figure 7.

- (a) Lesion size, namely, minor dots or lesion size of less than 0.5 cm² was scored with 1.0, lesion size of 0.6 – 1.0 cm² was rated as 2.0, likewise, lesion size of 1.1 – 2.0 cm² with 3.0 and lesion size of greater than 2.0 cm² with 4.0.
- (b) Position of lesion on the first one fourth portion from the tip of the stem of the plant carried 1.0 point, similarly, on the next second quarter it was 2.0, on the next third quarter it was 3.0 and finally on the last quarter it was 4.0.
- (c) Lesion type covering below 10 % diameter of the stem was given 1.0 point, in the similar fashion, lesion covering 10.1 – 25.0 % diameter of the stem was 2.0, 26.1 – 40.0 % was 4.0 and greater than 40.0 % carried 8.0 points.
- (d) Then percent disease index (PDI) was found out by sum of all numerical ratings multiplied by 100 and dividing it with number of plants observed multiplied by highest value, as given below.

(e) Accessions showing less than 10 % disease based on the PDI were selected and further tested.

Sum total of numerical ratings

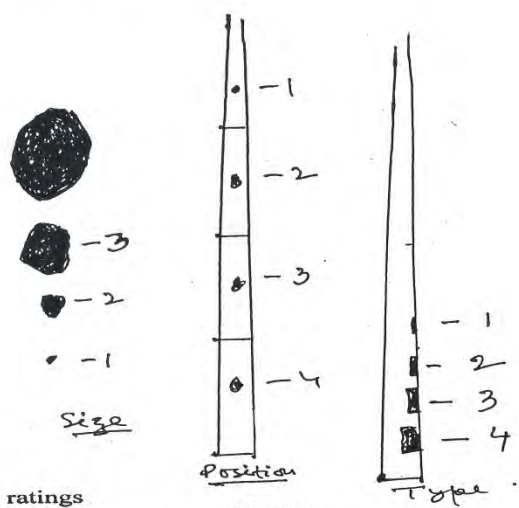
$$\text{PDI} = \frac{\text{Sum total of numerical ratings}}{\text{Number of plants observed} \times \text{Highest value}} \times 100$$

Selected accessions were further evaluated under pot culture condition for confirmation using suitable method of inoculation with JRO 524 and /or JRO 8432 as susceptible checks.

Example

Total number of plants observed = 150
 Number of plants infected by stem rot = 20
 Score value of each infected plant :

- Plant no 1 = 15
- Plant no 2 = 12
- Plant no 3 = 8
- Plant no 4 = 13
- Plant no 5 = 12
- Plant no 6 = 9
- Plant no 7 = 12
- Plant no 8 = 6
- Plant no 9 = 4
- Plant no 10 = 14
- Plant no 11 = 16
- Plant no 12 = 9
- Plant no 13 = 14
- Plant no 14 = 10
- Plant no 15 = 4
- Plant no 16 = 8
- Plant no 17 = 9
- Plant no 18 = 3
- Plant no 19 = 16
- Plant no 20 = 7



Total = 205

$$\text{PDI} = \frac{\text{Sum total of numerical ratings}}{\text{Number of plants observed} \times \text{Highest value}} \times 100$$

$$= \frac{(15+12+\dots+7) = 205}{150 \times 16} \times 100 = 8.54$$

PDI	1 or less than 1	= R
	1.1 to 5.0	= MR
	5.1 to 10.0	= MS
	10.1 to 15.0	= S
	More than 15	= HS

Figure 7. Scoring of stem rot of jute for evaluation of germplasm lines for resistance

Comparison of three methods of inoculation (leaf, soil and stem)

De (2016) compared three methods of inoculation, namely, by leaf, soil and stem, in order to devise a suitable method of inoculation for large scale use (Figure 8). Among four leaf inoculation

methods, tip cut and cotton swab method was better than inoculating floating leaf disc (8 mm), floating leaf and cotton swabbed detached leaf with typical symptom with light to dark brown spots in 100 % inoculated leaves within 48 hours on susceptible line JRC 412 which enlarged on further incubation.

Among three different times of soil inoculation, 7 days before sowing was more effective in causing infection in JRO 524 and JRO 8432 with 26.6 and 23.3% stem rot than soil inoculated during sowing (15%) and 7 days after sowing (10%). Resistance of four lines (OIN 125, OIN 154, OIN 651 and OIN 853) was confirmed by these three soil inoculation methods with JRO 524 as check.

Stem inoculation technique was highly efficient and caused 100% infection with typical stem rot symptoms with brown spots of different length and intensity encircling the stem in JRO 524 compared to earlier methods. The variation in virulence pattern of isolates was evident, as more virulent isolate (from Sorbhog, Assam) produced distinctly clear, longer and darker brown stem rot lesion than less virulent ones (from Barrackpore, West Bengal).



Figure 8. Leaf (left), soil (middle) and stem (right) inoculation of *M. phaseolina* causing jute stem rot

Disease Cycle

Stem rot disease of jute spreads through seed, soil as well as air in the field. The pathogen survives in soil and/ or in infected crop residues or root stubbles for long time in absence of host crop. It had very large host range with greater than 500 plant species belonging to greater than 50 different families. Seeds collected from infected crop produce infected seeds which upon germination produce diseased plants. Besides, abundant sporulation is often observed on infected seeds and stems with pycnidia with an ostiole (Figure 4 right). Presence of airborne conidia during crop

season may be responsible for secondary infection and may cause epiphytotic outbreak of stem rot disease in susceptible variety. Disease cycle of stem rot disease of jute is given in Appendix I.

The gestation (incubation) period, *i.e.*, time interval between the first appearance of the stem rot symptom on stem or leaf and the death of the plant ranges between one and twenty weeks.

Development of jute stem rot sick plot

For mass screening for resistance against jute stem rot of large number of entries, a sick plot with very high incidence of disease over the years is necessary. The high level of inoculums must be ensured to create high disease pressure for better evaluation of various entries. The procedure of development of sick plot against jute stem rot (Figure 9) is as follow:

- (1) Land selection is important as acidic soil is conducive for inoculum establishment, multiplication and development of jute stem rot disease.
- (2) The diseased plants should be collected all around the year, chopped into pieces and incorporated into the soil before crop season and allowed to rot.
- (3) The susceptible line, namely, JRC 412, may be grown all around year and off-season crops may be incorporated into the soil and fresh crop may be sown.
- (4) Inoculums may be multiplied on sterilized (autoclaved) old jute seeds in polypropelene bags for 10-15 day at $28\pm 1^{\circ}$ C in BOD incubator, added and incorporated into the soil repeatedly 4-5 times before and during the crop season.
- (5) The disease incidence and soil population of pathogen should be monitored on suitable selective media at fortnightly interval.
- (6) Once the inoculums level and disease pressure are stabilized for consecutively few years, the sick plot is ready for mass screening of large number of entries for resistance against jute stem rot.

Management Strategies

Besides soil borne, jute stem rot disease is both seed borne and air borne in nature. Hence, it becomes complicated to manage stem rot disease by either management of soil condition for soil borne inoculum, treatment of seed with inhibitory chemicals for seed borne inoculum and timely foliar spraying of fungicides to check the air borne spores, or judicious combination of both. Prophylactic measures to manage diseases are always better than curative application of toxic or hazardous chemicals because several ecological problems could be avoided by the former.

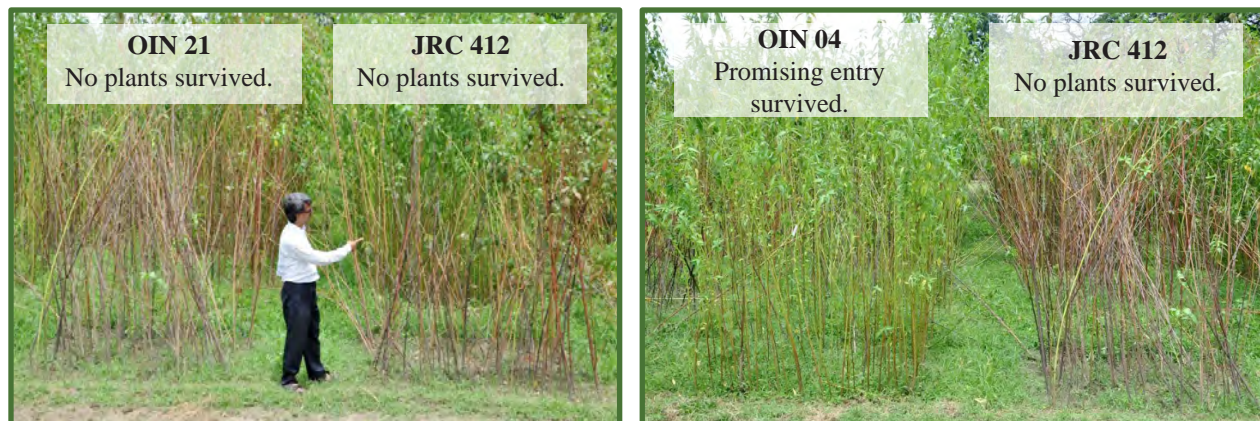


Figure 9. Distinct reaction of different entries of jute to stem rot disease with high plant mortality in the sick plot at ICAR-CRIJAF, Barrackpore.

(A) Cultural Management

- (a) **Selection of land:** Medium to high land with well drained sandy loam soil is very good for jute crop. K_2O / CaO ratio in leaf and stem of *C. capsularis* is an indicator of susceptibility to infection by *M. phaseolina* or *R. bataticola* as in resistant varieties JRC 918, JRC 212 and D 154 along with the highly susceptible JRC 412.
- (b) **pH of Soil and liming:** Jute crop in acid soils with pH 6.0 and below is more readily attacked than a crop at neutral soil. Depending upon pH level, application of lime or dolomite @ 2 – 4 t ha⁻¹ minimum 3 – 4 weeks before sowing once in 3 – 4 years is helpful in acidic soil. The soil where jute is grown in the state of Assam and few districts of northern West Bengal is acidic in nature and therefore the incidence of stem rot is more with high plant mortality as compared to soil of jute fields in the districts of southern West Bengal like, Murshidabad, Nadia, Hooghly and North 24 Parganas, where the soil is more or less neutral in nature.
- (c) **Selection of variety:** Though resistant variety as such is not yet available, the cultivated varieties showed differential reaction to the pathogens of different places (Mandal *et al.*, 2000) and accordingly, the varieties should be selected considering their status of susceptibility in a particular area.
- (d) **Adjustment of date of sowing:** In a field experiment with different dates of sowing of jute variety JRO 8432, early sown crop suffered from more stem rot than late sown crops. At 30 -90 days after sowing (DAS), stem rot incidence was highest (29 – 56%) in case of extra early crop sown on first of March. Stem rot disease showed declining trend in later sown

crop. Very late sown crop attracted lowest disease of 0.8%. In all the sowing dates, the stem rot was initially low at 30 DAS but with time it progressed slowly in late crop but rapidly in early crops to a higher peak at 90 DAS. Shifting the date of sowing just by a fortnight from first of April to middle to end of April significantly changed the disease scenario (De, 2013).

- (e) Spacing and plant population:** *C. olitorius* jute seed should be sown using CRIJAF - Multi row jute seed drill. The optimum spacing being row to row 25 cm x plant to plant 5-7 cm for a plant population density 50- 60 per sq m (= 5 – 6 lakh per ha). A pre or post sowing irrigation assures proper plant stand. Close spacing is conducive to stem rot infection.

De and Tripathi (2016) reported that with increasing plant population density to highest of 10 lakh per ha, the incidence of stem rot increased reaching peak of 16.3 and 27.4%, respectively, in broadcast and line sown crop. Minimum stem rot incidence of 5.4 and 7.4% was recorded in very low population density of 3 lakh per ha in line sown and broadcast crops. Stem rot incidence was at medium level of 7 – 9% in line sown and 10- 17% in broadcast crops in optimum plant population densities of 5– 6 lakh per ha.

- (f) Fertilizer application:** Well decomposed farm yard manure (FYM) should be applied @ 5-7 tonnes/ha and mixed thoroughly with soil during land preparation. Soil testing may be done before fertilizer application wherever possible. Apply fertiliser dose of N:P:K:: 60:30:30 in medium soil with N: 20 kg as basal, N: 20 kg at 21 days after emergence (DAE) and rest 20 kg at 30-35 DAE and for poor soil apply 80:40:40 in same pattern. Stem rot was reduced with soil application of micronutrients (Zn, Fe, Bo) along with NPK.

In a field study, De (2017) reported that more nitrogenous fertilizer enhanced jute stem rot but increase in potassic and phosphatic fertilizers reduced it. Among the different NPK fertilizer schedules, 120:30:30 attracted more stem rot, followed by 120:40:40, 100:30:30 and 80:40:40 on a new variety JRO 8432. With similar dosage of nitrogen, when phosphate and potash were increased, lower stem rot was recorded. Phosphate and potash fertilizer moderated the deleterious effect of nitrogen by reducing the stem rot incidence. Higher level of nitrogen with phosphorus and potash not only increased susceptibility of jute plants and killed more plants due to high prevalence of stem rot disease but also increased dry fibre yield.

- (g) **Crop rotation:** In the era of intensive and efficient cropping system, it is vital to understand that many familiar crops are also prone to *M. phaseolina* / *Rhizoctonia bataticola*. It has vast host range with greater than 500 plant species belonging to more than 50 different families. Therefore, non-host crop may be wisely selected for rotation. Rice / wheat / mustard crop should follow jute but not potato or other solanaceous vegetables for more than three years consecutively.
- (h) **Good agricultural practices:** namely, clean cultivation, removal of previous crop debris, use of healthy seeds, timely sowing in line, FYM, balanced fertilizer, timely weeding, thinning, rogueing of infected plants, regular field visit for monitoring, good drainage, soil solarization, etc. are very important for a good and healthy crop.

(B) Chemical Management

Once the pathogen enters into the field soil through infected seed, the fungus can survive in the soil for number of years (Mandal, 2001). Seed treatment is the first step of crop protection and most effective and economically efficient to reduce the losses due to this disease.

- (a) **Seed treatment:** Fungicide may directly reduce the seed borne inoculum at the first hand and may create a protective barrier around seed and later on growing radical and plumule and further to young seedlings. If the fungicide (say, carbendazim 50 WP) is systemic to plant system and provide protection from soil borne inoculums depending upon the weather and nature of the chemical used. Treatment of seeds can be visibly evident by physical presence of powder or liquid on the surface of treated seeds. However, liquid formulation of fungicides is not preferred for seed treatment, as it may enter into the embryo and hamper germination, as especially in case of tebuconazole and hexaconazole. Combined pre-sowing seed treatment with both insecticides and fungicides with good compatibility (using specialized formulation products, like, carbendazim 50 WP @ 2g/kg + imidacloprid @ 4g/kg) gave more promising results against early insect pests and diseases. Economics of seed treatment shows that it results in higher benefit cost ratio than any other agricultural practice or input, known so far. Carbendazim 50 WP @ 0.1% active ingredient per kg seed is the best choice for jute seed treatment.
- (b) **Foliar spraying:** Spraying of copper oxychloride 50 WP @ 5.0–7.0 g l⁻¹ or carbendazim 50 WP @ 2.0 g l⁻¹ of water is helpful to keep the disease under control. In higher infection,

alternate sprays of copper oxychloride 50 WP or carbendazim 50 WP at 10 days intervals (total three sprays) are recommended. Tebuconazole or hexaconazole @ 1.5 - 2.0 g l⁻¹ of water may also be sprayed.

- (c) **Seed transmission:** Infection of seed of jute ranged 1.4 – 2.1% under natural field condition. *M. phaseolina* treated seeds sown in sterilized soil reduced germination by 38% due to pre-emergence rotting (46%) and post-emergence rotting (7%). In component plating method of jute seed, *M. phaseolina* was mostly restricted to seed coat part of the seed. Disease-free quality jute seed production was studied by altering the sowing dates and fungicide schedule (Sarkar *et al.*, 2016).

Pod formation was the most susceptible stage for seed infection for the seed borne pathogens of jute and fungicide applied at this stage produced healthy seeds. Single spray of carbendazim or copper oxychloride at pod formation stage may be necessary to manage seed infection by the pathogens (De, 2012; De and Mandal, 2012b).

- (d) **Effect of pre-sowing soil application of bleaching powder [Ca(OCl)₂]:** This disease is spread through the triple means of seed and soil and air-borne conidia. In case, the incidence is very high causing heavy toll damaging and killing the jute crop entirely after year after, seed treatment alone is not sufficient. To take care of soil borne inoculums, option of soil application of bleaching powder or calcium hypochlorite [Ca(OCl)₂] was explored with very promising result on the economically viable management of jute stem rot.

The hyphal growth of *M. phaseolina* was completely inhibited *in vitro* at 5000 µg/ml of bleaching powder. In the field experiment, soil application @ 30 kg/ha 7 days ahead of sowing was found best against jute stem rot compared to check (with no soil application) and higher (50 – 150 kg/ha) and lower (5 – 20 kg/ha) doses in all the four dates (30 – 120 DAS) of observations.

Drastic decline in soil population of bacteria, fungi and other microbes was observed temporarily seven days after pre-sowing soil application of bleaching powder, however, it increased after 15 days and stabilized and was at par with initial level (De and Ghorai, 2017; 2019).

- (e) **Search for new fungicides:** Lowest stem rot incidence of 25% was recorded in pre-sowing seed treatment followed by foliar spraying of tebuconazole one month after sowing and it was at par with carbendazim (28.5%) and hexaconazole (28.6%) compared to 45.2% in check. They were the most effective fungicides against jute stem rot pathogen and it

was also observed *in vitro*. Tricyclazole, copper oxychloride and mancozeb followed them. Among the other fungicides, thiophanate methyl was least effective. In tebuconazole and carbendazim, disease progress was slowest. Propiconazole (10 µg/ml), turmeric oil (10 µg/ml), carbendazim 50 WP (25 µg/ml), copper oxychloride 50 WP (50 µg/ml), tebuconazole EC (50 µg/ml), hexaconazole EC (100 µg/ml), curcumin mixture (100 µg/ml) and tricyclazole (10000 µg/ml) caused complete inhibition of *M. phaseolina* under *in vitro* tests (De, 2014).

Carbendazim completely checked growth of *M. phaseolina* only at 25 µg/ml. Copper oxychloride followed carbendazim closely with 100% inhibition in 50 µg/ml. Other fungicides tested were thiram, and mancozeb. Two herbicides, namely, trifluraline and quizalofop ethyl completely inhibited the growth *in vitro* at 1000 µg/ml and 25 µg/ml, respectively, apart from their usual weed management ability in jute. Two organic fungicides, Dorina and Stup were also effective against *M. phaseolina*.

(C) Biological control

Fungal antagonists and plant growth promoting rhizobacteria (PGPR) were tested with promising results at the farmers' fields in jute. Among them, *Trichoderma viride*, *Aspergillus niger* AN 27 and fluorescent *Pseudomonas* became very effective biocontrol agents against stem rot in jute. Seed inoculation with bacterial biofertilizer, PGPR and soil drenching with vesicular arbuscular mycorrhiza (VAM) *Glomus mossae* and biocontrol fungi reduced root rot disease, increased plant biomass and enhanced fibre yield by 5 – 23 percent (Bandopadhyay *et al.*, 2008; Bandopadhyaya and Das, 2017; Bhattacharyya *et al.*, 2017). The effectiveness of PGPR in decreasing soil borne pathogens and improving the plant growth and vigour may be explained by their ability to produce siderophores (iron chelating agents) or toxins or enzymes or growth hormones (De *et al.*, 2009).

Isolates of fungal antagonists, like, *Trichoderma*, *Aspergillus*, *Penicillium*, PGPR isolates, fluorescent *Pseudomonas*, phosphobacter *Ps. striata*, *Bacillus* and *Azotobacter* exhibited promising antagonistic characteristics by inhibition of highly virulent isolates (R 9) of *M. Phaseolina* with production of volatile and nonvolatile antibiotics, enzymes, growth regulators, siderophores and phosphorus solubilization. Soil treatment (Srivastava *et al.*, 2010) and eco-friendly treatments (Meena *et al.*, 2014) were also effective.

Botanicals as alternative

Neem (*Azadirachta indica*) components, particularly, leaf extract, neem oil and seed kernel suspension and *Tephrosia indica* exhibited high inhibition whereas ramie (*Boehemeria nivea*) leaf was ineffective. Neem was closely followed by extracts of turmeric (*Curcuma longa*), garlic (*Allium sativum*) and kalmegh (*Andrographis paniculata*). The rate of growth of stem rot incidence was very less in neem extract as compared to check. Turmeric extract also arrested the hyphal growth to a large extent. Overnight seed soaking in turmeric, garlic and kalmegh extract boosted seedling growth and vigour initially indicating growth promotion effect (De, 2012). *Tephrosia candida* inhibited sclerotia formation and germination (De *et al.*, 2009). The extract of younger leaves of *Abroma augusta* (Devil's cotton), a Malvaceous plant, showed greater inhibition compared to older leaves owing to presence of more antimicrobial factors.

2. Anthracnose

Economic importance

Anthracnose is economically more serious disease in *C. capsularis*. *Olitorius* jute is rarely affected. In case latter is affected, it occurs at the very late stage of plant growth when the plants reaches almost harvest stage and the lesions are also not deep enough to affect fibre portion of the plant. In *capsularis* jute, the fibre is speky or knotty that leads to the 'cross bottom' fibre.

Geographic distribution

The anthracnose disease occurs regularly in the *capsularis* belt of India covering states of Assam, northern part of West Bengal, Bihar and Uttar Pradesh. It is also prevalent in Bangladesh and China. In all probability, anthracnose incited by *Colletotrichum corchorum* entered India unknowingly along with jute germplasm from Southeast Asia, particularly Taiwan.

India was enjoying comparative freedom from anthracnose, while in Bangladesh, it established firmly. In recent years in India, the disease is appearing in very severe form in *capsularis* jute at Bahraich areas in Uttar Pradesh and also in some places in North Bengal, Bihar and Assam.

Symptoms

The symptoms of anthracnose disease comprised of sunken spots of various colours on different part of plants, namely, leaves, stems, fruits or flowers. Irregular spots appear on stem, often enlarge, coalesce, cause deep necrosis, girdle stem, cracks and expose the fibre (Figure 10), slowly turn to brownish depressed spots. They lead to wilting, withering and ultimately

dying of infected plant tissues. Depressed spots are observed on pods also. Infected seeds are lighter in colour, shrunken and germination is poor.

Causal organism

Two different species of *Colletotrichum* infect two different species of *Corchorus*, namely, *Colletotrichum corchori* for *capsularis* jute and *Colletotrichum gloeosporioides* for *olitorius* jute. The teleomorph is *Glomerella cingulata*.



Figure 10. Cracks exposing the fibre in anthracnose in white jute (*C. capsularis*) caused by *Colletotrichum corchori* (on the left) and irregular spots on stem in Tossa jute (*C. olitorius*) caused by *Colletotrichum gloeosporioides* (on the right).

During the interaction with host, pathogen produces specialized structures, viz., conidia, acervuli, setae and appressoria. A number of acervuli and conidia are formed by *C. gloeosporioides* by colonization and injuring plant tissues. The conidia are hyaline, one celled, ovoid to oblong, slightly curved or dumbbell shaped and obtuse at apices. Acervuli are black, superficial (erumpent) and scattered. Conidiophores are simple, straight, hyaline bearing conidia singly. Conidia are falcate and germinate forming appressoria. For penetration into host cuticle tissues this fungal pathogen forms specialized infection structures called appressoria.

Epidemiology

Jute anthracnose is mainly soil, seed and air borne. The pathogen is cosmopolitan in distribution and has very wide host range. Primary inoculum is disseminated by wind or rain. High relative humidity coupled with continuous rain and temperature around 35 °C is favourable. Rain splash or overhead irrigation helps conidia to disseminate over relatively short distances and initiate new infection on other healthy plant tissues.

Management

- Seed treatment using carbendazim 50 WP @ 1.0 g kg⁻¹ of seed or captan @ 3 g kg⁻¹ of seed may be recommended to eliminate primary source of inoculum.
- Seed lots having 15 percent or more infection should not be used even after treatment and be discarded straightway without any consideration.
- Spraying carbendazim 50 WP @ 1.0 g l⁻¹ or captan @ 5 g l⁻¹ or mancozeb 75 WP @ 3 g l⁻¹ is advisable to reduce the spread of this disease.

3. Soft rot

Economic importance

Soft rot disease is still not so serious in jute crops but certainly a caution should be maintained for the jute growers due to its increasing trend. This was a minor disease, but now gradually increasing. The disease is present in all the jute growing areas but intensity is still low.

Symptoms

Attack of soft rot begins when the jute crop is 80–90 days old. The fungus first grows from soil and later slowly infects fallen leaves of jute. From there it infects stem base.

Soft, brown wet patch appears on the stem base. Skin peels off and exposed fibre layers turn rusty brown in colour and plants wilt. Typical white cottony mycelial growth is first clearly visible at the stem base and later brown mustard seed like sclerotia are observed in large numbers at the point of infection. Stem becomes weak and often may break in high wind (Figure 11). Soft rot decreases if fallen leaves are destroyed from the field.



Figure 11. White cottony mycelial growth at stem base of jute and mustard seed like sclerotia at infection site of stem which often breaks; *Sclerotium rolfsii* growth and sclerotia on PDA.

Causal organism: *Sclerotium rolfsii*

Sclerotium rolfsii is very notorious fungus causing huge damage to agricultural crops worldwide. This is mainly a soil borne pathogenic fungus. This pathogen can survive in soil

for many years even without any host crop forming hard and resistant sclerotia in soil. The pathogen has very wide host range and majority of agricultural crops are damaged by this pathogen with different degree of intensity and assumes severe form in certain pockets. Both *capsularis* and *olitorius* jute are affected.

Epidemiology

The fungus initially grows in the litter of fallen jute leaves. In hot weather and wet soil, it grows and initiates infection in the collar region. High rainfall, low sun shine, high plant population are favourable for soft rot.

Management

Cultural

- Deep ploughing during summer season to exposes sclerotia in soil to hot sun.
- Clean cultivation by removing the leftover of all previous crops and destruction by burning or burying under the soil, etc. is essential to reduce primary inoculum.
- Follow long term crop rotation using non-host crops.
- Adopt green manuring with sunnhemp or *dhaincha*.
- Use farm yard manure or organic manure during land preparation.
- Soil solarization using polythene sheet increases inside soil temperature by 15 – 20°C.
- Use neem or mahua cake.
- Biological control with application of *Trichoderma viride* in soil or through FYM are few good options for the checking this harmful pathogen.

Chemical

- Spraying copper oxychloride @ 4 -5 g l⁻¹ of water directed towards the basal region may contain the spread of the disease.
- With increasing dose of carbendazim 50 WP from 0 to 1500 µg/ml, the radial growth of *S. rolfsii* reduced causing only 36.8 % inhibition with low sclerotia.
- At 5000 µg/ml copper oxychloride, 41.3 % inhibition of growth of *S. rolfsii* was recorded with low production of sclerotia. It was also interesting to note that, *S. rolfsii* formed a clear transparent ring around its growth in the media amended with higher concentration of copper oxychloride, while rest of the media was coppery green. This indicated that, perhaps, *S. rolfsii* has the ability to detoxify (fully or partially) copper oxychloride and then grow over it.
- In the higher concentration of 2000 µg/ml of mancozeb, complete inhibition of growth of *S. rolfsii* was observed.

4. Black band

Economic importance

This was a minor disease in the past, but now gradually increasing with change in climate, cropping pattern and introduction of new varieties of jute. Now incidence is quiet high. Often no fibre and seed may be obtained from infected plant. It attacks two species of jute in all the jute cultivating areas but requires attention due to slow increase in intensity.

Symptoms

Dark coloured black spots appear on the infected stem with defoliation of plants. Initially, it may often be confused with stem rot because of similarity in symptom. On rubbing with finger on the infected spots profuse black sooty powdery spore mass adheres to the fingers, which is not observed in case of stem rot (Figure 12). Stem may break at the place of infection causing plant death. Crops raised from infected seeds show seedling blight symptoms also.

Causal organism: *Botryodiplodia theobromae*.

The pathogen is seed borne and air borne. It has very large host range.

Chemical Management

- Growth and sporulation of *B. Theobromae* are inhibited by carbendazim 50 WP and copper oxychloride 50 WP.
- Seed treatment using carbendazim 50 WP @ 1.0 g kg⁻¹ or mancozeb @ 4.0 g kg⁻¹ may be advocated.
- Spraying of copper oxychloride 50 WP @ 4.0 g l⁻¹ or carbendazim 50 WP @ 1.0 g l⁻¹ of water showed effective management of the black band of jute.

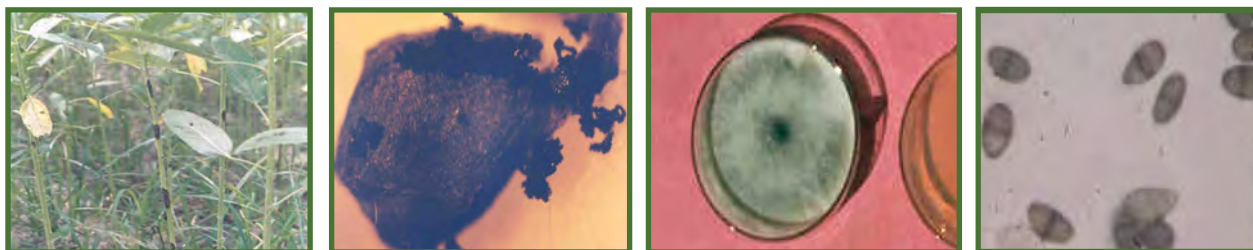


Figure 12. Blackish brown lesion, darker than stem rot with defoliation of plants in black band (on the left) and sporulation of *Botryodiplodia theobromae* on jute seeds (middle right); growth and spores on PDA.

5. Tip blight

Economic importance: Earlier tip blight was a minor disease but now it's increasing and establishing in new varieties, e.g., JRO 8432. Now incidence may be quite high in seed crop also.

Symptoms: Blighting of newly emerged tender tissue at the tip of young plants (Figure 13) is seen. Top soft folded leaves turn brown to black and water soaked and slowly rotten in high humidity. It was first observed by the author in jute seed crop in Guntur area of Andhra Pradesh and later also in Barrackpore on JRO 8432. Plants, however, do not suffer much as with change of weather with lowering relative humidity, as growth resumes and compensates with new leaves. The attack may be confused with damage caused by infestation of jute apion.

Causal organism: *Curvularia subulata*



Figure 13. Blighting of newly emerged tender top leaves of young plants in tip blight of jute; spores of *Curvularia subulata*

6. Stem Gall

Stem gall occurs on *olitorius* jute and is not observed in *capsularis* jute. Infection takes place in water logged field of jute only. The disease was noticed in the low lying areas of Bahraich, Uttar Pradesh and lower valley of Tripura, facilitated by alkaline soil, water logging in early stages (for at least 3 days) and late sowing.

Symptoms: Green galls of diameter 4- 10 cm develop on young stems at the base, where water comes in contact with stem. The galls appear lentil seed like outgrowth on the stem. The growth of plants slows as galls later turn rusty brown and plants wither and die. Stem gall is also known as pox of jute.

Causal organism: *Physoderma corchori* Lingappa

To check the disease, farmers should restrict cultivation of *olitorius* in medium to high land and avoid low lying areas with possibility of water logging. Deep ploughing of the field and timely sowing also reduce the stem gall occurrence.

Chemical Management

- Spraying of copper oxychloride 50 WP @ 4.0 g l⁻¹ of water showed effective management of the stem gall of jute.

7. Powdery Mildew

Powdery Mildew occurs at the pod stage in all dry areas of *capsularis* and *olitorius* jute, especially in seed crop. Although it is of minor importance to the fibre crop, it seriously affects the seed crop. It attacks in late August up to the harvesting of seeds.

Symptoms: Powdery mass of clean white spores is visible on leaves and pods of jute presenting a chalky, powdery appearance.

Causal organism: *Oidium* sp.

Chemical Management

- This disease can be checked by lime-sulphur dusting especially in the early hours of the morning (when dew effectively arrests particles) and by ensuring clean cultivation.

8. Sooty Mould

It occurs in seed crops, more particularly in the north-east and mid-eastern regions and promoted by heavy dew or rain and cloudy conditions.

Symptoms: The infection starts with sooty or brown mycelial growth on pods of both species, which shrivel up, with little and light seed, if any seed setting taking place at all. JRC 321 was found to be infected as patches on the stem covering 4-5 nodes and intervening internodes. The advancing zone is light grey to dark, while the central part is sooty dark, at which stage conidiophores with conidia could be seen. The infection seems to start at the leaf and in the advanced stages, the stem breaks and the fibre is shed.

Causal organism: *Corynespora cassicola*, *Cercospora corchori*, *Alternaria* spp.

Chemical Management

- The pathogen is sensitive to copper and a foliar spray of copper oxychloride 50% WP at the rate of 0.2%, is recommended on seed multiplication farms.

9. Die back

Die back disease is still not very alarming and is of minor importance, but now gradually increasing with change in cropping pattern and introduction of new varieties of jute, especially in jute seed crop. The grown up plants of both species are susceptible.

Symptoms: The leaves of stem begin to droop, wilt, wither and later the stem dries up gradually from tip downwards. Diseased branch slowly turn brown and later black and remain attached as dead and dry part. Predisposing factors to die back are low soil moisture and poor fertility status.

Causal organism: *Diplodia corchori* Syd.

Chemical Management

- Seed treatment with carbendazim 50 WP @ 1.0 g kg⁻¹ and spray of copper oxychloride @ 0.2% are effective.

Seed borne fungi of jute

Seeds provide very good nutrient base material for growth and sporulation of fungal and bacterial pathogens. Once infected, seeds may play role of carrying agent of pathogens and in the process later utilize the space and food base to multiply on the seeds. Evidence of sporulation of *M. phaseolina* (Figure 4 right) and *B. theobromae* (Figure 18 right) on jute seed is shown.

Experimental samples were collected from various seed sources, viz., Andhra Pradesh, Maharashtra and local markets in West Bengal showed presence of both *M. phaseolina* and *B. theobromae*. The extent of infection was however very low (0.25 to 7.25%). Other fungal pathogens recorded in jute seed were *Colletotrichum gloeosporioides*, *C. corchori*, *Curvularia* sp., *Sclerotium rolfsii* (contamination) and different *Fusarium*, *Penicillium* and *Alternaria* species (Mandal, 2001; De and Mandal, 2012b). In plating method of different component of jute seed, *M. phaseolina* was mostly confined to the seed coat (Sarkar *et al.*, 2016).

Bacterial diseases

10. Hooghly wilt

Economic importance

During late forties and early fifties, a typical wilt disease in jute (*C. olitorius*) was observed for the first time in Tarakeswar areas of Hooghly district, West Bengal. This malady was so widespread and the loss to jute crop was so severe that a new Pest and Disease Control Centre needed to be established at Tarakeswar in the heart of Hooghly district. This disease was later widely spread in other adjoining areas of same and surrounding districts, where jute used to be followed by potato in winter.

During late eighties and early nineties, 5–37 % disease was recorded in Kamarkundu area of Hooghly district and 2 –20 % in some areas of Nadia and North 24 Parganas districts (Mandal and Mishra, 2001). The Hooghly wilt was recorded in *olitorius* jute in Coochbehar in North Bengal but *capsularis* jute was free. In a survey in West Bengal, this bacterial wilt was found prevalent in jute along with many other crops and weeds with 1 – 91% incidence.

Symptoms

Typical drooping and wilting of leaves start from the base upwards. Affected stems are soft, slimy fluid comes out on slight pressing. Ooze test for bacterial Hooghly wilt disease is positive with quick release of bacterial cells into clear water turning it into turbid. Later plants defoliate making only naked stem with root remaining healthy and intact to stand erect in the field (Figure 14) which is visible from a long distance. Close examination of the infected plants clarifies the difference between wilting due to stem rot and to Hooghly wilt.

Causal organism

Earlier it was believed that this Hooghly wilt was incited by a complex combination of *Macrophomina phaseolina*, *Pseudomonas solanacearum* and *Fusarium solani* and was widespread in Hooghly where jute is followed by potato. T. Ghosh coined the name “Hooghly wilt” and isolated seven fungi and a bacterium from the infected or dead plants and later new term has been accepted. Repeated experiment established that *Ralstonia solanacearum* (= *Pseudomonas solanacearum*) is the original pathogen, whereas *M. phaseolina* and *Meloidogyne incognita* help in facilitating the entry of the bacteria. Presence of these pathogen causing root rot (*M. phaseolina*) and nematode causing root knot (*M. incognita*) increases the severity of Hooghly wilt as they create wound in the roots facilitating more primary bacterial pathogen, *R. solanacearum* to make entry (Mandal and Mishra, 2001).

Management

Cultural

- Potato or other solanaceous crops in the crop rotation need to be avoided at any costs. Jute: Paddy: Paddy or Jute: Paddy: Wheat is the most efficacious rotation, as the soil remain water logged during paddy crop and reduce bacterial population.
- In case where solanaceous crop is the base crop of the locality in the *rabi* season, it needs to be replaced by paddy or wheat at least for two years.
- Avoiding rejecting rotten potato tubers in the field itself, removing and burning wilted jute and other solanaceous crops from the field, avoiding water logging and application of cow dung manure are important agronomic practices to keep the Hooghly wilt under control.
- By adopting cultural practices especially the appropriate rotation of crops in Hooghly district the disease came down to 1– 2 percent compared to above 40 percent during the late eighties (Mandal and Mishra, 2001).



Figure 14. Wilting of leaves starting from base upwards with defoliation in Hooghly wilt caused by *Ralstonia solanacearum*

Chemical

- Seed treatment using carbendazim 50 WP @ 1.0 g kg⁻¹ seed and spraying the same fungicide @ 1 g litre⁻¹ of water helps to reduce stem rot, which favours the entry of the bacteria.

Viral diseases:

Jute crop is not very much prone to the viral diseases. Occurrence of some viral diseases, like, jute mosaic and jute chlorosis was known since long.

11. Jute mosaic (Synonyms: Jute leaf mosaic, Jute yellow mosaic, Jute golden mosaic)

Economic Importance

The disease was observed in *capsularis* jute from different jute growing belts of India, Bangladesh and recently from Vietnam. The occurrence of this disease has jumped to 20 - 40 percent now.

Symptoms

The disease symptoms consist of appearance of small yellow irregular dots (flakes) on leaf lamina in the early stage, which then gradually increase, intermingled with green patches and produces yellow mosaic in appearance. Infected plants appear pale; leaf size is reduced, initial chlorotic tissues become yellow (Roy *et al.*, 2008). Owing to infection sometimes the complete leaf may turn yellow (Figure 15).



Figure 15 . Jute mosaic virus is transmitted by whitefly (*Bemisia tabaci*)

Transmission

The causal virus was transmitted by whitefly (*Bemisia tabaci* Gen.) vector. Seed transmission of the virus is also possible. Adult whitefly (Figure 15 at the right) can take up (acquire) the virus in 30 minutes of its access to an infected plant and the acquisition becomes maximum after 8 hours of access. A viruliferous whitefly can transmit (inoculate) the virus to the test plants within 30 minutes of its inoculation access. Degree of infection is maximum with an inoculation access of 4 hours or more. A viruliferous whitefly can hold the virus up to 10 days.

Management

- Roguing of infected plant and spraying of systemic insecticide, like, imidacloprid @ 2.0–3.0 ml/10 litre, thiomethoxam @ 2.5 – 3.0gm/10 litre and acetameprid @ 1 g/5 litre could check the spread of the disease.

- A combination of seeds collected from healthy plants, spray of one insecticide around 30 days after emergence, along with field sanitation with roguing several times during the vegetative growth period and an extra booster dose of nitrogen at around 45 -50 DAS reduced disease spread.
- Inter-specific crosses between *C. trilocularis* (wild species) and *C. capsularis* was resistant to jute leaf mosaic disease.

12. Chlorosis of Jute

Economic Importance

Chlorosis of jute was observed to be limited to *C. olitorius* and occur in all the jute producing regions of West Bengal.

Symptoms

Mild mosaics like symptoms develop initially from the basal portion of the lamina. Then distinct yellow chlorotic spots with sharp margins irregularly formed on the lamina, which gradually coalesce giving rise to yellowish lamina (Figure16) and it may be compared as “Morphological imperfection”.



Figure16. Jute chlorosis

Nematode diseases

13. Root knot nematode (*Meloidogyne incognita*, *M. javanica*)

Root-knot nematodes are plant-parasitic nematodes of the genus *Meloidogyne*. They are found in soil. About 2000 plants worldwide are susceptible to infection by root-knot nematodes and they are responsible for approximately 5% crop loss globally. Root-knot nematode larvae infect plant roots, causing the development of root-knot galls that drain the plant's photosynthate and nutrients. Average degree of damage in jute crop is 15–20%.

Both *olitorius* and *capsularis* were prone to its infestation (Laha *et al.*, 1995).

Symptoms

Root knot nematodes produce white globular swellings in roots called galls (Figure 17) due to penetration and feeding of their larvae. As a result of this, translocation of nutrients and water is blocked. Infested plants appear yellowish with stunting of growth. Infection of young plants may be lethal, while infection of mature plants causes decreased yield. Sometimes they predispose the infested plant to stem rot and Hooghly wilt infection.

Root knot nematode facilitates entry of other bacterial pathogen *R. solanacearum* and fungal pathogen *M. phaseolina* by creating injury on roots of plant and cause heavy damage upon combined inoculation.

Management

- (1) Several insecticides and nematicides were tried for reducing the damage of root knot nematodes in jute, of which, Thiometon, Nematox, Nemagon are important. Granular insecticides, e.g., Carbofuran, Phorate, etc. reduced nematode population and increased fibre yield compared to control.
- (2) Various organic amendments, namely, cakes of *karanj*, *mahua*, groundnut, sawdust, cow dung, castor, chicken manure, etc., were tried for checking the nematode infestation.
- (3) Cultural practices, like, removal of stubbles, weeding, thinning, crop rotation with paddy and wheat for a period of two years reduced population of root knot nematode in jute field.
- (4) Screening for resistance against root knot nematode resulted in few tolerant lines in both species of jute (Laha *et al.*, 1995). JRO 524 and JRO 632 plants showed reduced height and green weight as a result of inoculation of J-2 of root knot nematodes.

- (5) Investigation on the seasonal variation of population indicated that population of *Meloidogyne*, *Helicotylenchus*, and *Hoplolaimus* gradually increased with growth of jute plants, but decreased during winter without suitable host plant, because they are endoparasitic in nature (Laha *et al.*, 1995).



Figure 17. Globular swellings in roots called galls by root knot nematodes in two species of jute; root knot nematode at the right

Development of IPM module for jute

New IPM module consisting of cultural, chemical, biological components was developed at ICAR-CRIJAF, Barrackpore and tested very promising at farmers' field level. IPM module consisting of cultural (deep ploughing to expose soil to sun, sowing in line with 5 - 6 lakh plants / ha, NPK: 60 (30+15+15):30:30, manual hand weeding once at 21 DAS, variety: JRO 204 (Suren)); chemical (soil application of $\text{Ca}(\text{OCl})_2$ @ 30 kg/ha at 7 DBS, seed treatment with (a) carbendazim 50 WP @ 1 g/kg + (b) imidacloprid @ 4g/kg, application of pesticides: spiromecifen @ 1 ml/litre, profenophos @ 2 ml/litre); biological (seed treatment with *Trichoderma viride* @ 10g/kg, soil application of *Pseudomonas fluorescens* @ 100g/ sq. m before sowing and spraying of neem oil @ 3 - 4 ml/litre) components was effective against stem rot, yellow mite, semi-looper, Bihar hairy caterpillar, apion and indigo caterpillar infestation of jute at institute farm level.

Stem rot was reduced to 2.8% in full IPM module from 21.5% in farmers' practice. Yellow mite was reduced to 0.8% in full IPM module from 6.3% in farmers' practice. Similarly, % semilooper and Bihar hairy caterpillar infested plant was 0.5 and 0.7 % in full IPM module compared to 5.1 and 5.7%, respectively, in farmers' practice. Greater fibre yield and benefit cost ratio of 32.9 q/ha and 1.77 were observed in full IPM module as compared to 14.7 q/ha and 1.29, respectively, in farmers' practice.

In the farmers' field in different villages in North 24 Parganas district of West Bengal, stem rot was major problem, followed by apion, yellow mite, semilooper and BHC. High damage of stem rot and insect pests in local broadcast crop showed that IPM module was effective. Stem rot was reduced from 29-30% in local broadcast crop to 4% in different varieties using IPM module. Insect

pests infestation declined from 15-23% in local broadcast crop to 2-8% using IPM module. Farmers got more fibre yield of 30-31 q/ha using IPM module compared to 16-17 q/ha for not using IPM module. Benefit- cost ratio was also more (1.7) in IPM module than their own practice (1.1). IPM module has tremendous potential for efficient management of insect pests and diseases of jute in the farmers' fields.

Expert system for integrated stress management in jute

A web-based expert system has been developed with the aim of improving decision-making by jute growers and other users. Knowledge was obtained from the literature and experts. The knowledge was then represented in the knowledge base of the expert system in a series of rules and heuristics. The system is a client-server application supported by a data base containing information of two domains - fibre production and seed production. Both the domains contain management information involving diagnosis and treatment to reduce losses due to weeds, diseases, insect pests (biotic stress) and hydric stress (logging and drought), respectively, responsible for 22, 12.9, 11 and 25% of the total fibre loss of 23% annually in India.

This integrated stress management is a part of the crop management system for judicious utilization of all components. The system is enhanced by photographs and drawings to assist the users in stress management of jute crop at the farm level. This user-friendly expert system can be helpful as a decision tool for farmers, technicians and policy makers towards early identification of the harmful agents and hydric stresses, their economic management and for education purpose as well (Chakraborty *et al.*, 2013; Website: www.crijaf.org.in). This computerized system provides simple and easy step by step approach for guidance for correct diagnosis and cheap management of diseases of jute at the users' level.

Integrated crop management in jute

Integrated crop management (ICM) is not a singular approach but encompasses all good agricultural practices from sowing to harvesting in judicious and compatible manner. It emphasizes the coexistence of crop and pests and pathogens at below economic threshold level (ETL) instead of eradication and no chemical harmful to environment is used. ICM is the prime requirements for promoting sustainable agricultural development. ICM protects and conserves the environment including natural enemies and biodiversity and make plant protection feasible, safe and economical even for the small and marginal farmers. ICM is highly effective, economically feasible and ecologically sound and sustainable over a long period of time and prevents development of resistance against pesticides, resurgence of pests, reduces residue hazards of pesticides. It does not upset the

balance of nature. ICM includes profitable management of crop with respect to environment. It is a dynamic system suited to local soil, climate and economic conditions (Pandit *et al.*, 2004).

Schedule of ICM in jute

- (1) Land preparation:** Deep ploughing and exposure of the soil to sun as long as possible and preparation of the land to a moderate tilth. Based on soil test report, apply lime or gypsum @ 2 – 4 tonnes /ha one month in advance, if the soil pH is above 5.8. Soil application of bleaching powder $[Ca(OCl)_2]$ at the rate of 25 – 30 kg per hectare 7 days ahead of sowing is a new option for areas with record of high stem rot and Hooghly wilt occurrence. Jute may be grown in medium to upland situation, as in low lying land jute performs poorly. In problematic areas, soil solarization may be practiced too. Adopt green manuring with sunnhemp or *dhaincha*. Use FYM or organic manure during land preparation. Use neem or mahua cake.
- (2) Seed treatment:** with carbendazim 50 WP @ 1.0 g kg⁻¹ or *Trichoderma viride* (formulated product on talc) @ 10 g kg⁻¹. Process of seed treatment of jute with carbendazim 50 WP @ 1.0 g kg⁻¹ is shown in Figure 18 with treated seed at the right.

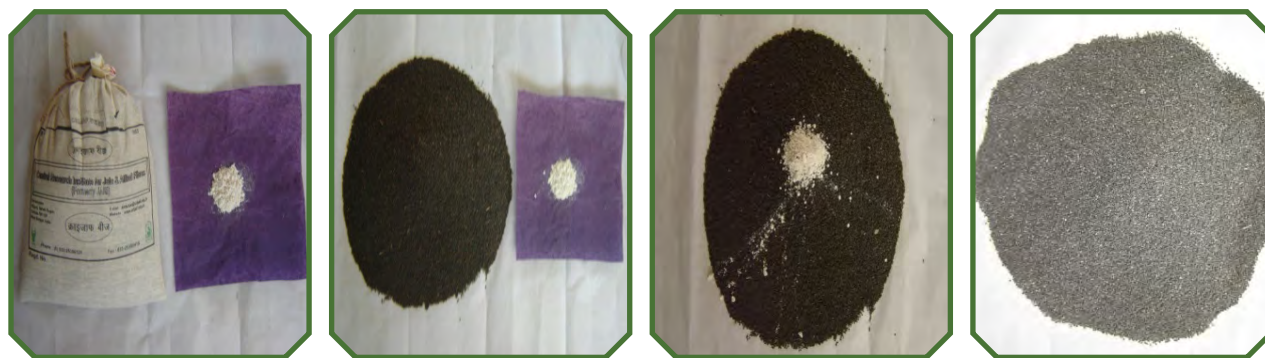


Figure 18. Process of seed treatment of jute with carbendazim 50 WP @ 1.0 g kg⁻¹, treated seed at the right.

- (3) Fertilizer application:** 60 (30 basal + 15 top dressing after first weeding + 15 top dressing after second weeding): 30: 30 = NPK kg ha⁻¹ along with FYM compost @ 5 t ha⁻¹
- (4) Sow jute** in middle of March to middle of April, preferably, in line with CRIJAF multi row jute seed drill (30 cm row spacing), as early sowing invites more stem rot disease.
- (5) Weeding:** Twice either manually at 15 and 30 days after sowing or by pre-emergence (pretilachlor or butachlor) and/or post- emergence (quizaliofop ethyl) herbicides.
- (6) Thinning** to desired plant population (5 – 6 lakh ha⁻¹ i.e. 5 – 6 cm plant to plant and 50 – 60 plants per square m). Dense plant population brings more diseases. Thin out the weak plants.

- (7) **Visit fields regularly** for close monitoring of insect and disease incidence.
- (8) **Foliar spraying of fungicides:** If the diseases exceed ETL of 2 %, foliar spray is advisable all over the field. Spray carbendazim 50 WP @ 1.0 g Litre⁻¹ of water or copper oxychloride 50 WP @ 3.0 - 4.0 g Litre⁻¹ of water. Spraying of newer fungicides, namely, tebuconazole @ 1.5 – 2.0 ml or hexaconazole @ 1.5 – 2.0 ml or propiconazole @ 1.5 – 2.0 ml per Litre of water are also very effective. Avoid repeated spraying of same pesticides in the same crop season, preferably systemic ones, to delay development of resistance. Spray mixture of 600 – 750 litres/ ha (for hand sprayer) depending on crop canopy.
- (9) Spray suitable **insecticides** for managing insect pests when their level goes above ETL of 10 % infestation.
- (10) Use **biological control** agent, namely, *Trichoderma viride* or *T. harzianum* or *T. virens* or *Pseudomonas fluorescens* or *Bacillus subtilis* or *Aspergillus niger* AN 27 as soil application or seed treatment formulations either alone or in compatible combinations or through FYM.
- (11) **Harvest** jute at 110 – 120 days for better fibre yield and quality, as older crop may produce more fibre yield but of poorer quality.
- (12) Clean cultivation by removing the leftover of all previous crops and destruction by burying under the soil, etc. are essential to reduce primary inoculum.
- (13) Follow long term **crop rotation** with non-host crop with paddy as the second crop.
- (14) **Rogueing** out of infected plants with burning or burying under soil when the disease is below ETL is very important.
- (15) Few **lines of jute are promising** against stem rot under multi-location testing. They are OIN 125, OIN 154, OIN 651 and OIN 853 in *olitorius* and CIM 036, CIM 064, CIN 109, CIN 358, CIN 360, CIN 362, CIN 371, CIN 386 and CIN 439 in *capsularis*.
- (16) **Good agricultural practices**, namely, clean cultivation, removal of previous crop debris, use of healthy seeds, timely sowing in line, FYM, balanced fertilizer, timely weeding, thinning, rogueing of infected plants, regular field visit for monitoring, good drainage, soil solarization, etc. are very important for a good and healthy crop.
- (17) Complete the retting process with **CRIJAF SONA™** powder in slow flowing water for 10-15 days, wash the fibre in clean water and dry it properly.

Future research strategy

Following research strategies deserve immediate attention for effective management of economically important diseases of jute crop in future.

- Quantification of losses caused by diseases either singly or collectively for assigning them major or minor status,
- Development of weather based disease forecasting and prediction models,
- Ecofriendly and sustainable options for disease management utilizing biological agents, botanicals (specific biomolecules) and PGPR, etc.,
- Sources and inheritance pattern of resistance and susceptibility for single and multiple diseases,
- Integrated crop management strategy including insects pests, diseases, weeds, soils, water stress, marketing, etc.,
- Development of easy kit for disease diagnosis based on serological and DNA probes at field level,
- Molecular characterization of pathogenic variability and identification of races of different pathogens across the different host crops,
- Cross infectivity of pathogens with large host range and role of other host crops in survival and evolution of virulence of pathogens,
- Newer alternative chemicals and non-chemicals, nano-particles, etc. for disease management.

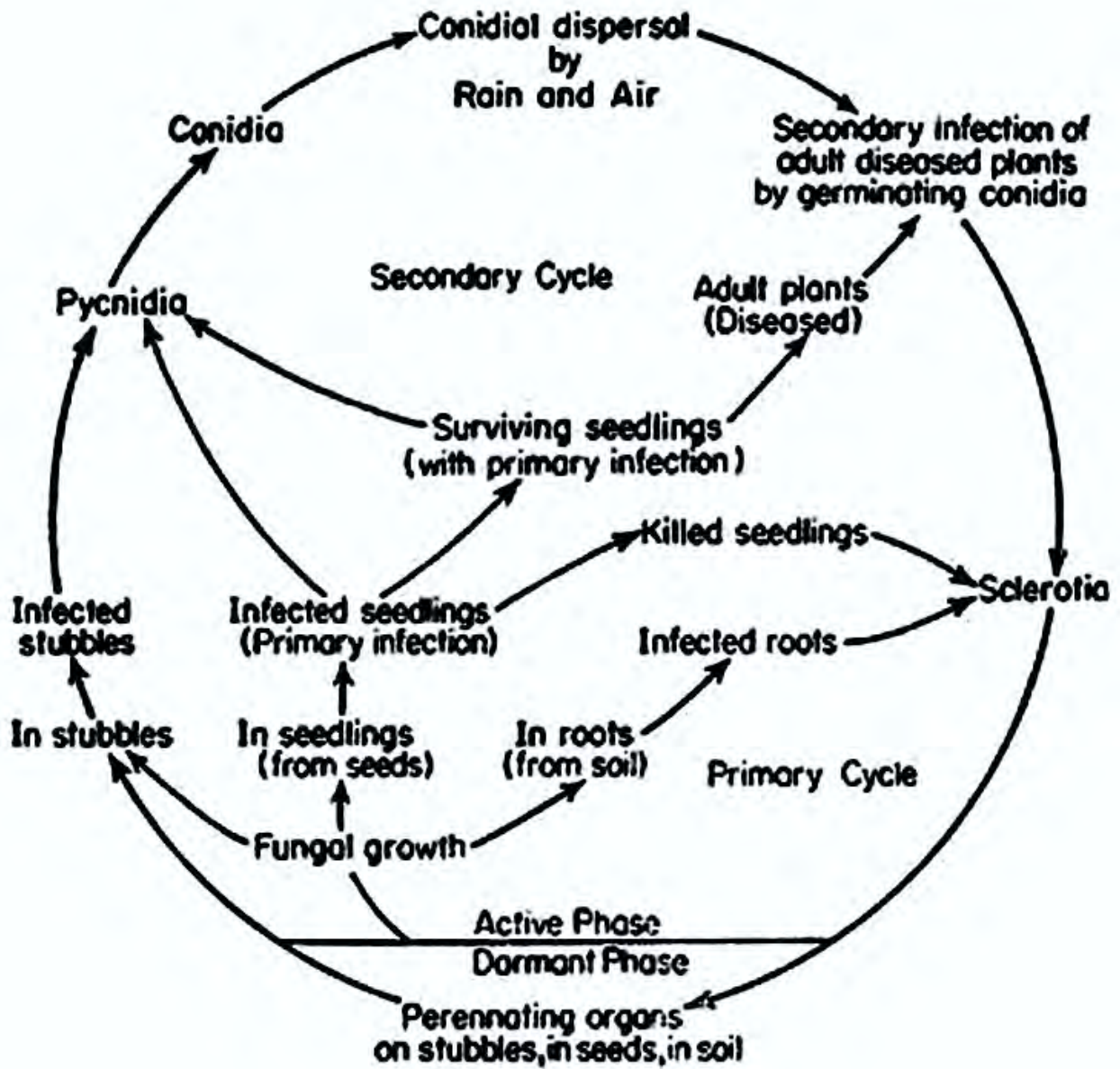
References

1. Bandopadhyay, A. K., De, R. K., and Bhattacharya, S. K. (2008). Beneficial traits of PGPR mediated strategy for disease management and enhanced plant growth in bast fibre crops. *J. Mycopathological Res.* **46**(1): 143.
2. Bandopadhyaya, A. and Das, N. (2017). Plant growth promoting microbial consortial formulations mediated biological control of stem and root rot disease of jute caused by *Macrophomina phaseolina* ((Tassi.) Goid. *International Journal of Current Science* **20**(1): E 1-15 ISSN 2250-1770.
3. Bhattacharya, S. K.; Sen, K.; De, R. K.; Bandopadhyaya, A.; Sengupta, C. and Adhikary, N.K. (2017). Integration of biocontrol agents with fungicides, weedicides, and plant growth regulators for management of stem and root rot of jute. *Journal of Applied & Natural Science jansfoundation.org/9*(2): 899-904.
4. Biswas, C., Dey, P., Mandal, K., Satpathy, S and Karmakar, P. G. (2014). In planta detection of *Macrophomina phaseolina* from jute (*Corchorus olitorius*) by a sodium acetate-based direct PCR method. *Phytoparasitica*, **42** (5): 673–676 DOI: 10.1007/s12600-014-0407-4
5. Biswas, C., Dey, P.; Satpathy, S., Sarkar, S. K., Bera, A. and Mahapatra, B. S. (2012). A simple method of DNA isolation from jute (*Corchorus olitorius*) seed suitable for PCR-based detection of the pathogen *Macrophomina phaseolina* (Tassi) Goid. *Letters in Applied Microbiology* **56**, 105--110 © 2012 ISSN 0266-8254.
6. Chakraborty, A. K.; Ghorai, A.K.; De, R.K.; Chakraborty, S.; Jha, S.K.; Mitra, S. and Goswami, K. K. 2013. Expert System for Integrated Stress Management in Jute (*Corchorus Olitorius* L. and *C. Capsularis* L.). *International Journal of Bio-Resource and Stress Management* **4**(2): 192-200.
7. De, R. K. (2012). Botanicals as good alternative to manage stem rot of jute (*Corchorus olitorius* L. *C. capsularis* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. Paper presented at National symposium on Blending conventional and modern plant pathology for sustainable agriculture held at Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bangalore 560089 on 4 - 6 December, 2012 P10 p 130.
8. De, R. K. (2013). Effect of date of sowing on the incidence of stem rot of jute (*Corchorus olitorius* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. *Journal of Mycopathological Research* **51**(2) : 251—257, 2013; (ISSN 0971-3719).
9. De, R. K. (2014). Search for new fungicides against Stem rot of jute (*Corchorus olitorius* L. and *C.capsularis* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. *Journal of Mycopathological Research*, **52**(2) : 217-225, (ISSN 0971-3719).
10. De, R. K. (2016). Comparison of three methods (leaf, soil and stem) of inoculation for stem rot jute (*Corchorus olitorius* L. and *C. capsularis* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. *Journal of Mycopathological Research* **54**(1): 67-69.
11. De, R. K. (2017). Effect of different NPK fertilizer schedules on the stem rot of jute (*Corchorus olitorius* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. *Journal of Mycopathological Research* © Indian Mycological Society **55**(1): 67-72, 2017; ISSN 0971-3719.
12. De, R. K. and Ghorai, A. K. (2017). Bleaching powder [Ca(OCl)₂], a new option for management of Stem rot of Jute (*Corchorus olitorius* L. and *C. capsularis* L.) caused by *Macrophomina phaseolina* (Tassi) Goid. *J. Mycopathol. Res.* © Indian Mycological Society. **55**(1): 1-8, 2017; (ISSN 0971-3719).
13. De, R. K. and Ghorai, A. K., (2019). Management of Jute (*Corchorus olitorius* L.) Stem Rot caused by *Macrophomina phaseolina* (Tassi) Goid – Comparison of Fungicides with Bleaching Powder. In abstracts poster presentations of NAAS XIV Agricultural Science Congress, NASC Complex,

- Dev Prakash Shastri Marg, Pusa, New Delhi from February 20-23, 2019 on “Innovations for Agricultural Transformation”. Abstract No. 1419. p 729.
14. De R. K. and Mandal, R. K. (2012a). Identification of resistant sources of jute (*Corchorus olitorius* L.) against stem rot caused by *Macrophomina phaseolina* (Tassi) Goid. *Journal of Mycopathological Research* **50**(2): 217- 222.
 15. De, R. K., and Mandal, R. K. (2012b). Seed infection of jute (*Corchorus olitorius*, *C. capsularis*) and its management. *J. Mycol. Plant Patholo.* **42**(4): 541.
 16. De, R. K. and Tripathi, A. N. (2016). Effect of Plant Population Density and Sowing Methods on Stem Rot of Jute (*Corchorus olitorius*, *C. capsularis*) Caused by *Macrophomina phaseolina* (Tassi) Goid. *International Journal of Tropical Agriculture* © Serials Publications, ISSN: 0254-8755. Vol. 33, No. 4: 1-4.
 17. De, R. K., Bandopadhyay, A., Bhattacharya, S.K., Biswas, B.; Mitra Roy, P.; and Bandopadhyay, A.K. (2009). Investigation on some botanicals and safer chemicals for the management of jute and mesta pathogens. Paper presented in Fifth international conference on Plant Pathology in the globalized era held at New Delhi on 10- 13 November, pp. 369. 693 (S-15).
 18. Laha, S. K., Mandal. R. K., and Dasgupta, M. K. (1995). Studies on the varietal susceptibility of jute against root- knot nematode and root- rot disease under field condition. *Indian Biol.* **26**(2), 27-29.
 19. Mandal, R. K. (2001). Seed borne fungi of jute. *J. Interacad.* **5**(3), 402- 405.
 20. Mandal, R. K. and Mishra C. D. (2001). Role of different organisms in inducing Hooghly wilt symptom in jute. *Environ. Ecol.* **19**(4), 969-972.
 21. Mandal, R. K., Sarkar, S., and Saha, M. N. (2000). Field evaluation of white jute (*Corchorus capsularis* L.) germplasm against *Macrophomina phaseolina* (Tassi) Goid under Sorbhog condition. *Environ. Ecol.* **18**(4), 814-818.
 22. Mandal, R. K., Sinha, M. K., Guha Ray, M. K., Mishra, C. B. P., and Chakrabarty, N. K. (1998). Variation in *Macrophomina phaseolina* (Tassi) Goid. causing stem rot of jute. *Environ. Ecol.* **16**(2), 424-426.
 23. Meena, P. N.; Roy, A.; Gotyal, B. S.; Mitra, S. and Satpathy, S. (2014). Eco-friendly management of major diseases in jute (*Corchorus olitorius* L.) *Journal of Applied and Natural Science* **6** (2): 541-544.
 24. Meena, P. N., De, R. K., Roy, A., Gotyal, B. S., Satpathy, S. and Mitra, S. (2015). Evaluation of stem rot disease in jute (*Corchorus olitorius*) germplasm caused by *Macrophomina phaseolina* (Tassi) Goid. *Journal of Applied and Natural Science* **7** (2): 857 – 859.S
 25. Palve, S. M., Sinha, M. K., and Mandal, R. K. (2004). Sources of stem rot *Macrophomina phaseolina* (Tassi) Goid. resistance in wild species of jute. *Trop. Agric. (Trinidad)*. **81**(1), 23-27.
 26. Pandit, N. C., Mandal, R. K., Ghorai, A. K., Chakraborty, A. K., De, R. K., and Biswas, C. R. (2004). Impact of integrated pest management in jute and mesta. Paper presented in “National seminar on raw jute” held between April, 16 and 17 at CRIJAF, Barrackpore, pp. 51-55.
 27. Roy, A., De, R.K. and Ghosh, S.K. (2008). Diseases of bast fibre crops and their management. In book, Jute and allied fibres updates, production and technology. Central Research Institute for Jute and Allied Fibres, (Indian council of Agricultural Research), Barrackpore, Kolkata 700120, India. pp. 217 – 241.
 28. Sarkar, S. K.; Chowdhury, H. and Satpathy, S. (2016). Disease-Free Jute Seed Production in West Bengal. *Bangladesh J. Bot.* **45**(3): 561-565.
 29. Srivastava, R. K.; Singh, R. K.; Kumar, N. and Singh, S. (2010). Management of *Macrophomina* disease complex in jute (*Corchorus olitorius*) by *Trichoderma viride*. *Journal of Biological Control*, **24** (1): 77–79, 2010.

Appendix I

Disease cycle of stem rot of jute



Appendix II

Ready reckoner of fungicides in disease management of jute *in vitro*

Disease	Pathogen	Fungicides	Maximum dosage (µg/ml) tested*	Dosage (µg/ml*) causing 100 % inhibition	Remarks	May be recommended (Yes / No)
Stem rot	<i>Macrophomina phaseolina</i>	Thiram	5000	2000	OK	Yes
		Carbendazim 50 WP	5000	25	Excellent	Yes
		Copper oxychloride 50 WP	5000	50	Very good	Yes
		Mancozeb 75 WP	5000	-	-	No
		Hexaconazole EC	1000	100	Good	Yes
		Tebuconazole EC	1000	50	Very good	Yes
		Propiconazole 25 % EC	10000	10	Excellent	Yes
		Tricyclazole 75 % WP	10000	10000	Poor	No
		Turmeric oil	10000	10	Excellent	Yes
		Curcumin mixture	10000	100	Very good	Yes
		Bleaching powder [Ca(OCl) ₂]	5000	5000	Excellent	Yes
		Dorina – Organic fungicide	25 000	10000	Very good	Yes
Stup – Organic fungicide	10 000	-	-	-		
Black band	<i>Botryodiplodia theobromae</i>	Carbendazim 50 WP	1500	5	Excellent	
		Copper oxychloride 50 WP	5000	-	-	No
		Mancozeb	5000	2000	OK	Yes
Soft rot	<i>Sclerotium rolfsii</i>	Carbendazim 50 WP	1500	-	Poor	No
		Mancozeb 75 WP	2000	2000	Good	Yes
		Copper oxychloride 50 WP	5000	-	Poor	No



Appendix III

Jute crop calendar*

Time	Feb	Mar	Apr		May	Jun	Jul	Aug
Soil/ Field	Deep ploughing/ exposure to sun + FYM/ Compost / Lime/Green manuring	Basal NPK=26:40:40/ha + Bleaching powder	First weeding at 15 DAS + Top dressing N 27 kg/ha	Second weeding at 45 DAS + Top dressing N 27 kg/ha				
Crop			Sowing		Thinning to 50- 60 plants / sq m		Har-vesting	Retting
Stem rot			Seed treatment with Carben-dazim @2 g/L		Spray Carben-dazim @2 g/L	Spray Tebuco-nazole @2 ml/L		
Insect pests				Spray profenophos /chloropyriphos @2ml/L	Spray chlo-ropyri-phos+-cyper-methrin @ 1.5ml/L			
Yellow mite					Spray Spiro-mecifen @ 1ml/L			
Weeds		Pre-emergence application of buta-chlor @3ml/L within 48 hr of sowing in moist soil		Post-emergence appli-cation of quizalofop ethyl @ 2ml/L at 15-20 DAS				

*Timing of each operation is based on past experience and may be finalized to suit local factors and conditions.





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