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Current Advances in Sustainable Cultivation, Climate Resilience, Crop Protection and Post-Harvest Management of Black Gram (*Vigna mungo* L.)

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Abstract

Black gram (*Vigna mungo* L.), commonly known as urd bean or urad dhal, is an important pulse crop of the Indian subcontinent and a valuable source of dietary protein, carbohydrates, minerals and other nutrients. It is cultivated under diverse agro-climatic conditions and contributes to food security, soil fertility and sustainable cropping systems. However, irregular rainfall, drought, high temperatures, soil constraints, insect pests, diseases, and post-harvest losses affect production. This review summarises current advances in the sustainable cultivation and management of black gram, with emphasis on climate resilience, agronomic practices, crop protection and post-harvest management. It discusses sustainable cultivation practices such as suitable sowing time, optimum plant spacing, efficient water management, organic amendments, crop rotation, intercropping, and weed management. The review also highlights the role of black gram in climate-resilient agriculture because of its relatively short duration, adaptability and ability to utilise residual soil moisture. Major insect pests and diseases, including aphids, pod borers, pod bugs, tobacco caterpillars, yellow mosaic disease, powdery mildew, leaf blight and anthracnose, are discussed along with integrated pest and disease management approaches. Particular attention is given to botanical pesticides, biological control agents and environmentally friendly management practices. Post-harvest operations, including harvesting, drying, threshing, seed storage and management of storage pests such as pulse beetles, are also reviewed. Finally, the review identifies major challenges and future opportunities for improving productivity, quality and sustainability of black gram production under changing climatic conditions.

Keywords: Black gram, *Vigna mungo*, sustainable cultivation, climate resilience, pulse crop, integrated pest management, plant diseases, biological control, botanical pesticides, post-harvest management, storage pests, sustainable agriculture.

1. Introduction

Black gram (*Vigna mungo* L.), commonly known as urad bean or urad dhal, is an important grain legume belonging to the family Fabaceae. It is considered to have originated in the Indian subcontinent, particularly India, which is also regarded as an important centre of diversity for the crop. The crop has been cultivated since ancient times and is now widely grown throughout India and other parts of South and Southeast Asia, including Pakistan, Bangladesh, Nepal, Myanmar, Thailand and other tropical regions. Its cultivation has also spread to several regions of Africa, the Caribbean and the Pacific. CABI Compendium.

Black gram is an erect, bushy and hairy annual herb, generally reaching about 30–100 cm in height. It possesses a well-developed taproot with lateral branches and root nodules that facilitate biological nitrogen fixation. The leaves are alternate and trifoliate, while the small, bisexual, papilionaceous flowers are generally pale yellow. The crop produces short, narrow, hairy pods containing several black or mottled seeds with a characteristic prominent hilum. These morphological characteristics contribute to its adaptation to a wide range of agricultural environments.

Black gram has considerable nutritional and food-security importance. Its seeds contain approximately 24–26% protein, together with carbohydrates, dietary fibre, minerals and other bioactive components. The protein-rich grain is particularly valuable in vegetarian diets and is commonly consumed as dhal and in several traditional foods. When combined with cereals such as rice or wheat, black gram contributes to a nutritionally complementary diet and supports household food and nutritional security. Its relatively good storage characteristics also make it an important source of food during periods when fresh food availability is limited.

Agriculturally, black gram is valuable because of its short duration, nitrogen-fixing ability and suitability for diverse cropping systems. It can generally mature within approximately 70–90 days, depending on variety and growing conditions, allowing it to be incorporated into intensive crop rotations and rice- and wheat-based systems. Biological nitrogen fixation through root nodules contributes to soil fertility and can reduce dependence on external nitrogen inputs. The crop can also be used as an intercrop, catch crop, cover crop and green-manure crop, thereby contributing to soil conservation and more efficient use of agricultural resources.

Black gram also has potential as a climate-resilient pulse crop. Its relatively short growth cycle allows farmers to fit it into different cropping sequences, while its developed root system enables the crop to utilise residual soil moisture after the rainy season. However, productivity can be affected by drought, excessive rainfall, high temperatures, soil-related constraints and other environmental stresses. Therefore, improved agronomic practices, suitable varieties, efficient water management, organic amendments, crop diversification and climate-smart production approaches are increasingly important for maintaining stable yields under changing climatic conditions.

Despite its adaptability, black gram production is constrained by insect pests, diseases, weeds and post-harvest losses. Important insect pests include aphids (*Aphis craccivora*), spotted pod borer (*Maruca vitrata*), pod bug (*Clavigralla gibbosa*) and tobacco caterpillar (*Spodoptera litura*). Major diseases include yellow mosaic disease, powdery mildew, Cercospora leaf blight and anthracnose. These biological constraints can substantially reduce yield and grain quality. Integrated approaches involving resistant varieties, cultural practices, biological control, botanicals such as neem and other environmentally friendly methods are therefore important components of sustainable crop protection (Nargund *et al*., 2024; ECHO, 2025).

Post-harvest management is another important component of black gram production. Timely harvesting, proper drying, threshing and maintenance of appropriate seed moisture are essential for preserving grain quality and reducing storage losses. The pulse beetle (*Callosobruchus chinensis*) is an important storage pest of black gram. Botanical materials such as neem oil, mustard oil and black pepper have been reported as potential alternatives for protecting stored grain and seed. Sustainable post-harvest technologies can therefore improve storage life, reduce losses and increase the economic value of the crop (Thakur & Pathania, 2013).

Considering its nutritional value, role in food security, nitrogen-fixing capacity, short duration, adaptability and economic importance, black gram has an important place in sustainable agriculture. At the same time, climate variability, pest and disease pressure, declining soil quality and post-harvest losses present continuing challenges to its production. Therefore, the present review focuses on the current advances in sustainable cultivation, climate resilience, crop protection and post-harvest management of black gram (*Vigna mungo* L.), with emphasis on environmentally sustainable practices, integrated management approaches, existing constraints and future research opportunities.

2. Botanical Description and Agronomic Characteristics

Black gram (*Vigna mungo* L.) is an upright, bushy, hairy annual herb of short-lived nature, usually attaining a height of 30-100 cm. The stem is covered in fine hairs and is branching (CABI, 2025).

System Root Directory: The plant has lateral branches and a well-developed taproot. Nitrogen-fixing bacteria in root nodules improve soil fertility by fixing atmospheric nitrogen to plant-available forms (Feedipedia; CABI, 2025).

Flowers and Foliage: The leaves are trifoliate, alternate, with 3 ovate to lanceolate leaflets. The small flowers, which are bisexual and papilionaceous, are borne in axillary clusters and are often pale yellow (CABI, 2025; Feedipedia).

Seeds and Pods: The crop has small, hairy, thin pods that are usually 4–7 cm long with 4–10 seeds. Seeds are black or speckled and usually have a visible hilum (FAO, 2022; ECHO, 2025).

Growth Phase: Black gram is a short-lived pulse crop with a life cycle of 70 to 90 days generally, but this varies according to the variety and environment (FAO, 2022).

Adaptation to Different Agroclimatic Conditions

Black gram is well suited to a variety of climates, such as warm and seasonally dry climates. It has a deep root system and, once established, is able to utilise any residual soil moisture and is therefore somewhat drought-resistant. It can be grown using various cropping techniques such as intercropping and rotations (ECHO, 2025).

3. Nutritional and Agricultural Importance

Black gram (*Vigna mungo* L.) is an important grain legume of great nutritional, agronomic, economic and ecological importance. It is widely grown in South Asia and makes a major contribution to food and nutritional security due to its high protein content and its ability to fit into a wide range of agricultural systems (Singh and Ahlawat, 2005; Venkidasamy *et al*., 2019).

3.1. The Importance of Nutrition

Black gram is an important pulse from a nutritional point of view and is a good source of plant protein, carbohydrates, dietary fibre, minerals, vitamins and bioactive compounds. The seeds are also a good source of calcium, phosphate and iron and typically include 24–26% protein and 56–60% carbohydrates (Directorate of Pulses Development, 2020; Venkidasamy *et al*., 2019). Black gram is especially effective in vegetarian diets and in locations where pulses form a major part of the daily diet, due to their relatively high protein content.

The protein of black gram complements the cereal proteins when taken along with rice or wheat, thereby improving the total nutritional quality of the meal. Black gram is an important ingredient of South Asian cuisine and is included in traditional dishes such as dal-rice, dal-roti, idli, dosa, vada, and papad (Venkidasamy *et al*., 2019). Black gram-based dishes can be increased in digestibility and sensory properties through fermentation and other traditional processing methods.

In addition to macronutrients, black gram contains several phytochemicals and bioactive components such as carotenoids, phenolic compounds, flavonoids, saponins, tannins and other secondary metabolites. These chemicals have gained increased interest from scientists due to their potential antioxidant and other biological properties (Venkidasamy *et al*., 2019; Kumar *et al*., 2025). More experimental and clinical research is required to establish the health significance of single bioactive compounds.

3.2. Nutritional and Food Security Support

Therefore, black gram is a major contributor to food and nutritional security since it provides cheap protein and other nutrients. Pulses are especially important in cereal-based diets since they contribute to the enhancement of the total amino acid composition of the meal (Venkidasamy *et al*. 2019).

The short duration of black gram also allows farmers to fit in another pulse crop in the existing crop rotations. It can be cultivated as a catch crop, intercrop, sequential crop or solo crop, promoting food and income security at farm level and enhancing land use efficiency (Singh and Ahlawat, 2005).

3.3. Soil Fertility and BNF

Black gram is one of the important crops that can establish a symbiotic connection with nitrogen-fixing rhizobia in root nodules. Biological nitrogen fixation reduces the need on externally supplied nitrogen fertilisers by conversion of atmospheric nitrogen to plant-usable forms (Singh and Ahlawat, 2005).

Thus, the use of black gram in crop rotations can improve soil fertility and nutrient cycling. After harvest, crop residues and roots decompose and can return nutrients and organic matter to the soil. Black gram hence holds significant potential for inclusion in sustainable nutrient-management systems, especially in cereal-based agricultural systems.

3.4. Intercropping and Crop Rotation Role

Black gram is an ideal crop for crop rotation and intercropping because of its short duration of development, highly flexible growth habit and ability to fix nitrogen. It can be intercropped with cereals and other crops like groundnuts, pigeonpeas, cotton, sorghum, maize and pearl millet (Directorate of Pulses Development, 2020).

Intercropping using legumes with suitable crop combinations and planting patterns can boost economic returns, utilisation of resources and land-use efficiency. Kumawat *et al*. (2015) reported that in rainfed pigeonpea–black gram intercropping systems, the economic returns, productivity and nutrient uptake could be affected by the nutrient management.

Introduction: The black gram crop rotation can help break the cycles of pests and illnesses, boost soil biological activity and diversify agricultural products. The incorporation of black gram in different cropping systems can contribute to the ecological sustainability of agricultural production.

3.5. Importance of Rainfed and Climate-Resilient Agriculture

Black gram is very important in rainfed and moisture-stressed agriculture. Due to its short growing period, farmers can select the proper sowing time and integrate the crop in sequential cropping systems. Furthermore, cultivars that mature early might reduce the susceptibility to terminal dryness and other environmental issues late in the season (Singh and Ahlawat, 2005).

This crop is particularly important in rice-fallow and post-rainy season production systems because it can utilise residual soil moisture. A recent study (Frontiers in Agronomy, 2026) has shown opportunities to enhance black gram and water production by appropriate agronomic management, cultivar selection and smart use of available soil moisture.

But black gram is susceptible to certain environmental stresses such as waterlogging, drought, high temperature and heavy rainfall. Development and deployment of climate-resilient cultivars, improvement of sowing techniques, water management and fertiliser management are important to stabilise output under changing climate conditions.

3.6. Living and Economics – Why They Matter

Black gram is an important pulse and food grain of economic importance. It offers farmers choices for income generation, particularly in rainfed and smallholder agriculture systems. Its short duration enables farmers to grow the crop as an intercrop or in between major cropping seasons, thereby increasing production without occupying agricultural land for a long duration (Directorate of Pulses Development, 2020).

Additionally, the crop generates waste and fodder which can be used to feed animals. Processing into dhal, flour, papad, fermented foods and other products can also add value to it and generate opportunities for rural enterprises.

3.7. Sustainable Agriculture and Its Role

Black gram contributes to sustainable agriculture in a number of interlinked processes. Its short growth time permits intensification and diversity of agriculture. Its biological nitrogen fixation can help nutrient cycling. Its compatibility with crop rotation and intercropping can reduce the dependence on monocropping systems and improve resource use efficiency (Singh and Ahlawat, 2005). Thus, incorporating black gram into varied farming systems may aid in: enhanced soil fertility, biological nitrogen fixation, crop diversity, effective use of residual soil moisture, increased farm revenue, improved land use efficiency, increased availability of dietary protein and increased tolerance of agricultural systems to climate variations.

3.8 Overall Significance

Black gram is a classic pulse crop with considerable agricultural and nutritional importance. It is an important crop for sustainable agricultural development due to its high protein content, nutritional value, short growth cycle, nitrogen-fixing capacity, adaptability, intercropping potential and economic value. Singh and Ahlawat (2005) highlighted the need of genetic improvement and better production technologies for improving productivity and sustainability of black gram agriculture.

Future research should focus on the creation of high-yielding, climate-resilient, drought- and heat-tolerant, pest- and disease-resistant cultivars in addition to precision fertiliser management, efficient water usage, biological inputs, improved post-harvest technology and value addition. Such integration of approaches can improve the contribution of black gram toward food security, farmer livelihoods and ecologically friendly agriculture.

4. Sustainable Cultivation Methods

Black gram (*Vigna mungo* L.) has to be grown on a sustainable basis. The soil, water, nutrients, seed, labour and other agricultural resources should be used judiciously and efficiently to preserve soil health and output. Several cropping systems, optimum plant population, organic nutrient management, efficient water use, weed control and proper sowing time are required for sustainable and ecologically sound production (Singh and Ahlawat, 2005; Directorate of Pulses Development, 2020).

i). **Soil and pH:** Black gram does well in loamy to sandy-loam soils having adequate organic content and proper drainage. It is suitable for soils with pH between 6.0 and 7.5. Avoid thick, poorly-drained and damp soils as too much moisture may prevent root growth and increase the risk of disease. Addition of organic matter can improve microbial activity, availability of nutrients and soil structure (Directorate of Pulses Development, 2020).

ii). **Climatic and Temperature Conditions:** Black gram is a warm-season pulse crop grown in tropical and subtropical regions. The optimum temperature for growth and development is between 25 and 35 °C. However, during germination, flowering and pod formation stages, adequate moisture is very important and heavy rainfall and waterlogging are detrimental to the crop. Short duration varieties are useful in tuning up the production with changing environmental circumstances (Singh and Ahlawat, 2005; FAO, 2022).

iii). **Choosing and Sowing Seeds:** To establish a uniform crop, seed of high germination, disease-free, genetically pure and healthy needs to be used. The best is to use certified or quality-stated seed. Treating the seed with beneficial biocontrol agents and suitable biofertilizers such as Rhizobium may improve biological nitrogen fixation and reduce the possibility of disease transmission via seeds and soil. Sowing should be carried out at the recommended period for the agroclimatic region to avoid extreme drought, heavy rainfall and pest pressure (Directorate of Pulses Development, 2020).

iv). **Seed Depth:** Black gram seeds are usually sown three to five centimetres deep in good soil. Too shallow seeding may lead to drying out of seeds and low soil moisture, whereas too deep sowing may limit or delay emergence. The seed should be sown at the proper depth to ensure fast and uniform germination (Directorate of Pulses Development, 2020).

v). **Ideal Plant Spacing:** Adequate sunshine penetration and healthy air circulation will be achieved by optimum plant spacing, leading to a balanced plant population. Generally, plants should be spaced 5 to 10 cm apart and rows 20 to 30 cm apart, depending upon the type and production system. As per the Directorate of Pulses Development (2020), suitable spacing helps to reduce conducive conditions for several foliar diseases along with undue competition among plants.

vi). **Organic Manures and Vermicompost:** Soil physical properties, organic carbon, microbial activity and nutrient availability may be improved by the use of vermicompost, compost and farmyard manure. It is excellent practice to add organic amendments to the soil before planting. Integrated nutrient management includes organic sources along with recommended mineral fertilisers and biofertilizers which can sustain long-term soil fertility and improve nutrient-use efficiency (Kumawat *et al*., 2015).

vii). **Water Management:** Black gram is well suited to rainfed and residual-moisture conditions, as it requires generally less water than many long-duration crops. However, yield might be reduced by moisture stress during germination, flowering and pod filling. Where irrigation is available, it should be used judiciously and timely throughout critical stages of growth. However, black gram is sensitive to prolonged waterlogging, and so proper drainage is essential (Singh *et al*., 2020).

viii). **Weed Management:** Black gram competes with weeds for space, water, nutrients and light, particularly at the early stages of crop growth. This requires early clearance of weeds so that high yield is maintained. Good weed control includes timely intercoalition, hand weeding, appropriate plant spacing, crop rotation and judicious use of herbicides as necessary. Integrated weed management reduces the over-reliance on one control approach (Directorate of Pulses Development, 2020).

ix). **Crop Rotation:** Another important sustainable practice is to rotate the crop with cereals and other non-legume crops. Black gram can be rotated with crops like rice, wheat, sorghum or maize to boost the cycling of nutrients, diversify agricultural output and assist in breaking the cycles of pests and illnesses. Legume-based rotations can boost soil fertility through biological nitrogen fixation (Singh and Ahlawat, 2005).

x). **Growing Together:** Black gram can be successfully grown in association with pigeonpea, cotton, maize, sorghum, pearl millet and other suitable crops. Intercropping increases the efficiency of land usage and diversifies production while at the same time providing farmers with more revenue and food from the same area. Appropriate row arrangements and combination of crops are important to minimise the competition for water, nutrients and sunlight (Kumawat *et al*., 2015).

xi). **Growing Catch Crops:** The growing period of black gram is short (70-90 days) and so it can be produced as a catch crop in between two major cropping seasons. It is especially useful when there is residual soil moisture or after harvesting crops such as rice. Catch-crop agriculture improves cropping intensity and land-use efficiency and provides an alternate source of pulse production without a long growing season (FAO, 2022; Directorate of Pulses Development, 2020).

5. Black Gram and Climate Resilience

Black gram (*Vigna mungo* L.) is a short-season crop with relatively low water requirement, ability to fix biological nitrogen and can be grown under diverse production environments. Thus, black gram is seen as a crop with promise for resource-use efficiency and climate resilience. Germination, flowering, pod development and production can all be negatively affected by dry conditions, high temperatures, heavy rains and unpredictable weather patterns. Therefore, climate-smart cultivars along with improved agronomic methods are important to sustain stable output under changing climatic conditions (Singh and Ahlawat, 2005; Directorate of Pulses Development, 2020).

i). **Drought-Tolerance:** Black gram has a root system that enables it to utilise the available soil moisture and can tolerate short periods of water stress, especially after establishment. Another benefit of the short duration of growth is that it allows the crop to complete its life cycle before serious terminal drought arises in some scenarios. But protracted dry spells can lead to very low yields, especially at flowering and pod filling. Drought resistance can be improved through the use of early maturing and drought-resistant cultivars, timely sowing, mulching and moisture conservation practices (Singh and Ahlawat, 2005).

ii). **Dealing with Remaining Soil Moisture:** Black gram has a relatively short growth season and needs less water. It can be cultivated on the residual soil moisture, notably after rice and other rainy season crops. This is a useful feature in rice-fallow situations where irrigation supplies may be limited. The appropriate use of residual moisture can raise the cropping intensity and provide the farmers an additional pulse crop without much additional irrigation (Directorate of Pulses Development, 2020).

iii). **The Effect of High Temperatures:** Vegetative growth, flowering, pollen viability, pod setting and seed development are adversely affected by high temperatures. Excessive heat during reproductive stages might result in reduced whole pod and final grain yields and more blossom abortion. To minimise heat-induced yield losses, development and promotion of heat-tolerant cultivars, adjustment of sowing dates and maintenance of adequate soil moisture is important (Singh and Ahlawat, 2005).

iv). **Impact of Rainfall Unpredictability:** Changes in the timing, amount and distribution of rainfall can lead to conditions of moisture deficiency and excess moisture.

Heavy rainfall can lead to waterlogging, nutrient loss and increased disease risk, while delayed rainfall can influence crop establishment and germination. Unpredictable rainfall during flowering and pod formation might also impair reproductive success. Careful land preparation, raised beds or adequate drainage, timely sowing and selection of proper variety can minimise the adverse effects of rainfall variability.

v). **Efficiency of Water Use:** Compared to many long duration crops, black gram is less water demanding and can give a second harvest with little or no moisture. Timely sowing, optimum plant population, moisture conservation, judicious irrigation scheduling and efficient weed control are all required for enhancing water use efficiency. If irrigation is available, water should preferably be delivered during critical stages like flowering and pod development rather than with unnecessarily frequent irrigation (Singh *et al*., 2020).

vi). **Climate-Smart Crop Management Practices:** Climate-smart black gram farming includes improved cultivars, efficient water management, soil-health approaches and a variety of cropping choices. Key processes are: cultivars that are climate-resilient and early-maturing. Planting time based on regional rainfall trends. Seed treatment with suitable biofertilizers and biocontrol agents. Use of vermicompost, compost and farmyard manure. Mulching and adequate tillage to maintain the soil wet. Needs-based irrigation effectiveness. Integrated pest, disease and weed management. Intercropping and rotation of crops. Better drainage in areas that are prone to heavy rain. Decisions on crop management dependent on weather. These strategies are integrated for improving environmental sustainability, stability of yield and resource use efficiency (Kumawat *et al*., 2015; Directorate of Pulses Development, 2020).

vii). **Role in Resilient Crop Systems:** Black gram is a short-duration crop with nitrogen-fixing capabilities and compatibility with cereals and other crops; hence, it is an important component of resilient and diversified cropping systems. It can be used in rice-based, cereal-based, rainfed, intercropping and sequential production systems. Black gram can improve nutrient cycling, diversify farm production, and provide another source of cash and protein. Its role is especially significant in rice-fallow systems because leftover soil moisture can be used to grow pulses. Thus, black gram can help to increase cropping intensity and improve overall efficiency of available land and water resources. Crop-modelling research in recent years has also demonstrated opportunities to increase water productivity and black gram yield under a variety of Indian circumstances through improved management and adaptation strategies (Frontiers in Agronomy, 2026).

viii). **General Importance:** Black gram is a short-duration, flexible and relatively low-water-requiring crop, utilises residual moisture and can fix nitrogen, all of which make it a viable crop for climate resilience. But it certainly has its limits, especially in prolonged drought, extreme heat and flooding conditions. Hence, future research should be directed toward drought- and heat-tolerant cultivars, climate-based sowing strategies, effective irrigation, soil moisture conservation, precise nutrient management and integrated pest and disease control. In this way, black gram can make a major contribution to climate-smart agriculture by helping to maintain crop diversification, improve soil fertility, produce pulses, increase water-use efficiency and resilience of farmers to more unpredictable weather.

6. Major Insect Pests of Black Gram

Black gram (*Vigna mungo* L.) is susceptible to a number of insect pests in vegetative, flowering and pod development phases. The main pests are aphids, spotted pod borer, pod bugs and tobacco caterpillars. These insects feed on leaves, flowers and pods, suck plant sap or damage developing seeds, directly damaging the plant. Temperature, humidity, rainfall, crop stage and neighbouring vegetation influence their incidence. An integrated pest control (IPM) strategy consisting of mechanical, biological, botanical, cultural and need-based chemical treatments is recommended for sustainable management (Singh and Ahlawat, 2005; Directorate of Pulses Development, 2020).

6.1. Identification of Aphids *Aphis craccivora*

Aphids are minute, soft-bodied insects that form colonies on tender stems, young leaves, flowers and pods. They are often green, dark green or black. Winged and wingless adults can be found.

Symptoms of Injury: Adults and nymphs both feed on plant sap, and this results in: Young yellow leaves curl. Retarded growth of plants. Dwarfed young shoots. Reduced pod development and flowering. Sooty mould growth is aided by honeydew production. Severe infection can markedly decrease plant vigour and yield. Good Conditions, Aphid populations tend to increase under quite dry, warm circumstances, especially when there is a lot of fragile plant growth. Excess nitrogen fertilisation can also stimulate succulent growth, which promotes aphid reproduction.

Management: Use species that are tolerant and healthy when possible. Avoid over-fertilising with nitrogen. Early removal of heavily infested shoots is recommended. Preserve natural enemies such as parasitoids, lacewings and ladybird beetles. Apply botanical therapies of neem if appropriate. Apply selective pesticides only when pest populations are above the locally recommended economic threshold.

6.2. Identification of Spotted Pod Borer, *Maruca vitrata*:

The larva is usually greenish to brown with longitudinal stripes; the adult is a small moth. The larvae are usually found inside the pods, stalks and webbed flowers. Signs of Damage The larvae feed on: young shoots. Buds and blossoms. Create pod. Seed-pod. Infested blossoms and pods may web together with feeding holes and larvae faeces on damaged pods. They may cause a reduction in seed and bloom drop due to eating on reproductive systems.

Favourable Circumstances: Warm, humid weather, intense crop growth and the presence of flowering and pod-forming plants are all conducive to the pest. Continuous pulse growing and overlapping crop seasons can also cause carry-over of pests.

Management: Don't plant too close together, and seed at the right times. Remove and destroy heavily affected plant parts. Use light or pheromone traps to monitor adult moths. Promote natural enemies like parasitoids. Where possible, employ botanical remedies based on neem. Apply the recommended selective insecticides when necessary, rotating the groups of pesticides to prevent the development of resistance.

6.3. Pod Bug Identification: *Clavigralla gibbosa*

Clavigralla gibbosa is a brown beetle that sucks the pods of medium-sized plants. Nymphs and adults are commonly found on developing pods and flowers.

Signs of an Injury: Adults and nymphs penetrate developing pods and seeds using their mouthparts. May cause damage to: Pods may have brown or discoloured spots. Badly shaped or shrunken seeds reduce seed bulk. Deterioration of grain, discolouration. Severely contaminated pods may dry out prematurely or become distorted.

Good Position: Pod bugs love warm weather and flowering crops and crops that produce pods. Continuous pulse cultivation can ensure adequate host availability, while dry conditions during pod development may favour population build-up.

Administering: Keep the land clean and remove any other host plants. Follow timely sowing.

Don't grow the same pulse crop year after year. Watch the plants for flowering and setting pods.

Keep your natural enemies. Neem botanicals can be used in an IPM program. Only use indicated insecticides where economically justified.

6.4. Identification of Tobacco Caterpillar (*Spodoptera litura*)

The tobacco caterpillar is a polyphagous noctuid bug. Larvae often show distinct longitudinal patterns and vary in colour from greenish to brown or dark. The mature moths are modest in size with patterned forewings.

Signs of Injury: Young larvae feed voraciously on leaves and cause scraping or windowing damage. Older larvae can consume a lot of the foliage and become more harmful, which can result in: holes in the leaves. Significant leaf loss. Reduced photosynthesis area. Damage to flowers and pods due to heavy infestation. Reduction in plant yield and development.

Positive Situations

The pest is encouraged by warm weather, the presence of host plants and times of comparatively high humidity. The polyphagous nature of the pest enables it to survive on a variety of weed and cultivated hosts around black gram fields.

Administration: Deep summer ploughing may leave pupae vulnerable to predators and the environment. Weed and rotate host plants around fields. Monitor the adult moth population with pheromone traps. If feasible, remove and collect larval aggregations and egg masses. Encourage natural enemies and microbial biological control agents such as Beauveria bassiana and Nomuraea rileyi if locally available. Neem botanicals are useful for reducing the early stages of larvae. Use the recommended selective insecticides on populations threatening the economy.

6.5. Other Important Insect Pests:

In addition to the major pests described above, black gram may be affected by several other insects depending on the region and season. Important examples include:

Table 1: Other Important Insect Pests of Black Gram (*Vigna mungo* L.) and Their Major Damage

Insect Pest	Major Damage
Whitefly (*Bemisia tabaci*)	Sap sucking and transmission of yellow mosaic virus
Thrips	Damage to tender leaves, flowers and growing points
Leafhoppers/jassids (*Empoasca* spp.)	Leaf curling, yellowing and reduced plant vigour
Bean fly (*Ophiomyia phaseoli*)	Damage to seedlings and stems
Gram pod borer (*Helicoverpa armigera*)	Feeding on flowers, pods and developing seeds
Hairy caterpillars (*Spilarctia* spp.)	Defoliation
White grubs	Root feeding and weakening of plants
Termites	Damage to roots and underground plant parts

Prevalence and economic importance of these pests are affected by location, season, cultivar, cropping system and environmental conditions. Therefore, regular field monitoring is needed to detect pest outbreaks at initial stages (Directorate of Pulses Development, 2020).

6.6. Integrated Pest Management of Black Gram

Integrated pest management should be the basis for the use of a holistic approach to insect-pest control rather than chemical pesticides alone. The primary components are: preventive measures are balanced fertilisation, timely sowing, field sanitation and quality seeds. Cultural management includes crop rotation, optimisation of plant population and removal of alternate hosts. Mechanical control methods include collection and destruction of egg masses, larvae and badly infested plant parts. Biological control is the conservation and augmentation of parasitoids, predators and microbial biocontrol agents. Botanical control is the use of neem and other plant-based medications when they are effective. Monitoring consists of regular reconnaissance and light or pheromone traps. Chemical control is the application of locally recommended insecticides on an as-needed basis when pest populations reach economically harmful levels.

This integrated approach can reduce pesticide residues, retain beneficial species, eliminate unnecessary pesticide applications and encourage ecologically sustainable black gram production (Singh and Ahlawat, 2005; Directorate of Pulses Development, 2020).

7. Common Diseases of Black Gram

Black gram (*Vigna mungo* L.) is prone to numerous viral, fungal and soil-borne diseases that impact plant growth, pod formation, grain yield and seed quality. The most prominent of these is yellow mosaic disease, but under favourable environmental conditions, powdery mildew, Cercospora leaf blight, anthracnose and Fusarium-linked diseases are also important. For successful management, an integrated disease-management (IDM) strategy involving resistant cultivars, healthy seed, field sanitation, proper sowing time, crop rotation, biological control, and need-based fungicide application is required (Singh and Ahlawat, 2005; IIPR, 2020).

7.1. Cause of Yellow Mosaic Disease

Yellow mosaic disease of black gram is caused mainly by mungbean yellow mosaic virus (MYMV) and associated begomoviruses, depending on the area. The major vector of the viruses is the whitefly *Bemisia tabaci* (Nene, 1972;

Maruthi *et al*., 2007).

Indications: Common signs and symptoms include: Young leaves often contain small yellow spots or dots. Green and yellow mosaic designs which grow over time. Leaf area reduction and severe chlorosis. Weak growth of plants. Reduction in pod formation and flowering. Infected plants may have fewer and poorly formed seeds. Infections early in the season generally cause greater yield losses than infections at later growth stages

Disease Development: Virus transmission is mostly by whitefly vectors. Inoculum may be derived from other hosts and from infected crop plants. The warm weather and increasing numbers of whitefly favour the development and spread of the disease. The disease can spread rapidly within a field when vulnerable plants and vector populations are high.

Administration: Use tolerant or resistant cultivars when available. Use good quality certified seed. Remove and kill infected plants as soon as feasible. Integrated vector control for whitefly population reduction. Remove weeds and possible hosts of the virus or vector. Do not plant overlapping pulse crops that can harbour vector and virus populations. Integrate biological approaches and neem-based products in IPM. Use recommended pesticides for whitefly sparingly and only when necessary, and in accordance with local recommendations.

7.2. Powdery Mildew

The Cause Powdery mildew of black gram is caused by the obligate fungus Erysiphe polygoni (syn. *Erysiphe diffusa* reports have also been detected on some legume hosts.

Symptoms: The features of the disease are white powdery fungus on the leaves. Firstly, it's small areas of white. Colonies powdery, spreading slowly over the leaf surface. Leaves that are badly infected dry out and become yellow too fast. Reduction in photosynthetic activity. Severe infection leads to poor development and lower production.

Disease Development: The disease is usually found in rather warm, relatively dry environments with adequate humidity, especially where air movement is impeded by dense crop canopies. This pathogen produces a significant quantity of airborne spores that can spread swiftly between plants. Management: Grow tolerant or resistant cultivars where possible. Allow adequate air circulation and space between the plants. Don’t use too much nitrogen. Remove heavily polluted plant debris. Rotate crops as appropriate. If the illness is severe, use recommended fungicides, such as sulfur-based treatments or other locally-approved fungicides. Integrated sickness management programs could involve botanical and biological ingredients.

7.3. The Pathogen of *Cercospora* Leaf Blight

Cercosporin canescens and other Cercospora species are commonly associated with Cercospora leaf blight/leaf spot of black gram.

Signs: Common signs and symptoms include small, uneven patches of brown, reddish-brown or greyish leaves; The borders of spots may get darker. Multiple lesions may coalesce to form larger zones of necrosis. Severe infection leads to premature leaf senescence and defoliation. Lower photosynthetic activity can result in lower pod growth and yield.

Pathogenesis: Disease development is favoured by warm, humid conditions, frequent rains and long periods of leaf wetness. The pathogen produces spores that are carried by wind and rain splashes and can survive on contaminated plant debris. A dense canopy of crops can encourage the development of illnesses and raise humidity.

Administration: Use healthy seed that is free of disease. Where available, tolerant or resistant cultivars should be grown. The infected crop residues should be removed or disposed of properly. Allow sufficient distance between things for better aeration. Avoid long periods of leaf moisture and over-irrigation. Use non-host crops in your rotation. Apply the appropriate fungicide at the locally recommended rate when disease levels reach commercially significant levels.

7.4. Anthracnose

The Causal Agent: Black gram anthracnose is primarily associated with species of Colletotrichum, especially *Colletotrichum lindemuthianum* and other Colletotrichum taxa reported from Vigna crops.

Symptoms: The following symptoms may occur on leaves, stems, petioles and pods: dark brown to black tiny lesions. Long lesions on the stem and petiole. Lesions may become larger and sink. Pods may be diseased or have dark spots. A bad infection causes the tissues that are affected to shrivel up. Poor quality or contaminated seed may be produced from sick pods.

Development of Disease, Anthracnose thrives in warm, humid, and wet conditions. Contaminated plant debris can transfer spores to healthy plants by rain splashes. The pathogen can survive between seasons on contaminated seed or agricultural wastes, allowing for disease transmission.

Administration: Use certified, pathogen-free seed. Seed-borne infections can be reduced by seed treatment with fungicide or biological agents. Remove any tainted plant remains. Change the crops you plant each year. Do not over-irrigate and maintain prolonged leaf wetness. Space your plants correctly. Where tolerant or resistant cultivars are available, use them. Apply recommended fungicides if necessary.

7.5. Organisms Associated with Fusarium Diseases

Several Fusarium species have been associated with black gram root and wilt diseases. Depending on the disease complex and the geographic location, species such as Fusarium oxysporum may be involved.

Symptoms and Signs: Common indications and symptoms may include: golden leaves. Lack of vigour in plants. died away and withered. Discolouration or browning of the vascular tissue. Rot of the roots. Negatively affected: early drying and then death of plants. Scattered in patches over the countryside are diseased plants.

Development of Diseases: Fusarium diseases are frequently soil-borne and can persist for lengthy periods in soil and infected plant debris. Disease development is affected by plant stress, temperature, moisture, soil conditions, and presence of sensitive hosts. Build-up of the pathogen may be helped by continual cultivation of susceptible pulse crops.

Management: Use healthy and disease-free seed. Inoculate seed with beneficial microbes or recommended fungicide. Ensure that the soil is well-drained. Do not grow black gram and other legumes, which are susceptible, continually. After crop rotation, use suitable non-host crops.

5. Use fully decomposed organic manure to promote biological activity of soil.

Use biological control agents such as Trichoderma spp. as recommended locally Develop and increase resistant cultivars where possible.

7.6. Other Important Diseases

In addition to the major diseases described above, black gram may suffer from several other diseases depending on cultivar, season, geographical region and environmental conditions.

Table 2: Important Diseases of Black Gram (*Vigna mungo* L.), Their Causal Organisms and Major Symptoms.

Disease	Major Causal Organism	Important Symptoms
Urdbean leaf crinkle disease	Urdbean leaf crinkle-associated virus/virus complex	Leaf crinkling, curling, distortion and reduced plant growth
Root rot	*Macrophomina phaseolina* and other soil-borne pathogens	Root browning, wilting and plant death
Dry root rot	*Macrophomina phaseolina*	Drying, root decay and sudden plant death
Alternaria leaf spot	*Alternaria* spp.	Brown to dark leaf spots and premature defoliation
Bacterial leaf spot/blight	*Xanthomonas* spp.	Water-soaked lesions, necrotic spots and leaf blighting
Web blight	*Rhizoctonia solani*	Water-soaked lesions, web-like fungal growth and rapid leaf blighting
Seedling diseases	*Rhizoctonia*, *Fusarium*, *Pythium* and related pathogens	Poor emergence, seed decay and damping-off

The occurrence and severity of these diseases vary considerably between regions and seasons. Consequently, disease diagnosis should be based on field symptoms, pathogen confirmation and local disease history before selecting management measures.

7.7. Integrated Disease Management

Sustainable disease management in black gram should combine multiple approaches rather than depending solely on chemical fungicides. The major components include:

i). **Resistant Varieties:** Cultivation of disease-resistant or tolerant varieties is one of the most economical and environmentally sustainable approaches.

ii). **Healthy Seed:** Use of certified, healthy and pathogen-free seed can reduce the introduction and spread of seed-borne pathogens.

iii). **Seed Treatment:** Appropriate fungicidal or biological seed treatments can protect seedlings against several seed- and soil-borne pathogens. Trichoderma spp. may be incorporated into biological disease-management programmes.

iv). **Field Sanitation:** Removal and proper disposal or decomposition of infected plant residues can reduce sources of primary inoculum.

v). **Crop Rotation:** Rotation with suitable non-host crops can reduce the build-up of soil-borne pathogens, particularly Fusarium, Macrophomina and Rhizoctonia.

vi). **Optimum Plant Population:** Maintaining appropriate plant spacing improves air circulation and reduces humidity within the canopy, thereby limiting some foliar diseases.

vii). **Water Management:** Avoiding excessive irrigation and waterlogging is particularly important for reducing root and soil-borne diseases.

viii). **Biological and Botanical Approaches:** Beneficial microorganisms such as Trichoderma spp. and selected botanical products can be integrated into sustainable disease-management programmes.

ix). **Need-Based Chemical Management:** Where disease pressure is economically significant, locally recommended fungicides should be used at the appropriate dose and growth stage. Fungicides should be rotated between different modes of action to reduce the risk of fungicide resistance.

8. Conclusion

Black gram (*Vigna mungo* L.) is an important nutritious, short-duration and climate-resilient pulse crop with significant value for food security, soil fertility and sustainable agriculture. Its biological nitrogen-fixing ability, adaptability to diverse environments, efficient utilisation of residual soil moisture, and suitability for crop rotation, intercropping and catch-crop systems make it an important component of resilient farming systems. However, drought, high temperature, irregular rainfall, insect pests, diseases, weeds and post-harvest losses continue to limit productivity. Adoption of quality seed, suitable sowing practices, organic nutrient management, efficient water use, integrated weed management, climate-smart agronomy, resistant varieties, integrated pest and disease management, biological and botanical control, and improved storage technologies can reduce these constraints. Future research should focus on high-yielding climate-resilient varieties, precision resource management, eco-friendly crop protection and improved post-harvest technologies. An integrated and sustainable approach will be essential for enhancing black gram productivity, profitability, grain quality and long-term contribution to food and nutritional security under changing climatic conditions (Singh and Ahlawat, 2005; Directorate of Pulses Development, 2020).

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