Major Pests of Pigeon Pea and Its Management

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ISBN: 978-81-19149-06-3

18. Major Pests of Pigeon Pea and Its Management

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Abstract:
Red gram is an annual crop cultivated and consumed mostly in developing countries across the world. It is widely grown in India, which is the world's top producer and consumer of this crop. Different pests have a negative influence on red gram productivity and are responsible for 30-80% of the projected yearly losses. Among them worst pests are the lepidopteran, hemipteran, dipteran, and coleopteran groups of insects. The chief diseases causing sizable losses are phytopthora blight, sterility mosaic, and fusarium wilt. The pigeon pea cyst nematode is a significant nematode pest of pigeon pea that causes 25–67% losses. This chapter provides a quick overview of the major pigeon pea pests.

Keywords:
Pigeon pea; Helicoverpa; Fusarium wilt; sterility mosaic virus; nematodes

18.1 Introduction:

Pigeon pea (*Cajanus cajan* L.; Family: Fabaceae), The highly proteinaceous drought-tolerant legume crop is ranked sixth in the world behind soybean, peanut, bean, chickpea, and cowpea. (Nedumaran et al. 2015). It is mostly grown in dry and tropical parts of Asia and Africa, with India serving as the pigeon pea's centre of origin, accounting for more than 70% of global output (Jorrin et al. 2021). Despite the major producer, disparity between supply and demand and burgeoning population growth, stagnated productivity of about 0.7 tonnes per hectare from last few years made India net importer of red gram from other countries like Myanmar, Tanzania, Kenya and Malawi (Singh et al. 2020). Besides the major biotic stresses like diseases and arthropod pest causes sizeable number of damages, often resulted in complete failure of the crop which pose additional reduction in the overall net production of red gram (Abate et al 2012). According to various reports, pigeon pea was infested by at least 150 - 250 species of insect pest (Lateef and Reed 1990; Srivastava and Joshi 2011) of which many of them cause little or no economic damage to the crop. The compensatory ability of the plant itself can tolerate the pest infestation on vegetative or pre-flowering damages, however the infestation during the post flowering pod formation stages by various pod borer complex from different feeding guilds cause serious problem to the crop productivity (Shanower et al 1999). The chewing pests of borer complex comprises *Helicoverpa armigera, Maruca vitrata, Maruca testulalis, Melanogromyza obtuse* and sucking pests of pod such as *Calvigralla gibbosa, C. scutellarius* are major concern to crop productivity to all the major growing regions of India and other countries (Saxena et al 2018). However, the frequency and intensity of pest damage by particular species varies from region to region depending on local environment, variety used and other practices followed by farmers. Apart from field pest, infestation by bruchids (*Callasobruchus chinensis*, *C. maculatus* and *C. analis*) cause extensive damage to the legumes during storage which accounts for huge losses worldwide (Sharma et al. 2005). Knowledge of insect ecology and biology enables prompt action to minimise economic losses to a minimum. In the coming up section will see the insect pests of major

concern to the pigeon pea productions and ways to mitigate them with all the available options reported. Despite the enormous area under pigeonpea cultivation, most pigeonpea growing regions have relatively poor productivity and overall production, and there is a significant difference between the yield of pigeonpea attained in experimental plots and farmer's fields. Low yields are mostly due to pigeonpeas' susceptibility to several diseases from the seedling stage till harvest. Disaeses like Fusarium wilt (*Fusarium udum*), phytopthora blight (*Phytopthora drechslei* sp. *cajani*), and sterlity mosaic (*Pigeonpea Sterlity Mosaic Virus*) are the major pathogens inflicting substantial losses. Minor diseases like Cercospora leaf spot (*Cercospora indica*), powdery mildew (*Leveillula taurica*), Alternaria blight (*Alternaria* spp.), stem canker (*Macrophomina phaseolina*), collar rot (*Sclerotium rolfsii*), bacterial canker (*Xanthomonas campestris* pv. *cajani*), In particular circumstances in a limited area, the virus's *tobacco mosaic, yellow mosaic*, and *mung bean yellow mosaic* cause losses.

18.2 Major Insect Pests of Red Gram:

18.2.1 Gram Caterpillar: Helicoverpa Armigera (Hubner) (Lepidoptera: Noctuidae)

The *Helicoverpa* may be found ubiquitous and has a host range of more than 150 agricultural plants as it is the highly polyphagous pest. Adults are having yellowish to greenish with V shaped specks on the forewing. Hindwings having dull broad black border on the apical margin of the wings with sparse grey spots on it. Larvae are often smooth and typically darkens during six instar stages, however colour can vary greatly depending on the feeding character. Greenish broken lines run down the side of the caterpillar's bodies. Older larvae head capsules are dark yellow or orange in colour (Sharma et al 2010).

A. Symptoms of damage:

It is considered as one of the key pests of pigeon pea, at times it causes damages of up to 60 percent in early and late maturing varieties (Sarkar et al 2018). The annual losses incurred by this pest to pigeon pea is about $317 million worldwide (Shanower et al 1999). Neonate's larvae are found to scrapping the young leaf epidermal tissues soon after emergence then they wonder towards the flower buds or young pods. Later stage larvae were having higher preference towards mature leaves and pods for difference in nutritional requirements. The *Helicoverpa* larva's distinctive method of feeding on pods involves creating circular bore holes in the pods with the head inside and the rest of the body hanging outside. (Saxena et al 2018).

B. Life cycle:

Adult females lay sphere-shaped eggs on flowers one at a time. Preferentially on young pods and flower buds and egg period will be approximately last for 3-14 days, depending on temperature. Normally, there are 5-7 instars and lasts for 12 to 32-day before pupation takes place. Pupation takes place in earthen cell. The Pre-pupal development will require 1-5 days and the pupal stage of the bollworm will persist between 10 and 14 days if it is not present in diapause. If the *Helicoverpa* is in diapause the pupal phase might last for several months (Yadav et al 2020).

18.2.2 Pod Fly: Melanagromyza obtusa Malloch (Diptera: Agromyzidae)

In Southeast Asia, pod fly is considered as one of the significant pests of pigeon pea. Attacks are more common in Karnataka and North and Central India (Sharma et al 2011). It mostly feeds on pigeon peas and related *Cajaninae* subtribe species (Hillocks et al 2000). Adult are metallic blue or black in colour with oval abdomen and prominent eyes.

A. Symptoms of damage

Because of narrow feeding niche it causes extensive damage to pigeon pea from 10 to 80 per cent to the total monitory loss of around US $ 256 million (Patange et al 2017). The damage is majorly incurred by the maggots. The first instar maggot hatches out from inside the pods as eggs being laid by adults directly into the pods. The first instar begins eating by directly drilling into the tender seeds, but the subsequent stages drill deeply into the seed to eat the starchy embryo and endosperms. A single seed is appropriate for one maggot to its whole growth, causing significant weight reduction and rendering them unsuitable for human consumption. There are no visible signs of its ingress in afflicted pods. Only the pest damage is visible after opening. At the early phases of the pod development, it is hard to notice the exterior pod fly incidence. The infested pod may be easily identified as having pores that are about 1mm diameter with a thin membrane at a later stage of infestation. After the emergence of the adult, exit holes are seen (Saxena et al 2018).

A. Life cycle:
Small blackflies release their tiny eggs into the delicate flower buds and pod tissue. Fly deposit eggs by penetrating the pericarp with their ovipositors and are visible as needle-like projections from the pods. The female flies lay 80-90 eggs over its lifetime, or 4 eggs each pod with 3-day egg period. Maggots eat the insides of seeds after entering them, sometimes the cover is undamaged. Larval time is 6 to 10 days. Within the grooves of the pod's full-grown larvae will pupate, 8–12 days will be the pupal phase. Adults emerge by slicing the tiny patch that the maggots have already left (Sharma et al 2010).

18.2.3 Spotted Pod Borer: *Maruca Vitrata* Fabricius (Lepidoptera: Pyralidae)
This pod borer causes devastating damage to the legume crops intermittently in tropical and semitropical regions such as Africa, southeastern Asia, Australia, Mexico, and certain regions of South America. It primarily affects the determinate type pigeon pea rather than the indeterminate kind. The forewings of the adult moths are brown with three white spots, and the hindwings are greyish with crossbands that resemble clubs. Larva with characteristic black spots that appear serially on every body segment (Sharma et al 2010).

A. Symptoms of damage: The larva causes around 30 percent pod damage in the crop which significantly reduces the grain yield. This pest is responsible for total monetary loss of US $ 30 million worldwide. The characteristic symptom of this larva includes webbing and rolling of leaves, flowers and pods with frass like material and feed inside them. The concealed habit of larva makes management practices highly challengeable (Sharma 1998).

B. Life cycle:
The eggs are arranged singly in the sepals, petals, buds, or on the pods. The egg takes two to three days to fully develop into a larva, after which the caterpillar spends about two weeks feeding on tender leaves, flower buds, and maturing seeds in pods. Pigeon peas have two instars: the first likes to eat flowers over leaves and pods, while the third prefers to consume pods. After crawling out of the pigeon pea pod during the night, it pupates for 6 to 14 days before crawling to the ground and hiding amid leaf litter. 30 to 35 days are needed to complete the full life cycle (Ganapathy 2010).

18.2.4 Plume Moth: Exelastis Atomosa Walsingham (Lepidoptera: Pterophoridae)
It is a specific red gram pest in India that can be found all year long depending on the availability of the host plants. The moths are grey, less than 12 mm long, and slender with long, thin wings. The forewings are divided into two segments while the hind wings are broken into three sections and feature a fringe like a borer. The fully-grown caterpillar is 10–12 mm in length, is greenish-brown in colour, and has little hairs and spines on its fringe.

A. Nature & Symptoms of damage:
Caterpillar first scrapes the surface of the pods before piercing a small hole through the pod and eating the seeds inside. In contrast to pod fly, attacked seed is totally consumed by the caterpillars. The larva also eats the anthers from unopened flower buds, which results in floral drop. This insect is often present during flowering and is known to severely harm red gram. This pest's attack can result in significant bud, flower, and pod loss.

B. Life cycle:
Adults lived an average of 6.59 0.38 days. An adult female typically laid 93 to 101 eggs on spherical pods, flower buds, and young leaves, one at a time which hatched in approximately 3 days. It took 23 days for it to transition from its five larval instars to the pupal stage. Pupation occurred on the surface of the infected pods, at the entrance to the hole, or inside the burrowed pod, and the pupal stage lasted for approximately one week. In 40 to 42 days, it completes its life cycle (Subharani and Singh 2008).

18.2.5 Pod Sucking Bugs: Clavigralla Gibbosa Spinola, (Hemiptera: Coreidae)
Nymphal and adult stages are found to cause damage to pigeon pea and other legumes. They suck out the sap from growing pods and also from stem, leaves and flower buds. Adults are brown, robust, and about 10 mm long, with two spines extending internally on the pro thorax.

A. Symptoms of damage:
Sucking out of sap cause intermittent yellowing and shrivelling of the pod walls and seed coat which ultimately reduce the seed viability.

B. Life cycle:
Adult lays about 200-250 eggs in clusters on the pods or underside of the leaves. After incubation of 3 – 20 days' neonate hatch out of the eggs. Nymphs takes about 1 to 3 weeks to undergo five moulting to become adult (Purohit et al. 2018).

18.2.6 Blue Butterfly: Lampides Boeticus Linn. (Lepidoptera: Lycaenidae)
It is a less serious pest that typically preys on tender bean, cowpea, and pigeon pea pod buds, flowers, and pods. Adult butterfly with brownish fore and hind wings that are tinted with blue. There is an eye-like mark on the apical border of the hind wings.

A. Symptoms of damage:
After hatching, neonate larva bore into the buds, flowers, and young pods and begin to develop from inside. After the pods have reached maturity, bore hole damage is evident.

18.2.7 Blister Beetle: Mylabris Pustulata Thunberg (Coleoptera: Meloidae)
Blister beetle are usually dark in colour with sclerotised fore wing having two prominent red colour bands.
They found all around the year. The grub stage of this beetle feed on grasshoppers' egg where as the adult stage are feeding on the flowers of pigeon pea, cowpea, green gram and black gram.

A. Symptoms of damage:
Adult beetle voraciously feed the flowers of various grams which result in damage up to 95 percent.

B. Life cycle:
Females roughly lays about 60 - 80 cylindrical egg cluster in to the dirt at the 2 – 3 cm deep. The early neonates are highly active searching for the grasshopper's egg cases in the soil. Whereas the late instars are sluggish with reduced legs. They pupate inside the soil.

18.2.8 Pulse Beetle: Callosobruchus Chinensis Linn., C. Maculatus Fab. (Coleoptera: Bruchidae)
In India, four species of bruchids associated with the genus *Callosobruchus* have been recognised as pests of pigeon peas. *Callosobruchus chinensis*, *C. analis*, and *C. maculatus* are three species that attack pigeon pea in both fields and storage, but *C. theobromae* is primarily restricted to fields. The mature beetle is oval, reddish brown, between 3 and 4 mm long, vigorous, and has two spots on its dorsal side and ivory in colour. Its abdomen is noticeably enlarged. Grubs are 3–4 mm long, white, cylindric, meaty, and have a light brown head. In most cases, damage begins in the field itself, when the leguminous pods are transported to the storage godowns. In storage, nevertheless, they do significant harm.

A. Symptoms of damage:
The pest's damage is distinguished by the existence of circular exit holes in affected pods and seeds, diminishing their value and rendering them unsuitable for planting or human consumption. Both grubs and adults harm crops by consuming the entire grains contents and just leaving the shell behind (Saxena et al 2018).

B. Life cycle:
One female beetle may lay 40–120 eggs each day, at a pace of 1–40. The juvenile larva penetrates the grain and develops entirely inside it. Larval stage will be approximately 10–12 days. It takes them between 120 to 170 days to fully mature during the winter hibernation. The fully developed larva moves toward the perimeter until it reaches the seed coat, where it lies down and develops into an oval, white pupa. Puapal stage is of 5-30 days. In a year, there are 7-8 overlapping generations.

18.2.9 Leaf Webber: Grapholita Critica Meyr (Lepidoptera: Tortricidae):
The two leaf Webbers reported to cause the most crop damage is *G. critica* and *Legumnivora ptychora*. The *G. critica* moth deposits its eggs on developing leaves and leaf buds. The larva, which has a creamy-yellow colour and is frequently seen linking leaves together, consumes chlorophyll while staying inside the web. The leaflets are connected by silk, and the larva feeds inside the web. The terminal bud is frequently included in the web, preventing the shoot's continued development. The infestation starts at the seedling stage and can persist until the reproductive stage when the larvae feed inside flower buds and immature pods. Within the web, the fully developed larvae pupate. Infestation that begins at the seedling stage significantly damages the crop, remains throughout the growth season and may even injure floral buds.

18.2.10 Pod Wasp: Tanaostigmodes Cajaninae Lasalle (Hymenoptera: Tanaostigmatidae)

In southern India, pod wasps are an emerging insect threat. It is the first Tanaostigmatid species described in India which is reported by ICRISAT. In terms of morphology, it resembles *T. globosus* more.

The forelegs are darker in colour and the middle and hind legs are golden to honey yellow in colour in adults. Wide, shallow scrobal impression and a tiny carina are seen on the head's ventral and marginally lateral surfaces. Ocelli are present as extremely obtuse triangle on the vertex. The antenna features two anelli, six funicular segments, and a three-segmented cub. Scape is generated and flattened ventrally.

The pronotum is vertical and the scutellum is long and broad, with a pointed anterior end and a slightly rounded posterior end, with a few dispersed setae along the adjacent borders. Hyaline wings with light brown veins. The flattened, transparent, round eggs are placed singly on the immature pods and flower thalamus.

A. Symptoms of damage:

The white, apdous larva, which develops to be 2.5 mm long, enters the pod and feeds on a seed as well as the inner pod wall. The adult emerges via a small hole in the pod wall after metamorphosis takes place inside the pod locule. In a lab environment, the larval stage is 8 to 10 days, the pupal period is 5 to 7 days, and adults can live for up to 7 days (males) and 9 days (females). Numerous infected pods are shed or continue to exist on the plant after not developing. Insects that are normal adults, emerge from the immature pods. The locules that are not affected grow properly and provide quality seeds. The most frequently infected locule is the basal one, while other locules might sometimes rarely be infected. The infected locules are still small and constrictive.

B. Life cycle:

The biology of *T. cajaninae* was reported by Lateef et al. in 1985. On flowers and young pigeonpea pods, eggs are deposited. Larvae enter the pod after hatching. Each pod typically contains one larva, which feeds on the seeds and or inner pod wall.

The adult emerges via a tiny hole already drilled in the pod wall after pupation takes place within the pod, such pods may not grow and may not shed.

18.2 11 Bihar Hairy Caterpillar: Spilosoma Obliqua Walker (Lepidoptera: Arctiidae)

This pest is active in the winter, especially in the states of Uttar Pradesh, Bihar, and Haryana, although it has lately begun to occur throughout the summer as well. Reddish-brown adult moth with black patches. Black dots may be seen on both pinkish wings.

Females deposit masses of eggs on leaves. The larvae have yellow hair all over their bodies and are a light yellow colour. They consume leaves, are polyphagous, and defoliate trees, which results in loss. Only stems are left in extreme situations. Additionally, feeds on capsules in defoliated crops. Pupate near to the plants in the leaf litter.

18.2.12 Red Headed Hairy Caterpillar: Amsacta Moori B, A. Albistriga W. (Lepidoptera: Arctiidae)

Red hairy caterpillars are the most detrimental to Indian agriculture of all the hairy caterpillars. The red hairy caterpillars are thought to be two distinct species of the genus Amsacta, yet they share the same behaviours, types of injury, and other traits.

They have multi-voracious and a significant pest that harms the rainfed groundnut crop. It is an endemic pest, and the regional agricultural methods and climatic conditions have a significant impact on when it emerges each season in various tracts. It starts to spread like the plague in vast numbers after the first monsoon rains in early June.

18.3 Marks of Identification:

Amsacta moorei: The band on the head and the forewings' anterior marginal streak both have red colour. In appearance, several characters resemble *A. albistriga*. Both of these species fully grown caterpillars have a reddish brown colour with black bands on either end, and they have warts forming on them all over their bodies that are covered in long reddish-brown hairs.

Amsacta albistriga: The adult moth is a medium-sized moth. While the hind wings have black markings, the forewings are white with brownish streaks all over and a yellow stripe along the anterior border. On the head, there is a stripe of yellowish colour.

18.3.1 Nature and Symptoms of Damage:
Early stages of the caterpillars may be seen in bunches on the underside of the leaves, where they eat by scraping. Later, they spread out and defoliate nearby plants. Field after field may need to be re-seeded early in the season in years with significant out breaks, and subsequently it may be too late even for re-sowing. Caterpillars eat from roughly May until September.

A. Life cycle:
Adult moths emerge from clay cells in the twilight hours after receiving heavy rains in June and July. On the same day, they begin oviposition and mate. The creamy or light yellowish eggs are generally clustered together on the underside of leaves or dry twigs etc. In 3–4 days, a female produces 300–1000 eggs, which hatch. In a month, the larva fully develops, turning reddish brown with thick hairs covering its entire body. The larvae bury themselves 10–20 cm deep in the wet soil, where they pupate in an earthen cell. The insect goes through pupal diapause on the soil till the next year and remain as a pupa for a brief period of time before emerging in certain places.

18.4 Other Insect Pests:
Aphid: Aphis craccivora Koch (Hemiptera: Aphididae)
Cowbug: Otinotus oneratus W, Oxyrachis tarandus F. (Hemiptera: Membracidae)
Grey weevil: Myllocerus undecimpustulatus Faust (Coleoptera: Curculionidea)
Mealybug: Phenacoccus solenopsis T, Coccidohystrix insolita Green (Hemiptera: Pseudococcidae)
Pod weevil: Ceuthorrhynchus asperulus (Coleoptera: Curculionidae)
Scale: Ceroplastodes cajani Maskell (Hemiptera: Coccidae)

Management Options Available Against Major Insect Pest of Pigeon Pea

18.4.1 Host Plant Resistance:
The relationship between plants and insects varies greatly depending on the morphological, physiological, and molecular characteristics of the genotypes of plants. Screening of this interaction might helpful to pick the superior genotype which harbouring lesser pest population without any compromise in the yield (War et al 2012). Morphological characters like presence of non-glandular trichomes, thickness of epidermal tissues, tight fitting of pod wall to the seeds and physiological attributes like presence of anti-nutritional factors and secondary metabolites imparts minimum to moderate level of resistance to pigeon pea insect pests (Sharma 2016). Accessions for different insect like *H. armigera* (Kumari et al 2006; Sujayanand et al 2019), *M. vitrata* (Sai et al 2018), *M. obtusa* (Sharma and Keval 2021), *C. gibbosa* (Dasbak et al 2012) and *L. boeticus* (Sharma et al 2022) has been identified through various screening processes. These accessions can be either recommended for farmers or may used as idiotype for further hybridization programmes.

Genetic engineering of pigeon pea genome by addition of insecticidal proteins helps to develop transgenic insect resistant plant. Reports from previous researches (Ghosh et al 2017; Singh et al 2018; Ramkumar et al 2020) proves that transgenic expression of insecticidal crystal protein from *Bacillus thuringensis* effectively suppresses pod borer infestation.

18.4.2 Cultural Approaches:
Habitat manipulation by including trap crops or intercrops in to the pigeon pea cultivation modify the microclimate of the crop canopy which helps to significantly reduces pest infestations. Introduction of *Crotalaria juncea,* a trap crop reduces the *M. vitrata* infestation in pigeon pea as female are found to attract to the trap crop for oviposition (Jackai and Singh 1981). Integration of cereals like maize, sorghum and pearl millets into pigeon pea cultivation as intercrop in the ratio of 1:3 to 1:1 ratio reduces the *M. vitrata* pod damage (Gopali et al 2010). Likely sunflower as intercrop found to reduces *H. armigera* problem (Kerketta et al 2018). De synchronizing the crop phenology with insects' biology by adjusting the sowing date helps the plant to escape from pest damages since damage causing stages of insect will not be ready at that time. Early sowing of pigeon pea faces minimal pod borer complex infestation whereas late sowing helps to mitigate pod fly damage (Chopade et al 2020).

18.4.3 Biocontrol Approaches:
Biocontrol methods includes use of natural enemies like predators and parasitoids of pigeon pea pests and their microbial pathogens (bacteria, fungi and virus) to keep their infestation below economic injury level.

A. Predators and Parasitoids:

Table 18.1: Predators and Parasitoids

Natural Enemy	Pest	Reference
Predators		
Mantid spp., Coccinella magnifica	H. armigera	Sharma et al 2010
Potter wasps (Delta conoideum) Pyrrhocorid (Antilochus coquebertii) Spiders	M. vitrata	Sahoo and Senapathi 2000 Borah and Dutta 2001
Parasitoids		
Copidosoma floridanum, Bracon hebetor, Campoletis chlorideae, Trichogramma chlionis	H. armigera	Sharma et al 2010
Phanerotoma hendecasiella	E. atomosa	Sharma et al 2010
Gryon clavigrallae	C. gibbosa	Romeis et al 2000
Apanteles taragamae Caenopimpla sp., Temelucha sp.	M. vitrata	Srinivasan et al 2021
Apanteles taragamae	G. critica	Sahoo and Senapathi 2000
Ormyrus orientalis, Euderus agromyzae	M. obtuse	Sharma et al 2010
Pseudotorymus sp Neanastatus sp.	T. cajaninae	Durairaj 2010

18.4.4 Entomopathogens:

Microbial entomopathogens often check the pigeon pea pest infestation below the critical limit. Their performance may be level below the chemical pesticides, however their specificity towards target pest without much effect on natural enemies and problems over pesticide resistance made them as preferable option. Applications of different formulations of *B. thuringensis* and their native isolates reduces the pod borer complex in various studies (Vinayaka and Murali 2014; Taggar et al 2014). Fungal bioagents like *Beauvaria bassiana*, *Lecanicillium lecanii* and *Metarhizium anisopliae* effectively controls both sucking as well as chewing pest of pigeon pea during various stages of development (Mahalakshmi et al 2016; Ahmed et al 2020; Chethan 2021).

18.4.5 Botanicals:

Botanicals like neem seed powder, neem seed kernel extract (NSKE) and neem oil reduce pest infestation because of feeding deterrence or anti-feedant effect. Application of 5 per cent NSKE and 3 per cent neem oil reduces the pod borer complex during reproductive phase of the crop (Ganapathy 1996). In addition to neem various studies have tried pongamia extract to control *M. vitrata* infestation (Srinivasan et al 2021).

18.4.6 Chemical Approaches:

Chemical pesticides are the only last resort option to keeps the pest infestation to the safer level. However, the problems associated with chemicals like resistance, resurgence and residue makes various changes in pesticide applications like sequential application of different chemicals with different mode of actions, treatment window approaches, using chemicals along with other management practices. For controlling pod borer complex application of Spinosad 45 SC @ 73g a.i/ha, Indoxacarb 14.5 SC @ 50g a.i/ha were recommended (Nithish and Rana 2019; Ramkumar et al 2022). Thiamethoxam 25 WG@ 75g a.i/ha provided better control to *M. obtusa* and *C. gibbosa* infestations (Ramkumar et al 2022). Flonicamid 50WG and Acephate 75 SP were recommended for pod sucking bug complex of redgram (CIB&RC 2020).

18.4.7 Integrated Pest Management:

Integration of all the above said control measures with location specific and pest specific modifications makes the integrated pest management approaches of pigeon pea. Under National Food Security Mission during 2010-14 the district wide Integrated Pest Management of redgram was

initiated at Gulbarga district of Karnataka, wherein holistic plant protection was utilised starting from use of information technology for timely advisory to farmers, different seed treatment practices, use of botanicals and green labelled newer molecule pesticides with appropriate equipment's made a big difference between the IPM versus non-IPM adopters. The grain yields were 15-20 per cent higher in IPM field than the non-IPM with potential reduction of number of pesticide sprays (Sharma et al 2018). Similarly, including complicated management methods for preventing pod borer infestations, such as planting resistant varieties, maize as a border crop, pheromone traps, and bird perches with 1 per cent azadirachtin at vegetative stage followed by sequential application of Chlorantraniliprole and Flubendiamide significantly reduces the pod borer damage and gave better yield returns in comparison with farmer's practices (Satyagopal et al 2014; Thilagam and Gopikrishnan 2020).

18.5 Major Diseases of Red Gram/Pigeon Pea:

Incidence of large number of diseases affecting red gram crop is perhaps the main constraint causing significant yield decline and overall quality deterioration. Red gram crop has been found to be affected by more than 50 diseases (Agrawal 2003).

18.6 Fusarium Wilt:

18.6.1 Causal Organism: Fusarium Oxysporum F. SP. Udum

An estimate of 71 million US dollars is lost yearly as a result of fusarium wilt in India. The prevalent is high in Madhya Pradesh, Andra Pradesh, Uttar Pradesh, Maharashtra, and Bihar.

A. Symptoms:

The symptoms of fusarium wilt can be seen in all stages of the crop. It includes light interveinal chlorosis and loss of leaf turgidness. There may be light to severe chlorosis of leaves, premature drooping of plant followed by wilting of entire plant within few days of symptom appearance. Wilting is usually observed from base to top. Moreover, leaves remain attached on the wilted plants. Browning of xylem vessels is yet another typical symptom of fusarium wilt. It can be seen in roots and stem which is due to blockage of xylem with fungal mycelia (Kalita 2020).

B. Pathogen:

The fungus has septate and hyaline mycelium. It has both micro and macro conidia. Microconidia are single or double celled whereas macroconidia are 3-4 septate. The fungus also produces chlamydospores which are born singly or in chains.

C. Disease Cycle, Survival and Spread:

Fusarium is a soil borne fungi. It can survive in soil. It can also survive in stubbles of diseased plants. The primary spread of wilt is by soil-borne chlamydospores and seeds. The secondary spread is through contaminated implements and water used for irrigation. In humid areas, pinkish mycelia can be seen in the base of wilted plants. The disease spread is seen in a concentric pattern and the disease incidence occurs as patches in the field. The disease occurs when the soil temperature is around 17-25˚C. Monocropping and ratooning pre-disposes the plants to wilt. Older plants are more susceptible to wilt.

D. Management:

Ensure proper field sanitation practices and destroy plant debris. Avoid monocropping of red gram. Adopt crop rotation of tobacco and mixed cropping of sorghum with red gram. Talc formulation of *Trichoderma viride* at 4g or *Pseudomonas fluorescens* at 10 g or carbendazim or thiram at 2-3 g can be used for treating 1 kg seed. In order to enhance the growth and efficiency of Trichoderma, neem cake can be incorporated in soil as a basl application at 150 kg per hectare of land. Moreover, *P. fluorescens* or *T. viride* at 2.5 kg / ha along with 50 kg of well decomposed FYM can be applied in soil at 1 month after sowing (Biswas and Ghosh 2016). Spot soil drenching with carbendazim at 1 g/l of water is also effective. Grow resistant cultivars like Jawahar, Sharad, Maruthi, Malviya Arhar-2, Pusa-9, C-11, Narendra Arhar-1, Birsa Arhar-1 (Hemavathy and Karthika 2021).

18.7 Dry Root Rot:

18.7.1 Causal Organism: Macrophomina Phaseolina (Sclerotial Stage: Rhizoctonia Bataticola; Pycnidial Stage: Macrophomina Phaseolina)

A. Symptoms: Typical symptoms of dry root rot include rotting in stem base and roots with presence of plethora of tiny fungal sclerotia under the bark of infected stem or bark. The affected area gradually

becomes black and the plants die. The disease affects both young seedlings as well as mature plants. Mature leaves show yellowing, drooping and premature defoliation (Basandrai et al 2021).

B. Pathogen: The fungus has dark filamentous hyphae. Hyphal constrictions are present at the junction of hyphal branching. Sclerotia are black, round, smooth, hard, and tiny. It has ostiolated dark brown pycnidia. The conidia are hyaline and aseptate.

C. Disease cycle: The pathogen is both a seed- and soil-borne in nature. The primary and secondary methods of transmission are contaminated soil and contaminated seed, respectively. The pathogen persists in the soil as sclerotia, resting structures, stubbles, and plant detritus that has been infected. High temperature (28-35˚C), as well as prolonged drought followed by irrigation favors the disease incidence.

D. Management: Follow the same seed treatment, spraying and soil drenching practices recommended for fusarium wilt.

18.8 Powdery Mildew:

18.8.1 Causal Organism: Leveillula Taurica

It is an oidiopsis type of powdery mildew fungus with endophytic mycelium. The disease is air borne in nature.

A. Symptoms: Yellowing may be apparent on the top surface of the leaves, while white powdery growth can be noticed on the underside. Conidiophores and conidia of the fungus can be seen inside the powdery growth. In severe cases of powdery mildew infection, the upper leaf surface may even exhibit the white growth. Typically, disease initially manifests in fully developed leaves. Later stages of infection result in the defoliation of the diseased leaves.

B. Pathogen: The fungus lives inside plants as an intercellular organism and feeds through haustoria. The conidiophores are hardly branching, non-septate, and hyaline. Conidiophore bears single conidium and it rise out through leaf stomata. The conidia are also hyaline, and aseptate. The fungus also produces cleistothecia which has asci. Each ascus produces three to five ascospores which are also hyaline and unicellular.

C. Management: Neem seed kernel extract (5%) or neem oil (3%) can be sprayed two times per 10 days from the first appearance of symptom. Carbendazim at 1g or Wettable sulphur at 2.5g per litre of water can also be sprayed.

18.8 Phytophthora Stem Blight:

18.8.1 Causal Organism: Phytophthora Drechsleri F. Sp. Cajani

A. Economic Importance: Phytophthora blight or stem blight is the third major disease of red gram caused by the fungus *Phytophthora drechsleri* after Fusarium wilt and sterility mosaic contributing to high economic losses. It is a debilitating disease that kills young plants which leaves large gaps in plant stands in field (Kumar et al 2020).

B. Symptoms: Sunken lesions are apparent on stems or petioles, but dark to black water-soaked lesions emerge on leaves. Stem girdling results from lesions that have formed on the stem. The result of the stem girdling is the breaking and withering of plant's entire structure or individual branches. On diseased red gram plants, the stem occasionally develops galls.

C. Pathogen: The fungus possesses coenocytic and hyaline mycelium. The sporangiophores are hyaline and contain sporangia that are non-papillate, ovate, or pyriform. Each sporangium is capable of producing several zoospores. The oospores are smooth, round, and solid.

D. Disease cycle, survival and spread: The fungus is soil borne and persists as mycelium and oospores (resting structures) in the soil and infected plant waste. Oospores cause primary infection, whereas zoospores cause subsequent spread. The splash of rain and tainted irrigation water both contribute to the proliferation of zoospores.

E. Favourable conditions: The optimal temperature for the infection is 28-30°C. Cloudy weather and drizzling rain predisposes to infection. It requires continuous leaf wetness for 8 hours. Soils with poor drainage, low-lying locations, and heavy rain from July to September exacerbate the disease.

F. Management: Avoid sowing red gram in fields likely to get water logged. The sowing time of the crop has to be fixed so that crop stand does not overlap with heavy downpour. Treat seeds with 4g *T. viride* formulation or 6g metalaxyl per kg of seeds. Spray Metalaxyl at 0.2% or 500 g/ha. Grow resistant varieties like ICPL 150, ICPL 304, ICPL 288, BDN-1, and KPBR 80-1-4.

18.9 Sterility Mosaic Disease:

18.9.1 Causal Organism: Pigeonpea Sterility Mosaic Virus

A. Economic importance: It is a serious issue among red gram growers in India as well as Nepal. The estimated annual grain losses due to this viral disease is around $ 282 million.

B. **Symptoms:** This viral disease might affect any stage of the red gram. The very first signs are vein clearing in younger leaves. The afflicted plants have neither flowers nor pods and seem bushy and light green. The leaves are thin and have a distinctive mosaic design (Jones et al 2004). Depending on the genotypic make up, three different symptoms are observed. They are: *Severe mosaic and sterility*: The leaves look small, narrow and bushy in severe cases. These plants are usually infected at an early stage (upto 45 days after planting) and become near completely sterile. There can be yield loss up to 95 %. *Mild mosaic and partial sterility*: The susceptibility of red gram to the disease decreases after 45 days and they show only partial sterility. *Chlorotic ringspot without any noticeable sterility*: In infected plants, if pods are developed, the seeds appear to be small and wrinkled. Some varieties even show ring spot in leaves.

C. Pathogen: The virus is a segmented, negative sense, single-stranded RNA virus which is transmitted by an eriophyid mite, *Aceria cajani* in a semi-persistent manner.

D. Favorable conditions: The disease occurs in severe forms when red gram is interring cropped or mixed cropped with millets especially sorghum. Humidity accompanied with shade boost multiplication of *Aceria cajani*, especially in high temperature conditions and hence, encourage multiplication of the virus also.

E. Disease cycle, survival and spread: The virus is not sap transmitted. It is transmitted by an eriophyid mite, *Aceria cajani*. It retains the virus for approximately twelve to thirteen hours. A single vector is enough to transmit the disease. Moreover, perennial and volunteer red gram as well as the ratooned growth of harvested plants serve as pools of vectors as well as the virus (Mishra et al 2021).

F. Management: As for any other viral diseases, first step for control is to rogue out the infected plants up to a month after planing. The main aim is to control vectors. Hence, spraying Fenazaquin at 1 ml/l or Dicofol 3ml or Sulphur 3g/l to control mite vector immediately after symptom appearance is necessary and can be repeated fortnightly in early stages (Kumar et al 2005). Grow tolerant varieties like Asha, ICPL 227, Jagruti, ICP 7035, Purple 1, DA11, DA32, VR3, ICP 6997, Bahar, BSMR 235, ICP 7198, PR 5149, Bahar, ICP 8861 and Bhavanisagar 1.

18.10 Yellow Vein Mosaic:

18.10.1 Causal Organism: *Red Gram Yellow Mosaic Virus*

This viral disease was reported first from Sri Lanka.

A. Symptoms: Yellow specks develop on the leaves, eventually expanding to form yellow and green patches. The initial flushes are smaller and yellower in colour. Stunted and seldom producing pods are the affected plants. The white fly (*Bemisia tabaci)*, an insect vector, spreads this virus.

B. Management: The infected plants can be pulled out and removed (rogue out) up to one month after planting. The virus harbour in weed hosts and it has to be removed intermittently. To control insect vectors, Methyldemeton can be sprayed at 500 ml per hectare of the cropped area.

18.11 Alternaria Blight / Leaf Spot:

18.11.1 Causal Organism: *Alternaria Alternate*

A. Symptoms: Necrotic spots appear on the leaves and gradually grow and form distinctive lesions with dark and light brown concentric circle. The middle of the spot is straw in colour. The lesions ultimately coalesce and leaves will look blighted.

18.12 Cercospora Leaf Spot:

18.12.1 Causal Organism: Cercospora Indica

A. Symptoms:

Small spots that are brown in colour appear on leaves and leave shot hole symptoms later. In severe cases, there will be premature defoliation and black lesions on petioles and stem.

B. Management for Fungal Leaf Spots:

Destroy the infected plants after harvest. Mancozeb at 2 kg or Carbendazim at 500 g per hectare of land can be sprayed immediately after the symptom appearance in leaves and repeat after 14 days of first spraying.

18.13 Minor Diseases of Red Gram:

18.13.1 Halo Blight: Pseudomonas phaseolicola is the causal agent. Small dark spots with chlorotic halo appear on leaves. The spots grow and create a brown, dry zone. On the petioles, stem, and pods, brown, elongated streaks can be seen.

18.13.2 Anthracnose: caused by *Colletotrichum lindemuthianum.* On the stem, black lesions appear and spread to the leaf petiole and leaves. On the pod, black sunken lesions are formed.

18.13.3 Brown Blotch: purple brown discoloration appears as a brown blotch on stems, peduncles, leaf veins, pods, and petioles. Pods develop distortions and contain fruiting bodies that are dark. Causal organism is Colletrtrichum capsici.

18.13.4 Seedling Blight: small brown water-soaked lesions form at the collar area of seedlings and eventually grow to become irregular necrotic spots that girdle the stem and cause the seedling to die. The disease is caused by *Sclerotium rolfsi*i. Stem rot: seedlings between two and three weeks' old are seriously harmed. On adult plants, greyish green water-soaked lesions form, causing the stem to girdle. Caused by *Pythium aphanidermatum.*

18.13.5 Other Diseases:

Sclerotinia rot caused by *Sclerotinia sclerotiarum*, Fungal canker caused by *Diplodia cajani*, Botrytis grey mold by *Botrytis cinerea*, Bacterial leaf spot/stem canker by *Xanthomonas campestris* pv. c*ajani*.

18.14 Nematode Pests of Red Gram:

18.14.1 Pigeonpea Cyst Nematode (PCN): Heterodera Cajani Koshy (Tylenchida: Heteroderidae)

PCN is a serious nematode pest of this crop, and they may be found in all of India's prime growing regions. Additionally, reported damage caused by this nematode came from Pakistan, Egypt, and Myanmar. Many nations, including the USA, include PCN on their list of potentially dangerous organisms. Early diagnosis of this pest and halting its spread depend on the development of accurate and sensitive molecular diagnostic techniques (varaprasad et al 1997).

It is an obligate sedentary endoparasite, causing severe reduction in the development and produce of pulse crops. In India, the yield loss brought about by this nematode on cowpea, pigeon pea and green gram range between 25 to 67.5% even at low populaces of 0.2-0.5 larvae/g soil. Additionally, it antagonistically influences the nitrogen fixation by rhizobia bacteria.

A. Symptoms:

The primary signs of PCN infection include slowed development and damage of root system in the host. The size and number of flowers and pods have decreased. PCN juveniles were discovered 48 hours after infection in the cortex of pigeon pea plants, with the migration being largely intracellular. The stelar area is where syncytia originated and the cell walls of the cells near to the feeding site thickened and became angular. Giant cells featured 4-5 nuclei and thick, granular cytoplasm. The xylem vessels were severely injured, and the majority of juveniles positioned in the cortex became males, whilst those placed in the stelar region were females.

B. Life cycle:

The PCN life cycle takes 26 days with an average soil temperature of 29°C. Within 48 hours of infection, the Second-stage juveniles (J2) penetrate the roots. On the third day, the moulting will start, and it will end on the fourth. On the tenth day, juveniles in the fourth stage with advanced reflexed ovaries are discovered. On the twelfth day, lemon-shaped adult females were spotted. On the 12th or 13th day, males were discovered. Numerous eggs were visible on the 14th day, both within the white females and in the egg sacs. A few males that had been seen in the egg mass also came out of the cysts (Walia et al 2003).

C. Management:

The Cyst nematodes are particularly resistant to chemical control because the female, after dying, changes into a hard-brown case that protects the eggs. The nematode population is decreased by the seed treatment fensulfothion. The essential oils of *Mentha piperita, Ocimum sanctum, Cymbopogon martini, C. nardus, C. winterianus, C. flexuosus, Ocimum basilicum, and Xanthium strumarium* root extract, green manures of *Sesbania bispinosa*, *Crotalaria juncea*, *Vigna radiata*, and *Vigna unguiculata* have a considerable controlling impact. Apply *Pseudomonas fluorescens* or

Trichoderma viride 2.5 kg/ha to the soil before planting. It is advised to treat seeds with *P. fluorescens* and *T. viride* each of 5 g/kg seed. Natural predators and parasites of plant parasitic nematodes found in soil, potentially offering biological control. *H. cajani* has been controlled with a combination of biocontrol drugs and vesicular arbuscular mycorrhizal fungi. such *Bacillus subtilis, Bradyrhizobium japonicum,* and *Glomus fasciculatum*. *H. cajani* has a rather small host range and is largely restricted to the Fabaceae. Growing the host crop in alternate years with non-hosts can help maintain populations below critical levels. On the densities of H. cajani and other nematodes, the impact of rotations, single crops (fallow crops during the rainy season), and double crops (intercrop and sequential crops) (Zaki et al 1986).

18.15 Other Nematode Pests: Other Minor Nematode Pests Are

A. Root-knot nematode *Meloidogyne* spp.,

B. Lance nematode: *Hoplolaimus* spp.,

C. Reniform nematode: *Rotylenchulus reniformis* Linford and Oliveira.

18.16 Conclusion:

Pests and diseases are a major constraint to pigeon pea production, causing significant yield losses and reducing the overall quality of the crop. The research conducted on insect pests and diseases of pigeon pea has provided important insights into the biology, ecology, and management. Effective management strategies such as the use of resistant varieties, cultural practises, and insecticides have been developed to control the damage caused by pests. However, the sustainable management of pests in pigeon pea production requires a holistic and integrated approach that incorporates various control methods, considering the specific conditions of each production system. Further research is needed to develop and refine these strategies and to better understand the interactions between pests and other biotic and abiotic factors that affect pigeon pea production. With continued research and the implementation of effective management practises, we can minimise the impact of pests on pigeon pea production and ensure a sustainable supply of this important crop for years to come.

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