PIGEONPEA WILT AND ITS MANAGEMENT : A REVIEW

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Pigeonpea [*Cajanus cajan* (L.) Millspaugh] is the fifth prominent pulse crop in the world and second most important pulse crop after chickpea in India. Pigeonpea crop suffers from over 210 pathogens (83 fungi, 4 bacteria, 19 viruses and mycoplasma and 104 nematodes) reported from 58 countries (Reddy *et al.*, 1990; Nene *et al.*, 1996). The major diseases that assume significant importance include wilt (*Fusarium udum* Butler), sterility mosaic (Pigeonpea sterility mosaic virus) and phytophthora blight (*Phytophthora drechsleri* Tucker f. sp. *cajani* Kannaiyan *et al.*). Among these, wilt is the most serious disease causing irreversible losses and lethal damage to crop.

The causal organism

The wilt of pigeonpea was recorded for the first time in India by Butler (1906). The causal organism described initially as *Fusarium udum* by Butler (1910), was subsequently described as *F. butleri*, *F. uncinatum*, *F. lateritium* var. *uncinatum*, *F. oxysporum* f. sp. *udum*, *F. lateritium* f. sp. *cajani* and *F. udum* f. sp. *cajani* (Vishwa Dhar *et al.*, 2005). However, the name *F. udum* was accepted as an imperfect state (Booth, 1971) because of the macro-conidia having well distinguished prominent hook. *Fusarium udum* is host specific to pigeonpea (Padwick, 1940; Subramanian, 1963; Booth, 1971).

Cultural, Morphological and Pathogenic Variability in the Pathogen

Baldev and Amin (1974) revealed differential response of pigeonpea varieties and pathogenic races of *F. udum*. Shit and Gupta (1980) reported that seven isolates of *F. udum* from pigeonpea collected from different regions of India varied in cultural characters such as aerial mycelium, texture and their ability to sporulate. Further, they noted that isolates producing scanty mycelium were more pathogenic with no correlation between intensity of sporulation and pathogenicity and thus, suggested the existence of physiologic races of *F. oxysporum* f. sp. *udum* on the basis of pathogenic behaviour. Pawar and Mayee (1983) collected 25 isolates of *F. udum* and reported that isolates were pathogenic and distinguished into five categories on the basis of virulence. Patil (1984) reported an average size of micro-conidia measuring 9.4-12.0 x 3.1-3.3 µm while, macro-conidia measured 19.2 x 3.5-5.0 µm. The pigmentation of the culture growth of *F. udum* was mostly whitish. Reddy and Chaudhary (1985) studied the strain variation in six isolates of *F. udum* and noted that five isolates were fast growing. All the isolates produced moderate to excellent sporulation. Among the six isolates, macro-conidia in two isolates were bigger in size with 2-5 septa. Evaluations of 71 isolates of pigeonpea wilt pathogen revealed great deal of variation and were categorized into seven groups on the basis of colony characteristics, growth rate, sporulation, dry mass and pathogenic virulence when seven cultivars were inoculated (Kotasthane *et al.*, 1988). Gaur and Sharma (1989) reported that *F. udum* isolates differed in their cultural and morphological characters with marked diversity in virulence towards susceptible variety T-21. Rajendra and Patil (1992) observed variation in micro- and macro-conidia in different isolates of *F. udum*. Micro-conidia measured from 3-4 X 1-2 µm to 12-13 X 4-5 µm and macro-conidia measured from 7-9 X 3-4 µm to 37-39 X 3-4 µm. The pigmentation was mostly whitish except few isolates having pinkish colour. Pathogenicity of these isolates on ten pigeonpea cultivars exhibited pathogenic variation (Rajendra and Patil, 1993). Okiror and Kimani (1997) verified diversity in *F. udum* in Kenya using several isolates. Das and Sengupta (1998) reported that although variability existed in the cultural characteristic of test isolates, some features like abundant production of micro-conidia and formation of chlamydospores were common. Joshi (2000) concluded that the pathogenic races of *F. udum* of Nepalgunj and Sarlahi were two distinct types as they showed different types of reaction to pigeonpea differential lines. Madhukeshwara and Sheshadri (2001) described six isolates of *F. udum* with distinct colony characteristics, pigmentation and sporulation. The size of micro- and macro-conidia varied from 18-21 X 4-5 µm and 23-26 X 4-5 µm, respectively. Pigmentation was noticed from white to dusky red.

The 56 isolates of *F. udum* collected from various districts of Kenya showed a high level of variability in aerial mycelia growth, pigmentation and colony diameter. The aggressiveness of 17 isolates on seven pigeonpea varieties varied and five aggressive groups were reported with no relationship among cultural characteristics and aggressiveness (Kiprop *et al.*, 2002). Shashi Mishra and Vishwa Dhar (2003) characterized 17 isolates of *F. udum* on the basis of variation in size and septation of macro-conidia in to three group's *viz*., smaller conidia, medium conidia and large conidia. They also observed that isolates with large conidia and more septation were most virulent causing 100 per cent mortality; medium conidia were moderately virulent causing 76.5 per cent wilting and smaller conidia were less virulent causing 55.5 per cent wilting in inoculated plants. Forty-eight isolates of *F. udum* studied for their cultural, morphological and pathogenic variability revealed that 13 isolates were fluffy, 17 were moderately fluffy, 6 were appressed and 12 were intermediary types. Pigmentation in substratum also varied appreciably. The isolates were grouped in different five categories based on length of macro-conidia. Pathogenicity test of these isolates on a susceptible cultivar Bahar revealed that 32 isolates were highly virulent (> 75 % wilt), 9 moderately virulent (51-75 % wilt) and 7 were weakly virulent (up to 50 % wilt) (Vishwa Dhar *et al.*, 2007).

The results of 195 isolates of *F. udum* revealed that 135 were highly pathogenic (> 50 % wilt), 33 moderately pathogenic (30-50 % wilt) and 32 were weak pathogenic (<30 % wilt) (Anonymous, 2007-08). Variation with respect to mycelial colour, pigmentation and colony characters among 41 isolates of *F. udum* collected from different parts of India were reported (Mahesh *et al.*, 2010). Shashi Tiwari and Vishwa Dhar (2011) observed wide range of cultural, morphological and pathogenic variability among 51 isolates and noted differential response to 10 genotypes and described them as new variants of *F. udum.*

Symptomatology

The disease appears in early stage of plant growth (Nene *et al.*, 1979) as gradual or sudden withering and drying. Butler (1906) and Kotasthane and Gupta (1981) reported association of flowering with wilt incidence.

Management

(i) Host Plant Resistance

Observations on resistance of pigeonpea varieties to wilt disease was reported earlier by Butler (1908), who observed that few strains of pigeonpea showed promise and were found to be somewhat resistant to wilt disease. Ravishanker (1936) described EB-38, a strain from CP type 9 possessing the greatest resistance to wilt disease of pigeonpea. Field tests conducted at different locations indicated that NP (WR)-15, apart from maintaining high yield, had a high degree of wilt resistance (Deshpande *et al.*, 1963). Subramanian (1963) reported NP-15 as least susceptible to wilt since no spores were produced due to lack of proper substrate in the root system or the action of some inhibitory substance in the xylem in that variety. Screening of 58 varieties of *Cajanus cajan* for resistance to *Fusarium udum* revealed that none was resistant, but nine were moderately resistant (Mukherjee *et al.*, 1971). Raut and Bhombe (1971) documented twelve selections (Seven Bori-11 selections, Tuljapur 455, Latur 466-I, Latur 467-II, DT-230 and MXK-132) showed considerable degree of resistance to wilt. Bhargava (1975) reported pigeonpea varieties Kanke-9 and Kanke-3 as resistant and moderately resistant to wilt disease, respectively. Singh and Mishra (1976) described that pigeonpea varieties *viz.*, C-1, C-28, C-36, F-18, NP (WR)-15, NP-41 and T-17, which were earlier described as resistant or tolerant to wilt have proved susceptible, however, lines viz., Bori-192-12-5-1-2 and Bori-192-15-2-2-11-42 were moderately resistant. Murthy and Bhagyaraj (1980) reported that total alkaloids and flavanols were more concentrated in the resistant pigeonpea cv. C-11-6 than in the susceptible cv. TS-136-1. Among the 90 elite and diverse *Cajanus cajan* lines planted in a plot having inoculum of *Fusarium udum,* 14 were reported as resistant. The most promising line Purple-1 (Malaviya Arhar-1) showed multiple resistant reaction for wilt and sterility mosaic (Venkateswaarlu *et al.*, 1980). Evaluation of highly susceptible pigeonpea varieties *viz.*, AS-3, HY-2 and JA-7 belonging to early, medium and late maturity groups indicated increased early mortality due to wilting in AS-3 compared to HY-2 and JA-7 (Kotasthane and Gupta, 1981). Nene and Kannaiyan (1982) screened more than 11000 entries of *Cajanus cajan* and reported 33 as resistant to *F. udum.* Lines ICP 7182, ICP 7336, ICP 8863, ICP 8869 and BDN 1 had less than 5 per cent incidence compared with more than 90 per cent incidence in the susceptible control ICP 2376 (Zote *et al.*, 1983). Evaluation of 100 lines of pigeonpea for resistance to wilt revealed that ICP 8863 was the most resistant and suitable for use in breeding programme (Haque *et al.*,1984; Konda *et al.*, 1986). Dasgupta and Sengupta (1988) studied the reaction of 21 *Cajanus cajan* lines for resistance to *F. udum* and reported that 6 lines *viz.*, ICP 8863, ICP 10957, ICP 10958, ICP 11290, ICP 11292 and ICP 11294 showed no wilt symptoms, 4 had low (5-25 %) and 5 had very high (75-100 %) wilt incidence. Among the 61 promising lines of pigeonpea evaluated in a wilt sick plot, 2 lines *viz.*, GAUT 82-9 and GAUT 82-74, were free from infection (Patel *et al.*, 1988). Screening of 950 genotypes of pigeonpea for resistance to *F. udum* revealed that none was free from the disease, but 19 had less than 10 per cent wilt incidence, which were graded as resistant (Agrawal *et al.*, 1991). Rajendra and Patil (1993) revealed that out of 31 pigeonpea cultivars screened, 16 cultivars were resistant to wilt, while 14 were observed moderately resistant. The cultivar BWR 369 recorded the highest degree of resistance (2.15 %) to wilt as compared to susceptible check N-290-21 (61.80 %). Evaluation of 40 cultivars and lines of pigeonpea to wilt caused by *F. udum* revealed that lines ICP 8863, ICP 8864, ICP 7942 and ICP 11295 were resistant, while remaining lines varied in their susceptibility to the disease (Chavan *et al.*, 1995). Reddy and Raju (1996) recorded only 7 per cent wilt incidence in resistant cv. ICP 8863 compared to 83 per cent in susceptible cv. ICP 2376. A short duration genetic male sterile line ICPM 93003 was reported as resistant to wilt and sterility mosaic and could be used in developing short duration disease resistant pigeonpea hybrid. (Saxena *et al.*, 1998). Chaudhary and Kumar (2000) reported that xylem vessels and vascular bundle of susceptible genotypes were significantly wider and roots were significantly thicker than genotypes that were resistant to *F. udum*. The research efforts of NARS in association with the ICRISAT resulted in identification of resistance sources from which several cultivars were evolved (Vishwa Dhar and Chaudhary, 2001). A total of 216 late maturing pigeonpea germplasm were screened for multiple disease resistance and reported that KAWR-1, KAWR-2, KAWR-7, KAWR-16, KAWR-45 and KAWR-73 were resistant to wilt caused by *F. udum* (Mishra *et al.*, 2003). Screening of 226 pigeonpea genotypes to assess their resistance reaction elucidated that 105 genotypes were resistant (0 – 10 % wilt), 33 genotypes were moderately resistant (10 – 30 % wilt) and 88 genotypes were susceptible (> 30 % wilt) (Madhukeshwara *et al*. 2004). Evaluation of 46 pigeonpea genotypes in artificially infected plots by growing the susceptible hedge of pigeonpea (ICP 8863) revealed that PT 25-2, PI-25, BSMR-841, BSMR-23, IPA-40 and KPL-43 were resistant to *fusarium* wilt and sterility mosaic (Mandhare *et al.* 2005).The study on evaluation of new elite pigeonpea germplasm against wilt in three different countries using wilt sick plots revealed that the genotype ICEAP 00040 consistently showed a high (< 20.0 %) level of resistance to the disease in all the three countries compared to 87.5, 92.0 and 90.9 per cent wilt score for the susceptible genotype ICEAP 00068 in Kenya, Malawi and Tanzania, respectively (Gwata *et al.*, 2006).

(ii) Biological control

Sumitha and Gaikwad (1995) reported that *Trichoderma harzianum* showed maximum zone of inhibition and inhibited spore germination completely at 8.42 X 10^7 spores per ml. They further noted that this antagonist did not show any adverse effect on germination of pigeonpea seeds with increased shoot and root length. Bhatnagar (1996) studied antagonistic activity of three *Trichoderma* species against *F. udum* at different temperatures, pH and C/N ratios and reported that all the isolates were almost equally efficient antagonists and showed maximum antagonistic potential at $35 \pm 2\ ^oC$ temperature and pH 6.5. Among the six isolates of *Trichoderma* spp. evaluated against *F. udum* by adopting two delivery system *i.e.* seed treatment and soil application, seed treatment with *Trichoderma viride* isolate H reduced the *F. udum* propagules from 19.4 X 10^2 to 2.5 X 10^2 cfu/g of soil, whereas *T. hamatum* reduced *F. udum* propagules from 10.9 X 10^2 to 4.9 X 10^2 cfu/g of soil and wilt incidence ranged from 7.3 to 15.5 per cent after the 35^{th} day of inoculation (Somasekhara *et al.*, 1996). Bidari and Gundappagal (1997) reported that seed treatment with *Trichoderma viride* to resistant cultivar was effective in integrated management of pigeonpea wilt under dryland cultivation. Pandey and Upadhyay (1997) evaluated several bio-agents and reported that a volatile compound produced by *T. viride* was most fungitoxic to wilt pathogen followed by *Gliocladium virens*. They further observed that non-volatile antibiotics of *T. viride* was highly toxic followed by *T. harzianum*, *T. viride, T. harzianum* and *T. koningii* were effective among the twelve *Trichoderma* isolates evaluated against *F. udum* (Somasekhara *et al.*, 1998). Biswas (1999) concluded that T_1 isolate of *T. harzianum* was effective antagonist among nine isolates evaluated against *F. oxysporum* f. sp. *udum.* Biswas and Das (1999) reported that *T. harzianum* was most effective antagonist followed by *T. hamatum, T. longiconis* and *T. koningii* among the five species of *Trichoderma* evaluated under *in vitro* dual culture against *F. udum*. They further noted that seed treatment of pigeonpea with *T. harzianum* spores failed to reduce wilt, whereas augmentation of soil with *T. harzianum* in maize meal : sand medium @ 40-60 g/kg soil resulted in a significant reduction of wilt incidence up to 89 per cent. Inhibition in growth of *F. udum* was highest with *T. viride* 1 (38.3 %) followed by *T. viride* 2 (35.3 %) (Singh *et al.*, 2002). Soil application of *T. harzianum* was more effective than seed treatment for disease suppression, thus, suggested the need to augment soil application of *T. harzianum* for obtaining effective control of pigeonpea wilt (Prasad *et al.*, 2002). Gholve and Kurundkar (2002) enumerated the compatibility of *T. viride* with eleven local isolates of *Pseudomonas fluorescens* and proved its usefulness in managing pigeonpea wilt. Local isolate of *T. harzianum* (L1) was the most promising and showed maximum inhibitory effect on mycelial growth (88.69 %) of *F. udum* as well as lowest incidence (20.37 %) of wilt in pots where seed treatment was given (Jayalakshmi *et al.*, 2003). Singh and Singh (2003) reported highest reduction (26.1 %) in the radial growth of *F. udum* with *T. harzianum* followed by other bio-agents tested. Comparison of different products of biological control agents, *Trichoderma* spp. against wilt of pigeonpea revealed that all the products reduced wilt incidence, however, seed treatment with phule Trichokill at 8 g per kg seed recorded the highest seed germination and lowest wilt incidence (Sawant *et al.*, 2003). Bio-intensive integrated pest management package including seed treatment of *Trichoderma* @ 4 g per kg seed reduced the incidence of pigeonpea wilt (Agrawal *et al.*, 2003). Khan and Khan (2003) observed differential response of *T. harzianum, T. virens, Pseudomonas fluorescens* and *Bacillus subtilis* in controlling fusarium wilt of pigeonpea and recorded decreased wilt incidence ranging from 17 to 48 per cent. Chaudhary and Prajapati (2004) evaluated six biological control agents against *F. udum* and reported that maximum colony growth inhibition in dual culture was obtained with *Gliocladium virens* (Pantnagar) and *Trichoderma viride* (Coimbatore). They also noticed that cultural filtrate of all the six biological control agents inhibited colony growth of *F. udum* by 18.1- 53.6 % at different concentration.Seeds treated with dry powder of *Trichoderma viride* at 4 g/kg before sowing significantly reduced wilt disease in all the cultivars of pigeonpea compared to untreated control (Mahalinga *et al.*, 2004).

Mandhare and Suryawanshi (2005) reported that application of *Trichoderma* spp. as seed and soil application was found effective showing 63.25 per cent wilt reduction. Roy and Sitansu (2005) documented that among the mutant isolates of *T. harzianum*, $50Th_3II$ (36.51 %) and $125Th_4I$ (33.86 %) significantly reduced the wilt disease over control in non-sterilized soil, while $75Th_4IV$ (33.33 %) was most effective in sterilized soil. Three bioagents *viz.,Trichoderma viride*, *Trichoderma harzianum* and *Gliocladium virens* varied in their efficacy in relation to ten isolates of *F. udum*. After 96 hrs of incubation, the per cent reduction in radial growth of ten isolates ranged between 35.5 - 54.8 against *T. viride,* 36.4 - 54.7 against *T. harzianum* and 36.4 - 57.3 against *G. virens* (Vishwa Dhar *et al.,* 2006). Seed treatment with *Trichoderma harzianum* @ 4 g/kg seed had significantly lower wilt incidence of 52.7 and 52.1 % compared to control (53.9 and 53.3 %) during first and second year, respectively (Gade *et al.*, 2007). Shukla and Chaudhary (2007) studied the efficacy of 30 different

Trichoderma isolates against *F. udum* and reported that two isolates showed highest colony growth reduction of 65.5 to 67.2 per cent, seven between 50 to 60 per cent and 21 isolates between 41-50 per cent. They further observed that eleven isolates reduced conidia production by >90 per cent. The culture filtrates of *Trichoderma* spp. also reduced > 90 per cent colony growth of *F. udum.* Hukma Ram and Pandey (2011) reported that *T. viride* and *Pseudomonas fluorescens* significantly reduced the growth of *F. udum.*

(iii)Use of Organic Amendments

Chauhan (1963) noted significant reduction in gram wilt incidence by amending the soil with de-oiledcakes of groundnut, til and mustard. Amendment of three oilcakes *viz.*, margosa, groundnut and mustard in soils infested with different cultures of *Fusarium* revealed that high dose of mustard and groundnut cake were inhibitory (Singh and Singh, 1970). Singh and Singh (1980) described that amendment of natural soil with autoclaved *Azadirachta indica* or *Ricinus communis* oilcakes, rice husk or saw dust with or without supplemental N greatly enhanced lytic effect of the fungus. Organic amendments in the form of oilcakes, crop residues, green manures and farm yard manure significantly reduced soil borne plant pathogens (Kotasthane and Gupta, 1986). Dasgupta and Sengupta (1989) reported that amendment with green manure (*Sesbania aculeata*) and de-oiled cakes (mustard and neem) reduced *F. udum* population and number of wilted plants of red gram. Chakrabarti and Sen (1991) used mustard cake (2 %), groundnut cake (1 %), margosa cake (2 %) and saw dust (1 %) as soil amendment for management of muskmelon wilt incited by *F. solani*. They reported that all the four organic amendments inhibited mycelial growth of *F. solani* under *in vitro* conditions. Further, they also noted that mustard cake reduced wilt incidence and pathogen population by 65 and 17 per cent, respectively. Tyagi and Alam (1995) evaluated the efficacy of de-oiled cakes of neem, castor, mustard and duan (*Eruca sativa*) against *F. oxysporum* f. sp. *ciceri* and reported that all the cakes significantly reduced the disease. Diyora and Khandar (1995) reported that mustard cake followed by groundnut cake was the most effective organic amendment for managing cumin wilt caused by *F. oxysporum* f. sp. *cumini*. Rai and Singh (1995) tested different oil cakes *viz.*, neem, mustard, mahua, coconut, linseed and sesamum at concentrations of 0.25, 0.5, 1.0 and 2.0 per cent against radial growth of *F. udum* and reported that neem, mustard and mahua cakes were most effective in reducing fungal growth. Further, they also reported that neem oilcake was most effective in controlling wilt incidence. Raj and Kapoor (1996) assessed groundnut, mustard, sesame and cotton seed oil cakes for their ability to reduce wilt of tomatoes caused by *F. oxysporum* f. sp. *lycopersici* and reported that groundnut and mustard oilcakes at 2 % concentration in soil (w/w) were most effective in reducing the pathogen population and disease incidence. However, groundnut oilcake was superior to mustard as it recorded higher reduction in disease index (77.1 %). Goudar and Kulkarni (1998) conducted pot experiment to determine the effect of organic amendments *viz.*, compost, Farm Yard Manure, groundnut oilcake and neem cake. They concluded that per cent plants affected by wilt were significantly less in the soil amended with different organic amendments (27.5 % in neem cake to 62.5 % in groundnut oilcake) compared to control (75.0 %). Padmodaya and Reddy (1999) reported that FYM and Neem cake were most effective against *F. oxysporum* f. sp. *lycopersici* causing seedling disease of tomato under glass house conditions. *F. udum* propagules were significantly decreased from 25.3 to 2.5 X 10^4 cfu per g in 35 days by *Pongamia sinensis* with wilt incidence of 6.6 and 20 per cent in unsterilized and sterilized soil, respectively compared to 93.3

per cent in control. The population of *Trichoderma viride* was significantly increased in tea waste and pongamia cake amended soil (Somasekhara *et al.*, 2000). Mayur and Deshmukh (2003) evaluated the efficacy of de-oiled mustard cake, groundnut cake and farm yard manure against *F. oxysporum* f. sp. *ciceri* and reported that all the soil amendments significantly reduced wilt incidence. Mori (2003) observed that mustard cake was most effective in inhibiting the radial growth of *F. oxysporum* f. sp. *momordicae*.Antifungal effects of organic amendments against *F. oxysporum* f. sp. *cubense* revealed that neem cake was most inhibitory to the mycelial growth of the pathogen followed by groundnut cake. In glass house experiment also, neem cake exhibited maximum reduction in the rhizosphere population of the pathogen and vascular discolouration index (Sarvanan *et al.*, 2004). Different oil cakes *viz.* mustard, sesamum and cotton were studied along with vermicompost and farm yard manure for their effect on *F. oxysporum* causing wilt of fenugreek. The results indicated that vermicompost was significantly superior in reducing the disease incidence (Mathur *et al.*, 2006). The combined effect of biological control agents *T. harzianum* and *T. viride* with aqueous neem leaf extract against *Alternaria solani*, *Fusarium oxysporum* and *Colletotrichum gloeosporioides* suggested that *T. harzianum* along with 10 and 50 per cent neem leaf extract resulted in 100 per cent inhibition of the growth of the test pathogens followed by *T. viride* with 50 per cent extract (Sharma *et al.*, 2008). Barakat (2008) reported that combination of *T. harzianum* and sheep manure reduced the total fungal population. He further observed that sheep manure alone was less effective in reducing bean damping-off and improving bean growth than a combination of both manure and *T. harzianum* isolate Jn14.

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