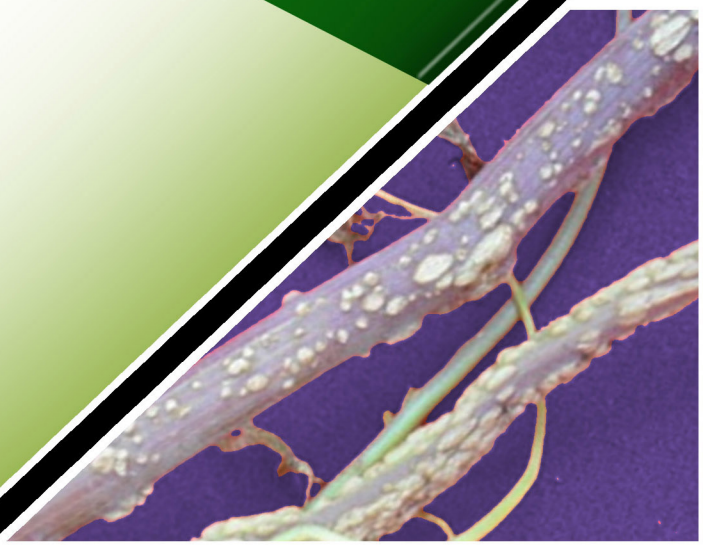
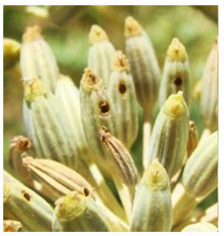
Technical Bulletin

Screening techniques for major diseases, insect pests and nematodes infecting seed spices

Technical Bulletin – 10 (2025/10)





ICAR-All India Coordinated Research Project on Spices

ICAR-Indian Institute of Spices Research

Kozhikode-673012, Kerala, India

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THE CONTENT

Screening techniques for major diseases, insect pests and nematodes infecting seed spices

भाकृअनुप
ICAR

CORIANDER

Coriander (*Coriandrum sativum*) is an annual Apiaceae herb, widely grown in India, with Rajasthan as the top producer. Rich in vitamins and aromatic compounds, it faces major losses from fungal diseases like stem gall and pests including aphids, thrips, mites, and whiteflies, affecting yield and quality significantly.

General recommendations for screening

A location with a known history of disease incidence or conducive environmental conditions should be chosen (cool and humid). Well-drained, loamy soil with neutral pH is ideal. Rabi (cool, dry season) is most favorable for natural disease development. Entries/ varieties to be screened should be sown in Randomized Block Design (RBD) or Augmented Block Design with 2–3 replications. Each test entries should be sown in paired row and after every three test entries two row of susceptible check should be sown. In absence of susceptible check, resistant check or released resistant variety can be used. Each block should start and end with one/ two rows of susceptible check. If available a resistant check should be included in the set of test entries/ varieties meant for screening for comparison. Recommended fungicide application meant for coriander stem gall/ powdery mildew/ wilt disease management should be avoided to ensure disease development. Uniform irrigation and basic agronomic care should be adopted. High humidity during active crop growth period should be maintained and overcrowding of crop should be avoided to encourage natural disease expression.

Stem gall

Coriander in India suffers most by the infection of *Protomyces macrosporus,* a gall-forming fungus. The pathogen has been observed on many other umbelliferous plants in India.

Symptomatology

Stem gall of coriander, caused by *Protomyces macrosporus,* appears as small tumour-like swellings on stems, petioles, flower stalks, and leaves. These galls, usually 9–12 × 3–5 mm, result from hypertrophy and hyperplasia of cortical cells surrounding intercellular hyphae, often replacing collenchyma with thin-walled parenchyma.

The pathogen disrupts oil canals, reduces sugars and free amino acids, and alters enzyme activities, increasing invertase, protease, acid phosphatase, and peroxidase while lowering polyphenol oxidase. Systemic infection before flowering induces organogenic changes, inhibits sporogenesis, and produces enlarged fruits.

Screening for disease resistance

If natural disease pressure is low or variable:

Source of inoculum: Infected galled seeds or stem tissues with visible galls should preferably be used as inoculum. The collected material should be roughly crushed and mixed with sand or soil for soil inoculation. This prepared inoculum should be applied in furrows between rows within one week of sowing, with a second application, if available, at 40-45 days after sowing.

Alternative method of inoculation: Galled tissues collected from the previous year should be crushed in sterile distilled water at a 1:10 (w/v) ratio. The resulting inoculum suspension should be filtered through muslin cloth, and the obtained spore suspension (1 x 10^6 spores/mL) used for inoculation. Freshly prepared spore suspension should be sprayed at 30 DAS in the evening, after sunset. Two to three additional foliar sprays should be applied weekly at the stem base and nodes to ensure better infection

Data recording:

Disease observations should be recorded at the seed maturation stage. For accuracy, at least five, and preferably ten, plants per test entry or variety should be randomly selected from each replication. Categorization of test entries or varieties into susceptibility or resistance groups can be done at either the vegetative to early reproductive stage (up to inflorescence) or at the reproductive (seed maturity) stage. Classification based on observations at the vegetative to early reproductive stage should follow the 0-4 disease rating scale (Anonymous, 2004).

Disease Score	Symptoms on plant	Disease Reaction
0	No gall	Highly Resistant
1	Galls on stem alone	Resistant
2	Galls on stem & leaf	Moderately Susceptible
3	Galls on inflorescence	Susceptible
4	Galls on stem, leaf & inflorescence	Highly Susceptible

Categorization of the test entries/varieties in different group of susceptibility or resistance can be done based on observation at reproductive stage i.e., seed maturity stage following modified 0-9 disease score as devised for grain moulds of sorghum (Mayee and Datar, 1986).

Disease Score	Per cent (%) galled seed/ umbellet
0	0
1	1.0
3	1.1 to 10
5	10.1 to 25
7	25.1 to 50
9	Above 50

Based on disease score, per cent disease index (PDI) of the disease can be worked out using formula:

$$\text{Per cent disease incidence (PDI)} = \frac{\text{Sum of all individual disease score}}{\text{Total no. of plants assessed/ observation x Maximum rating}} \times 100$$

Based on the PDI (%) the genotypes or plants under a particular treatment can be grouped in the different categories as mentioned below (Rathi and Tripathi, 1994).

PDI (%)	Disease Reaction
0	Immune
1-10	Resistant
11-25	Moderately Resistant
26-50	Moderately Susceptible
51-75	Susceptible
>75	Highly Susceptible

Selected references :

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research Calicut, Kerala. p. 62.
- Gupta, J. S. (1954). Disease appraisal of stem gall of coriander. Indian Phytopathology. 7: 53-60.
- Mayee, C. D. and Datar, V. V. (1986). Phytopathometry. Technical Bulletin No.1, University of Agricultural Sciences, Marathawad, Parbhani, India. p. 146.
- Rathi, A.S. and Tripathi, N. N. (1994). Assessment of growth reduction and yield losses in pea due to powdery mildew disease caused by *Erysiphe polygoni* DC. Crop Research (Hisar). 8(2): 371-376.

Powdery mildew

Powdery mildew of coriander, caused by *Erysiphe polygoni,* is an airborne disease causing 15–40% yield loss and poor seed quality. It produces white fungal growth on aerial parts, reducing photosynthesis and vigor. Favorable warm, dry days with cool, humid nights promote infection, impacting productivity, seed quality, and marketability.

Symptomatology

Powdery mildew appears as white to grayish powdery spots or patches on young plant tissues, sometimes covering entire leaves or organs. Tiny, spherical cleistothecia initially white, later yellow-brown, and finally black-may form singly or in groups on older infected areas. The disease primarily affects the upper leaf surface but can also spread to the undersides of leaves, young shoots, stems, buds, flowers, and fruits. Small white patches on leaves, stems, and buds enlarge and merge, covering the entire surface. Infected leaves become smaller, distorted, and may lead to premature sterility. Severe infections cause drying of umbels. Seed formation may be completely inhibited in affected plants.

Screening for disease resistance

If natural disease pressure is low :

Spores (conidia) collected from the infected coriander plants can be used for artificial inoculation. Collected spores (conidia) can be dusted or sprayed as spore suspension (prepared in distilled water with a drop of surfactant) evenly on test plants during early morning or evening. Inoculation should ideally be done when plants have 4-6 true leaves.

Observation:

Observations on powdery mildew incidence per replication should be recorded periodically date wise. Based on it, per cent disease index (Disease severity/ intensity) should be calculated. For recording observations on powdery mildew severity, ten (10) plants per plot per replications should be randomly selected and tagged before appearance of the disease in the crop sown at single date or if possible at different dates. Visual observations on the disease severity should be recorded on randomly selected tagged plants at seven days interval after first appearance of disease up to the crop maturity. Disease scoring should be done by applying 0-4 disease rating scale (Anonymous, 2004) as described below:

Grade	Disease Reaction
0	Healthy
1	Whitish small spots on leaf
2	Whitish growth covering the entire leaf
3	Growth on leaf and stem
4	Growth on leaf, stem and umbel

Based on the above disease scoring scale, Per cent Disease Index (PDI)/ Disease Intensity can be computed out as follows:

PDI = (Scale x Number of plants in each scale)/ (Maximum scale x Total number of plants) x 100

Based on the PDI, the entries/ varieties can be categorized in different group of resistance or susceptibility as depicted below given by Datar and Mayee (1981).

PDI/ Disease intensity	Disease Reaction
0	Immune
1-20	Resistant
21-40	Moderately Resistant
41-60	Highly Susceptible
>60	Susceptible

Selected references :

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research Calicut, Kerala. p. 62.
- Datar, V. V. and Mayee, C. D. (1981). Assessment of losses in tomato yield due to early blight. Indian Phytopathology. 34: 191-195.

Wilt

Coriander wilt, caused by *Fusarium oxysporum f. sp. coriandrii,* is a soil-borne disease that attacks the vascular system, blocking water and nutrient transport. Affected plants show wilting, water stress, and may collapse. It appears from vegetative to flowering stages, causing major yield loss, thriving in warm, poorly drained soils.

Symptomatology

The disease attacks coriander plants at all growth stages, with wilting observed from seedling to maturity and severity increasing with age. It is characterized by drooping terminal shoots, leaf withering, and eventual plant death. Vascular discoloration is visible in roots and stems, and partial wilting often arrests growth. Affected leaves turn pinkish-yellow to yellow, and seeds, if produced, are light and immature. Unlike patchy distribution, the disease can affect entire fields, often causing sudden rather than gradual wilting. Severe early infections may lead to complete crop failure.

Data recording:

Initial symptom of Fusarium root rot may be observed after germination, Coriander plants showing wilt symptoms should be uprooted from the soil, washed thoroughly to remove soil debris and root rot disease should be recorded upto 100 DAS at 10 days interval. The germplasm/entries/variety under screen can be grouped in different groups of susceptibility or resistance based on per cent disease incidence given by Anonymous (2004) as follows:

Disease Incidence (%)	Disease Reaction
1-10	Highly resistant
11-20	Resistant
21-30	Moderately Resistant
31-50	Susceptible
>50	Highly Susceptible

Out of total number of plants, number of wilted plants in each plot should be counted at 60 DAS or at 15 days of first disease symptom appearance.

Disease Incidence (%) can be computed based on following formula:

$$\frac{\text{Number of wilted plants}}{\text{Total number of plants}} \times 100$$

Selected reference

Anonymous (2004). AICRP on Chickpea Annual Workshop, RARI, Durgapura, Rajasthan, 1-3 Sept., 2014.

Coriander aphid (*Hyadaphis coriandri*)

Coriander aphids are sap-sucking pests that cluster on leaf undersides and stems, causing curling, yellowing, stunted growth, and honeydew that attracts ants and sooty mold.

Symptomatology

Hyadaphis coriandri is a major pest of coriander that feeds by sucking sap, primarily from young shoots and flower clusters, and later from developing seeds. This greenish-yellow aphid reproduces rapidly through viviparous parthenogenesis, enabling quick population build up. Its feeding causes yellowing, curling, and drying of leaves, withering of shoots, and shriveling of seeds. Honeydew secretions promote sooty mold growth, further reducing photosynthesis and plant vigor. Heavy infestations from flowering to maturity can cause severe yield losses, sometimes reaching 40–50%, if not managed at the economic threshold level

Screening for pest resistance

The experiment needs to be laid out in a randomized block design (RBD). The seeds of varieties/genotypes (treatments) needs to be sown in second fortnight of October, each replicated thrice. The plot size should be maintained at 2.0 x 2.25 m2 with the row to row and plant to plant distance of 45 and 20 cm, respectively. The observations on population of aphids will be recorded at weekly interval, starting from one week after germination to the harvest of crop. The population of aphid will be estimated by adopting zero to four indexes through the observations made on 10 cm terminal twigs of ten randomly selected plants. The following indices will be suggested by Patel et al. (2011) for estimation of aphid population.

Observation to be recorded:

No. of aphids/ 5 cm twig

Indices Description

Pest rating scale for aphid (1 to 4 scale)			
Aphid Index	**Degree of infestation**	**No. of aphids /5 cm twig**	**Aphid Reaction**
0	Plant free from aphid/ No aphids	0	Immune
1	Isolated singly on few tenter parts	1-5	Resistant
2	Singly on mature plant parts	6-10	Moderately Resistant
3	Colony countable	11-20	Susceptible
4	Uncountable colony on whole plant	21 and above	Highly susceptible

$$\text{Average aphid index} = \frac{0N + 1N + 2N + 3N + 4N}{\text{Total no. of plants observed}}$$

Where,

0, 1, 2, 3 and 4 are aphid index

N = Number of plants showing respective aphid index

Selected references

Patel, S. A., Patel, J.S., Patel, J. K. & Patel, P. S. (2011). Seasonal abundance of fennel aphid, Hyadaphis coriandri (Das) and associated bioagents in fennel crop. Trends in Biosciences. 4(1): 116-117.

Seed midge/ wasp

Among the various insect pests, seed midge, *Systole albipennis* has been reported as a regular and major pest of coriander in Rajasthan and other parts of the country. The adult female of seed midge, S. albipennis lays eggs in the developing coriander seed. After hatching, the young larva feeds inside the seed and pupates therein. The adults emerge out by making a round hole in the seed in the stores. Though the weight loss in low but qualitative loss is heavy because of non-acceptability by consumers. The pest significantly reduces the market value of coriander seed and is one of the major constraints in quality seed production (Agrawal et al., 2004). It attacks in field as well as in storage. Singh and Baswana (1984) reported seed infestation up to 15 percent in Haryana state due to seed midge, *S. albipennis* in coriander crop.

Screening protocol

The experiment needs to be laid out in a randomized block design (RBD). The seeds of varieties/genotypes (treatments) needs to be sown in second fortnight of October, each replicated thrice. The plot size should be maintained at 2.0 x 2.25 m^2 with the row to row and plant to plant distance of 45 and 20 cm, respectively. The crops will be subjected to natural infestation of S. albipennis. The observations on the incidence of S. albipennis, will be recorded from seed setting to harvest of coriander umbels. Seed damage due to seed midge will be recorded by selecting ten plants randomly in each sector. After seed setting at weekly interval, ten umbels will be selected randomly from each sector and 100 seeds from those umbels will be randomly collected and stored for 15 days and will be allowed for emergence of midge from the seeds. All the seeds should be thoroughly checked with the help of magnifying glass. The seeds with appearance of black spots or insect exit hole is considered as damaged seed and per cent infestation is calculated accordingly.

$$\text{Infestation (\%)} = \frac{\text{Infested seeds}}{\text{Total Seeds}} \times 100$$

Based on seed midge infestation (%) as given below, the germplasm/ entry/ variety can be grouped in different categories of resistance/ susceptibility.

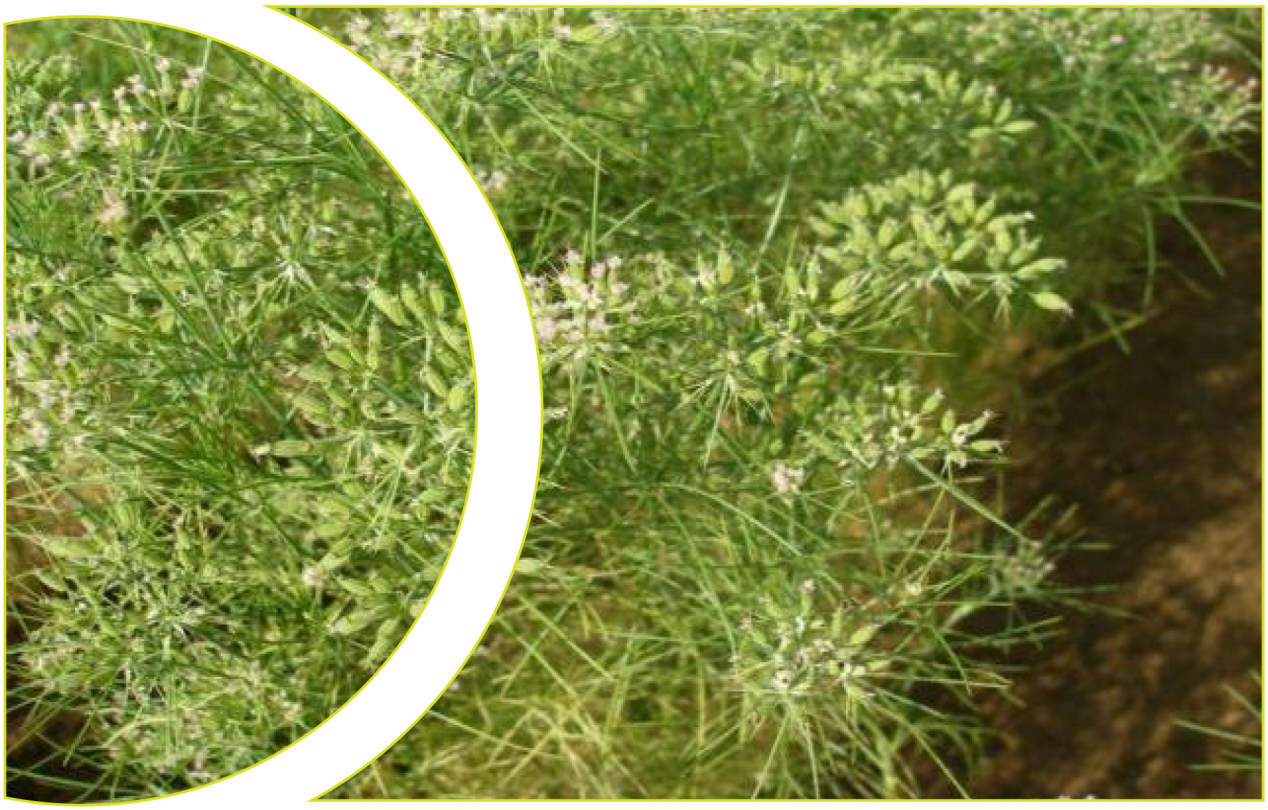
Seed Infestation (%)	Seed Midge Reaction
0	Highly Resistant
0.1 – 10	Resistant
10.1 -25	Moderately Resistant
25.1 -50	Susceptible
> 50	Highly Susceptible

Selected references:

- Agrawal, V. K., Sharma, S. L, Rajput, S. S, Sharma, B. M. (2004). New record of seed midge fly (*Systole albipennis* Walker) on fennel. In: National Seminar on New Perspectives in Commercial Processing and Marketing of Seed Spices and Medicinal Plants; Bikaner, India. Rajasthan Agricultural University. p. 74.

- Singh, G. and Baswana, K. S. (1984). Screening of coriander germplasm against chalcid fly (*Systole albipennis* Walker). Annals of Applied Biology. 104: 114-115.

CUMIN



Cumin (*Cuminum cyminum*) of the Apiaceae family is native to the Mediterranean and Near East. It is cultivated mainly in India, Egypt, Iran, Pakistan, and Turkey for its aromatic seeds used in flavoring vegetables, pickles, soups, bread, cakes, and biscuits. Its characteristic aroma comes from cumin-aldehyde present in volatile oil. Cumin oil is also used in perfumery, liquors, and food processing due to its antimicrobial and antioxidative properties.

General screening procedure for disease resistance

The trial should be laid out in randomized block design (RBD) [below 30 genotypes] with three replication. If genotypes are more than 30 numbers they should use Augmented block design (ABD) for each entries and checks. The duration would be three years. Recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. Plot size should be of 2 (two) rows of 3 m length per genotype with spacing of 30 cm between rows and 05 cm between plants. The test entries shortlisted along with known/reported/local susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as 3 paired rows of test entries followed by check (susceptible/ resistant/varieties). Disease free healthy cumin seed should be sown during second fortnight of November to first fortnight of December. The location/field should be endemic/conducive to natural infection of wilt disease wherein recurring infection is recorded/observed during the period of experiments and previous years. It should be known as a sick plot or hot spot or natural condition for all the diseases occurrence. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than wilt.

Wilt

Cumin wilt, caused by *Fusarium oxysporum f. sp. cumini,* is one of the most destructive diseases of cumin, widely prevalent across cumin-growing regions. The disease appears at the seedling stage, causing wilting, with brown vascular discoloration visible in longitudinally cut stems. The pathogen, first reported from Rajasthan by Mathur and Mathur (1956), survives in soil and infected plant debris as mycelium and chlamydospores, spreading through rain splash, irrigation water, wind, and cultural operations

Symptomatology

Plants are affected at all stages of growth, but the severity of wilting increases with plant age. When the plant reaches 2.5 cm to 5.0 cm in height, it wilts and dies. In older plants, the leaf color changes from green to yellow, starting with the oldest leaves and moving to the younger leaves. In severe stages, the tops and leaves of the plant fall off, leading to complete plant death. Such plants are easy to pull out of the ground. The roots of diseased plants have dark brown spots. Sometimes only partial wilting is seen. If plants become infected during flowering, they remain sterile (Mathur and Prasad, 1964). The seeds formed are thin, small and wrinkled. Seeds are often contaminated at harvest, allowing pathogens to spread to new areas. Partially wilted plants stop growing and the leaves turn pinkish-yellow.

Screening for disease resistance

Procedure:

For cumin wilt follow general screening procedure for disease resistance.

The cumin seeds will be sown in wilt affected field having a wilt pathogen population of 1.5 x 10^4 cfu/g of soil or more. The infected soil will be used because it permits the assessment of field resistance by allowing the infection process to take place under natural conditions, with realistic doses of naturally produced inoculums. Sometimes when there is no natural incidence of disease in particular location and we need to screen for wilt disease than artificial inoculation of soil should be done. The culture of *Fusarium oxysporum f. sp. cumini* will be raised on sterilized sorghum seeds in 500 ml flasks for seven days. The inoculum will be mixed with soil before sowing the seeds in plots. The size of each plot will be 2.4 m x 3.0 m (2 rows of each genotype) with row spacing of 30 cm. After three test entries will be alternated by susceptible/Resistant/Local check. Based on the proportion of plants exhibiting Fusarium wilt symptoms in susceptible germplasm, the data will be recorded for ten (10) randomly selected healthy and wilted plants from different genotypes and per cent disease incidence will be calculated. The seeds sown in plots, in which inoculum was not added served as control. Record observations at regular intervals: 25, 40, 55 and 70 days after sowing. The per cent wilt incidence will be calculated by following formula (AICRP Spices Proceeding, 2004).

$$\text{Per cent Disease Incidence} = \frac{\text{Number of wilted plants}}{\text{Total number of plants observed}} \times 100$$

Based on the per cent disease incidence the genotypes will be grouped in the different categories as mentioned below

Percent Disease Incidence (%)	Reaction	Designation
0-10	Resistant	R
10.1-20.0	Moderately Resistant	MR
20.1-30.0	Moderately susceptible	MS
30.1-50.0	Susceptible	S
>50.1	Highly susceptible	HS

Selected references:

- Mathur, B. L. and Mathur, R. L. (1956). Annual report of scheme for research in wilt disease of zeera (*Cuminum cyminum* L.) in Rajasthan. University of Rajasthan, Jaipur.
- Mathur, B. L. and Prasad, N. (1964). Studies on wilt disease of cumin caused by *Fusarium oxysporum f. sp. cumini.* Indian Journal of Agricultural Sciences. 34: 131-137.
- Singh, R. D., Choudhary. S. L. and Patel. K. G. (1972) Seed transmission and control of Fusarium wilt of cumin. Phytopathologia Mediterranea.11: 19-24.
- Mathur, B. L. and Mathur R. L. (1965) Metabolites of *Fusarium oxysporum* in relation to cumin wilt. Indian Phytopathology. 18: 335-339.
- Patel, P. N., Prasad, N., Mathur, R. L. and Mathur, B. L. (1968). Fusarium wilt of cumin. Current Science. 26: 181-182.

Root rot

Root rot of cumin, caused by *Rhizoctonia solani, Fusarium spp.,* and *Macrophomina* phaseolina, affects plants from seedling to maturity. It causes pre and post-emergence damping-off, basal stem rot, and root decay. Infected plants show stunted growth, yellowing, wilting, and eventual death. Roots exhibit dark discoloration, rotting, and fungal growth. Severe infections lead to hollow stems, toppling, poor flowering, shriveled seeds, or no umbels. The disease occurs in patches, spreading under warm (25-30°C), poorly drained soils, and continuous cropping. Early diagnosis is essential to limit losses, as root rot significantly reduces yield and compromises plant vigor throughout the growing season.

Screening for disease resistance

Procedure:

Same as cumin wilt

Alternaria blight

Cumin blight is the second most important disease caused by *Alternaria burnsii. A. burnsii* infect cumin and reduce the yield as well as economic value. Losses up to 70% have been reported (Holliday, 1980). *A. burnsii* causing blight of cumin was recorded for the first time in Pakistan (Shakir et al., 1995). In India, blight of cumin caused by *A. burnsii* was first reported by Uppal et al. (1938). It was first reported by Joshi (1955) from the state of Rajasthan.

Symptomatology

The disease impacts all aerial parts of cumin plants, exhibiting various symptoms such as tip burning and brown to black spots on leaves, stems, and inflorescences, ultimately leading to the blighting of many plant sections (Patel and Desai, 1971; Wadud et al., 2017). Initially, affected plants display small necrotic spots on all aerial parts, particularly on the tips of young leaves.

These spots enlarge and merge, potentially resulting in the death of the entire plant or its affected parts (Sharma, 2010). Affected plants may also show purplish, brownish, or blackish lesions. The severity of the disease peaks under humid conditions. Infections occurring during the flowering stage can destroy the umbels, leading to failed seed development in diseased plants. If seeds do develop, they often appear light and blackish, causing significant losses for growers. During winnowing, shriveled seeds are easily blown away.

Screening for disease resistance

Procedure:

Sometimes when there is no natural incidence of disease in particular location and we need to screen for Alternaria blight than artificial epiphytotic conditions need to be created using artificial inoculation of the pathogen. Prepare a spore suspension of 1.5 x 10^5 conidia/mL of *Alternaria burnsii* using sterile distilled water and inoculate plants at 40-60 days after sowing (DAS). Spray uniformly in the evening using a sprayer. Maintain high humidity (≥85%) through overhead irrigation or misting for 48 hours post-inoculation. Incidence of disease should be recorded employing 0-5 scale as described (Anonymous, 2004). Start scoring PDI at 7-10 days after inoculation. Repeat observations weekly for 2-3 weeks. After appearing of the disease the data were recorded at an interval of 10 days up to harvesting. For disease scoring, observations from 20 randomly selected plants per plot should be recorded. Per cent Disease Intensity (PDI) should be calculated for each replication for each month separately and average PDI can be calculated by combining data of other replications (average of two-month data would represent the disease level of a particular entry/check for a particular year of screening). Based on average PDI during a particular year, the entries can be delineated into different categories of susceptibility or resistance which needs to be validated based on the observations recorded during subsequent years.

Disease rating scale for cumin blight (0-5 scale)	
Category	**Symptoms on leaves**
0	Healthy plant
1	Blight symptoms on tips of the leaves
2	Most of the leaves showing blight symptoms
3	Symptoms on leaves and umbels
4	Symptoms on leaves and umbels and few lesions on the stem
5	Symptoms on leaves, umbels, seed and on the stem
Anonymous (2004)	

Based on these observations, per cent disease intensity (PDI) of the disease was worked out using formula developed by Wheeler (1969).

$$\text{Per cent Disease index (PDI)} = \frac{(n \times 0 + n \times 1 + n \times 2 + n \times 3 + n \times 4 + n \times 5)}{N \times 5} \times 100$$

Where, n = Number of plants in each score, 5 = Maximum disease grade

N = Total number of plants under observation

Based on the per cent disease intensity, the various genotypes were placed into different categories

Categorization based on PDI for blight		
PDI (%)	**Category**	**Designation**
0	Highly resistant	HR
0-10	Resistant	R
11-20	Moderately resistant	MR
21-40	Moderately susceptible	MS
41-60	Susceptible	S
>60	Highly susceptible	HS

Selected references:

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research Calicut, Kerala. p. 62.
- Holliday, P. (1980). Fungus disease of tropical crops. Cambridge University Press, Cambridge, UK. pp. 289-295

- Joshi, N. C. (1955). Note on two diseases of *Cuminum cyminum* L. hitherto unreported from Ajmer State. Sci. and Cult. 21: 101-102
- Patel, R. M. and Desai, M. V. (1971). Alternaria blight of *Cuminum cymimum* and its control. Indian Phytopathology. 24: 16-22
- Shakir, A. S., Mirza, J. H., Sahi, S. T. and Ansar, M. (1995). First report of *Alternaria burnsii,* the causal organism of cumin blight in Pakistan. Pakistan Journal of Phytopathology. 7: 219-223
- Sharma, S. (2010). Studies on cumin blight incited by *Alternaria burnsii* and its management. M.Sc.(Ag.) Thesis, Anand Agricultural University, Anand, India.
- Uppal, B. N., Desai, M. K. and Kamat, M. K. (1938). Alternaria blight of cumin. Indian Journal of Agricultural Sciences. 7: 49-62

Powdery mildew

Powdery mildew of cumin is caused by a fungal pathogen (*Erysiphe polygoni* DC). It reduces seed yield up to 50 per cent under favourable weather conditions. Under severe disease condition, the total failure of the crop has been observed (Patel et al., 2017).

Symptomatology

Powdery growth on cumin develops first on leaves which later can cover all stems and branches including flowers get covered with white powdery mass of conidia. Powdery mildew forms a white, powdery layer on the surfaces of leaves, reducing the amount of photosynthesis reaching the chloroplasts. The fungal growth on leaves can interfere with photosynthesis, the process by which plants convert sunlight into energy. This reduction in photosynthetic activity can impact the overall growth and development of cumin plants. The disease is transferred through airborne spores called Conidia and through direct contact and also by seed transmission. Mildew is most severe in crowded, shady, poorly aerated locations when nights are cool and days are warm. The late sown crop under irrigated condition gets severely affected (Khare et al., 2014). The primary infection of the disease is through soil as well as seed and secondary infection takes place by the dispersal of conidia through rain splashes and wind. Cool high humid weather (20-25°C) or cloudy weather with high relative humidity (RH) >80% is the favorable condition for conidial germination and disease development.

Screening for disease resistance

For powdery mildew of cumin follow general screening procedure for disease resistance. Infector row (Known highly susceptible variety/germplasm/breeding line) technique will be followed to spread the disease intensively. In addition, four rows of the susceptible check will also be raised all around the experimental plot to provide the disease inoculum facilitating screening of the genotypes under field conditions. Each of the genotypes will be sown in two rows of 3 m length with 30 × 05 cm spacing and replicated thrice. The crop will be raised adopting the all recommended package of practices. The screening disease data will be recorded when the disease incidence will be maximum on the susceptible check. Observation on disease reaction will be made on ten (10) randomly selected plants in each entry. Leaves will be scored in each plant, three each from the apical, middle and basal regions and all of them will be graded. The disease intensity will be scored adopting the following 0-4 grade (Mayee and Datar,1986).

Disease rating scale for powdery mildew (0-4 scale)	
Category	**Symptoms on leaves**
0	Healthy plant
1	Whitish small spots on leaf
2	Whitish growth covering the entire leaf
3	Whitish growth on leaf and stem
4	Whitish growth on leaf, stem and umbel
Anonymous (2004)	

Based on these observations, per cent disease intensity (PDI) of the disease was worked out using formula developed by Wheeler (1969).

$$\text{Per cent Disease index (PDI)} = \frac{(n \times 0 + n \times 1 + n \times 2 + n \times 3 + n \times 4)}{N \times 4} \times 100$$

Where, n = Number of plants in each score, 4 = Maximum disease grade

N = Total number of plants under observation

Based on the PDI (%) the genotypes will be grouped in the different categories as mentioned below (Rathi and Tripathi, 1994).

Classification of cumin based on PDI for blight		
PDI	**Category of resistance**	**Designation**
0	Highly resistant	HR
0-10	Resistant	R
11-25	Moderately resistant	MR
26-50	Moderately susceptible	MS
51-75	Susceptible	S
>75	Highly susceptible	HS

Selected references:

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research Calicut, Kerala. p. 62.
- Khare, M.N., Tiwari, S.P. and Sharma, Y.K. (2014). Disease problems in the cultivation of Cumin (*Cuminum cyminum L.*) and Caraway (*Carum carvi* L.) and their management leading to the production of high quality pathogen free seed. International Journal of Seed Spices 4(1): 1-8.
- Mayee, C. D. and Datar, V.V. (1986) Phytopathometry. Technology Bulletin, 1:218.
- Patel, N. R., Amin, A. M. and Amin, A. U. (2017). Management of blight and powdery mildew diseases of cumin by spacing and potash application. Int. J. Seed Spices, 7:44-47.

Root knot nematode

Root-knot nematodes are plant-parasitic nematodes caused the genus *Meloidogyne.* In India, Rajasthan and Gujarat are major cumin producing state and contributing more than 90% of total cumin production in India. The root-knot nematode, *M. incognita* is an important root parasite infecting cumin and causing about 43% reduction in the yield of the crop (Midha and Trivedi, 1991). Cumin crop suffer from numbers of insect pests and diseases and nematode problem which causes significant yield losses at field level. Root knot nematode (*Meloidogyne spp*.) has been reported on cumin as well as in fennel crop (Kant et al., 2013 and Patel 2011). Sharma and Trivedi (2005) also reported cumin crop infected with Meloidogyne incognita and Fusarium complex in Rajasthan. In the soil of affected fields, diseases like drying and yellowing are known symptom of nematodes population (Krishna Kant et al., 2017).

Symptomatology

Root-knot nematodes cause stunted growth where infected plants will be shorter and less vigorous than healthy ones, yellowing of foliage, leaves may appear lighter in color than healthy foliage. Visible swellings or knots on the roots are a tell-tale sign of root-knot nematode infestation and root galls. Infected plants may also produce fewer and smaller seeds.

Biology of root knot nematode:

Most species of plant parasitic nematodes have a relatively simple life cycle consisting of the egg, four larval stages and the adult male and female. Development of the first stage larvae occurs within the egg where the first molt occurs. Second stage larvae hatch from eggs to find and infect plant roots or in some cases foliar tissues. Under suitable environmental conditions, the eggs hatch and new larvae emerge to complete the life cycle within 4 weeks at 30 °C and 8 weeks at 20 °C. Nematode development is generally most rapid within an optimal soil temperature range of 21 - 26 °C.

Screening for root knot nematode resistance

Procedure:

General screening procedure are same as follow previous cumin diseases. Sometimes when there is no sick or hot spot for the root knot in particular location and we need to screen for root knot than artificial inoculation of soil should be done. Experiment needs to be carried out in CRD design under pot condition with three replications during rabi season. The seeds to be sown in earthen pots having 5 kg naturally infested soil (2 J2 larvae per gram of soil). The seeds sown in pot, in which inoculum was not added served as control. Plants will be uprooted 60-65 days after germination and the observation will be recorded for five (5) randomly selected plants from different genotypes and count galls on roots per plant and calculated Root Knot Index.

$$\text{Average root knot index (RKI)} = \frac{0N+1N+2N+3N+4N+5N}{\text{Total no. of plants observed}}$$

Where,

0, 1, 2, 3, 4 and 5 are root knot index

N = Number of plants showing respective root knot index

Average Galls / Plant	Root-knot Index (RKI)
0 (No Galls)	1
1-10	2
11-30	3
31-100	4
>100	5

Cumin varieties/germplasms will be categorized as highly resistant, resistant, moderately resistant, susceptible and highly susceptible based on root-knot index 1-5 scale basis (Hartman and Sasser, 1985).

Root-knot Index (RKI)	Category of resistance	Designation
1	Highly Resistant	HR
2	Resistant	R
3	Moderately Resistant	MR
4	Susceptible	S
5	Highly Susceptible	HS

Selected references :

- Hartman, K.M., Sasser, J.N. (1985). Identification of *Meloidogyne* species on the basis of different host test and perineal pattern morphology. An Advanced Treatise on Meloidogyne 2: 69-77.
- Kant, K., Meena, S. R. and Sharma, Y. K. (2013). Root knot infestation in cumin crop. Seed Spices-E-Newsletter 5: 2.
- Patel, A. D. (2011). Nematodes diseases of seed spices and their management. (In) Recent Advances in seed spices, 163-5.
- Sharma, N. and Trivedi, P. C. (2005). Microbial Bioagents: Economic multiplication and management of fungal nematode complex of cumin. Indian J. Biotechnol. 4: 419–21.
- Kant, K., Singh, B., Sharma, Y. K., Meena, S. R., Solanki, R. K., Mishra, B. K., Meena, N. K. and Siddiqui, A. U. (2017). Diversity of nematodes population in cumin (*Cuminum cyminum*) crop in semi-Arid regions of Rajasthan, India. Indian J. Agric. Sci. 87:1664–7.
- Midha, R.L. and Trivedi PC. (1991). Estimation of losses caused by *Meloidogyne incognita* on coriander, cumin, and fennel. Curr Nematol. 2:159-162.

Aphid

Aphids [*Myzus persicae* (Sulzer), *Aphis gossypii* Glover and Hyadaphis coriandri (Das)] has been reported as major pest of cumin. Aphid has been observed to attack 220 host plant belonging to 46 families throughout the world (Roy and Behura, 1883). Aphid is the major insect pest of cumin in Rajasthan (Meena et al., 2018; Yadav et al., 2018). Both nymphs and adults of aphid cause damage to the crop by sucking the cell sap from leaves, tender stems, inflorescences and developing grains and also by secreting honey dew. Due to their rapid multiplication within a few days, the aphids cover the entire surface of the apical shoots and feeding by large population can cause the leaves to turn yellow, curling and subsequent drying of leaves takes place resulting in poor and shriveled seed formation. Secondly, they excrete honeydew like substance. The excessive excretion of honeydew by the aphids led to growth of black sooty mould on the leaves which inhibit the photosynthetic activity of the plants. In unprotected crop, loss due to aphid infestation could be more than 50 per cent of total yield (Lal et al., 2014).

Screening for aphids resistance

Procedure:

The experiment needs to be laid out in a randomized block design (RBD) or ABD. The seeds of varieties/genotypes needs to be sown in second fortnight of November to first fortnight of December, each replicated thrice. The plot size should be maintained at 3.0 x 2.4 m^2 with the row to row and plant to plant distance of 30 and 05 cm, respectively. The test entries and the check varieties should be sown as 3 paired rows of test entries followed by check (susceptible/resistant/varieties). The observations on population of aphids will be recorded from ten randomly selected and tagged plants in plot at weekly interval, starting from one month after germination to the harvest of crop. The population of aphid will be estimated by adopting zero to four indexes through the observations made on 5 cm terminal twigs of ten randomly selected plants. The following indices will be suggested by Patel et al. (2011) for estimation of aphid population.

Pest rating scale for aphid (0-4 scale)	
Approx. No. of aphids /5 cm twig	**Aphid Index (AI)**
0	0
1-5	1
6-10	2
11-20	3
21 and above	4
Proceedings of the XVII workshop of AICRP on Spices, 3-5 Feb. 2004, IISR, Calicut, Kerala, PP. 61	

Observation to be recorded:

No. of aphids/ 5 cm twig

Indices Description

$$\text{Average aphid index} = \frac{0N + 1N + 2N + 3N + 4N}{\text{Total no. of plants observed}}$$

Where,

0, 1, 2, 3 and 4 are aphid index

N = Number of plants showing respective aphid index

Cumin varieties/germplasms will be categorized as highly resistant, resistant, moderately resistant, susceptible and highly susceptible based on aphid index 0-4 scale basis (Patel et al., 2011).

Aphid Index (AI)	Category of resistance	Designation
0	Highly Resistant	HR
1	Resistant	R
2	Moderately Resistant	MR
3	Susceptible	S
4	Highly Susceptible	HS

Selected References

- Roy, D.K. and Behura BK. (1883). Notes on host plants, feeding behavior, infestation and ant attendance of cotton aphids, *Aphis gossypii* Glover. Journal of the Bombay Natural History Society. 80(3):654-656.
- Meena, N. K., Lal, G., Kant, K., Meena, R. S. and Meena, S. R. (2018) Pest scenario of cumin (*Cuminum cyminum L.*) and population dynamics in semi-arid region of Rajasthan. Int. J. Seed Spices. 8(1): 80-83.
- Yadav, T., Acharya, V.S., Yadav, R. and Singh, V. (2018) Seasonal incidence of aphid, *M. persicae* (Sulzer) on cumin, *Cuminum cyminum* Linn. J. Pharmacogn. Phytochem.7(1): 1084-1086.
- Lal, G., Saran, P. L., Devi, G., Bijarniya, D. and Raj, R. (2014) Production Technology of Cumin (*Cuminum cyminum L.*), pp. 223-231. In: Advances in Vegetables Agronomy, New Delhi
- Patel, S.A., Patel, I.S., Patel, J.K., Patel, P.S. (2011) Seasonal abundance of fennel aphid, *Hyadaphis coriandri* Das and associated bioagents in fennel crop. Trends in Biosciences 4(1):116-117.

Thrips

Cumin is infested by thrips, *Thrips tabaci* Lindeman, *Scirtothrips dorsalis* Hood and *Frankliniella* schultzei Trybom.

Damage symptoms:

- Direct damage: Thrips damage the undersides of leaves by sucking their juices. They damage young and soft parts of plants such as new leaves and shoots. As a result, leaves curl downwards, and change to a blackish-silver color patches on leaves and stems. Severe infestation causes young leaves to wilt and dry out. Stunted plant growth.
- Indirect damage: Thrips can carry and spread viral diseases.

Biology of cumin thrips

- Egg: Eggs are white to yellow, kidney-bean shaped, microscopic in size. Develop within leaf tissue with one end near the leaf surface. Egg stage is 5-10 days.
- Larva: Instars I and II are active, feeding stages. White to pale yellow in colour, elongate and slender body, Nymphs resemble adult, but without wings. Antennae are short and eyes are dark in color. Crawl quickly when disturbed. Larval stage is 10-14 days.
- Pre-pupa and pupa: Instars III and IV are inactive, non-feeding stages called pre-pupa and pupa, respectively. Pale yellow to brown in colour; body more stout than younger instars. Antennae are bent to head; wing buds are visible. Found in the soil. Pre-pupal and pupal stages last 5-10 days.

- Adult: About 1.5 mm long; elongate, yellow and brown body with two pairs of fringed (hairy) wings. Mouthparts are beak-like and antennae are 7-segmented. Parthenogenic (asexually reproducing) females; males are extremely rare. Females insert eggs individually into leaves. Adult life span is about 1 month and females lay eggs for about 3 weeks.

Screening for thrips resistance

Procedure:

The experiment needs to be laid out in a randomized block design (RBD) or ABD. The seeds of varieties/genotypes needs to be sown in second fortnight of November to first fortnight of December, each replicated thrice. The plot size should be maintained at 3.0 x 2.4 m2 with the row to row and plant to plant distance of 30 and 05 cm, respectively. The test entries and the check varieties should be sown as 3 paired rows of test entries followed by check (susceptible/resistant/varieties). Five plants will be selected and tagged in each plot when the crop

should be 30 days old. Three leaves (Upper, Middle and Lower), each of the same five tagged plants, will labeled to record the thrip population. The test varieties/entries will allowed to be a natural infestation. The observations may recorded at weekly intervals on five randomly selected and tagged plants from each plot by counting the number of thrips per plant, starting from the appearance of the thrip population and continued until crop maturity. The peak thrip population on cumin entries recorded during the crop season will categorized as Highly Resistant (HR), Resistant (R), Moderately Resistant (MR), Moderately Susceptible (MS), Susceptible (S) and Highly Susceptible (HS).

Observation to be recorded:

Thrips population may count on three leaves (Upper, Middle and Lower)
No. of thrip/leaf = Total thrips/3

Categorization of genotypes/ cultivars
Different cumin genotypes/ cultivars will be categorized into Highly Resistant (HR), Resistant (R), Moderately Resistant (MR), Moderately Susceptible (MS), Susceptible (S) and Highly Susceptible (HS) categories. The scale used for categorizing different genotypes/ cultivars is as per statistical tools, mean value of individual genotype (Xi) will compared with thrips infestation data of all genotype (X) and standard deviation (SD) following the scale adopted by Patel et al. (2002).

Scale for resistance	Category of resistance	Designation
$X_i < X - 2SD$	Highly Resistant	HR
$X - 2SD < X_i < X - SD$	Resistant	R
$X - SD < X_i < X$	Moderately Resistant	MR
$X < X_i < X + SD$	Moderately Susceptible	MS
$X + SD < X_i < X + 2SD$	Susceptible	S
$X_i > X + 2SD$	Highly Susceptible	HS

Here, X = Mean value of all genotype, X i =Mean value of individual genotype and SD =Standard deviation

Selected Reference

Patel, I.S., Prajapati, B.G., Patel, G.M., and Pathak A.R. (2002). Response of castor genotypes to caster semilooper *Achaea janata* Fab. Journal of oilseed Research 19(1):153.

FENNEL

Fennel (*Foeniculum vulgare*) or 'Saunf' is an aromatic Apiaceae herb native to the Mediterranean and widely cultivated in India, especially in Gujarat and Rajasthan. The seeds contain 9.5% protein, minerals, vitamins and 0.7-1.9% volatile oil rich in anethole, Fennel is valued for its digestive and galactagogue properties and culinary uses. The plant parts also serve as vegetables, seasoning and natural dyes.

General recommendations for screening

The trial should be laid out in randomized block design (RBD) for test entries up to 30 and augmented block design (ABD) for more than 30 test entries and the duration should be four years. Recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. Plot size should be of 2-3 rows of 3 m length per genotype with spacing of 30 cm between rows and 15 cm between plants. Three replications should be maintained for each entries and checks. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as three test entries in paired rows followed by check (susceptible/resistant/varieties). The location/field should be endemic/conducive to natural infection of targeted diseases wherein recurring infection is recorded/observed during the period of experiments and previous years. Disease-free healthy fennel seeds should be sown during second fortnight of October. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than for the targeted pest/disease.

Ramularia blight

The Ramularia blight of fennel, caused by the ascomycete *Ramularia foeniculi,* is a highly destructive and widespread disease in India.

Symptomatology

The pathogen infects all above-ground plant parts. The initial symptoms include small, water-soaked lesions on older leaves which enlarge, coalesce and cause chlorosis, defoliation and blight of stems, umbels and immature seeds. Greyish-white fungal growth may appear on leaves under humid conditions. The infected plants show reduced vigour, poor flowering and shriveled, black seeds with low germination. The disease development is favoured by frequent dew, cloudy weather and intermittent rain during February-March. The pathogen spreads via air-borne conidia, rain splash, contaminated tools and seeds and survives in plant debris, soil or weed hosts.

Screening for disease resistance

Procedure:

If there is no natural incidence of the disease in a particular location, then artificial epiphytotic conditions should be created using artificial inoculation of the pathogen. For this method, prepare spore suspension of 1 x 10^5 conidia/mL of *Ramularia foeniculi* using sterile distilled water with 0.01% Tween-20 and inoculate the plants at 45-60 days after sowing (DAS). The spore suspension should be sprayed uniformly to the plants during the evening hours using a knapsack sprayer. Maintain high humidity (≥85%) through overhead irrigation or misting for 48 hours post-inoculation. Incidence of disease should be recorded employing 0-5 scale (Anonymous, 2004; Kakani et al., 2010). Start scoring PDI at 7-10 days after inoculation. Repeat observations at weekly interval for 2-3 weeks. After the appearance of the symptoms, the data should be recorded at an interval of 10 days up to harvesting. For disease scoring, observations from 10 randomly selected plants per replication should be recorded. Per cent Disease Intensity (PDI) should be calculated for each replication for each month separately and average PDI should be calculated by combining data of other replications (average of two-month data would represent the disease level of a particular entry/check for a particular year of screening). Based on the average PDI during a particular year, the entries will be delin-eated into different categories of susceptibility or resistance which needs to be validated based on the observations recorded during subsequent years.

Disease rating scale for *Ramularia* infection (0-5 scale)	
Scale	**Symptoms on leaves**
0	No incidence/Healthy
1	Symptoms on leaf tip and leaves only
2	Symptoms on leaves and petiole
3	Symptoms on leaves, petiole and stem
4	Symptoms on leaves, stem and inflorescence
5	Symptoms on leaves, stem, and inflorescence including seeds
Kakani *et al*. (2010)	

Based on the observations, Per cent Disease Intensity (PDI) should be worked out using the formula developed by Wheeler (1969).

$$\text{Per cent Disease Intensity} = \frac{\text{Sum of all individual disease rating}}{\text{Total number of plants assessed x Maximum rating}} \times 100$$

Based on the Per cent Disease Intensity, the test entries will be placed into different categories.

Categorization based on reaction towards Ramularia blight	
Categories	**Per cent Disease Intensity**
Immune/Highly Resistant	0
Resistant	0-10
Moderately Resistant	11-20
Moderately Susceptible	21-30
Susceptible	31-40
Highly Susceptible	>40

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research Calicut, Kerala. p. 62.
- Kakani, R. K., Lal, G., Anwer, M. M. and Meena, S. S. (2010). A manual on minimal descriptors of seed spices for characterization and evaluation. National Research Centre on Seed Spices, Ajmer (Rajasthan). pp. 57-64.
- Wheeler, B. E. J. (1969). An introduction to plant diseases. John Wiley and Sons Limited, London. p. 374.

Alternaria blight

Alternaria blight of fennel, caused by *Alternaria alternata* and *A. petroselini,* is a major constraint to production, particularly in Gujarat.

Symptomatology

The disease affects all above-ground parts, causing angular black lesions on basal leaves, necrotic spots on stems and pale-yellow dried buds. The infection often coincides with inflorescence development, leading to defoliation and seed damage. Greyish-white fungal growth appears on older tissues under warm, humid and cloudy conditions, which favour rapid disease spread, sometimes causing complete crop failure. The severity ranges from 16-65%, with field incidences of 30-100%, highlighting its significant impact on fennel yield.

Screening for disease resistance

Procedure:

If there is no natural incidence of the disease in a particular location, then artificial epiphytotic conditions should be created using artificial inoculation of the pathogen. For this method, prepare spore suspension of 1 x 10^5 conidia/mL of *Alternaria alternata* and *A. petroselini* using sterile distilled water with 0.01% Tween-20 and inoculate the plants at 45-60 days after sowing (DAS). The spore suspension should be sprayed uniformly to the plants during the evening hours using a knapsack sprayer. Maintain high humidity (≥85%) through overhead irrigation or misting for 48 hours post-inoculation. Incidence of disease should be recorded employing 0-4 scale (Anonymous, 2004). Start scoring PDI at 7-10 days after inoculation. Repeat observations at weekly interval for 2-3 weeks. After the appearance of the symptoms, the data should be recorded at an interval of 10 days up to harvesting. For disease scoring, observations from 10 randomly selected plants per replication should be recorded. Per cent Disease Intensity (PDI) should be calculated for each replication for each month separately and average PDI should be calculated by combining data of other replications (average of two-month data would represent the disease level of a particular entry/check for a particular year of screening). Based on the average PDI during a particular year, the entries will be delineated into different categories of susceptibility or resistance which needs to be validated based on the observations recorded during subsequent years.

Disease rating scale for *Alternaria* infection (0-4 scale)	
Scale	**Symptoms on leaves**
0	Healthy
1	Up to 25%
2	Up to 50%
3	Up to 75%
4	>75%
Anonymous (2004)	

Based on the observations, Per cent Disease Intensity (PDI) will be worked out using the formula developed by Wheeler (1969).

$$\text{Per cent Disease Intensity} = \frac{\text{Sum of all individual disease rating}}{\text{Total number of plants assessed} \times \text{Maximum rating}} \times 100$$

Based on the Per cent Disease Intensity, the test entries will be placed into different categories.

Categorization based on reaction towards Alternaria blight	
Categories	**Per cent Disease Intensity**
Highly Resistant	0
Resistant	0-10
Moderately Resistant	11-20
Moderately Susceptible	21-30
Susceptible	31-40
Highly Susceptible	>40

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research Calicut, Kerala. p. 62.
- Wheeler, B. E. J. (1969). An introduction to plant diseases. John Wiley and Sons Limited, London. p. 374.

Fusarium wilt

Vascular wilt of fennel, caused by *Fusarium oxysporum f. sp. funiculi,* is a widespread disease affecting all growth stages, particularly under high temperatures.

Symptomatology

The symptoms include drooping, yellowing and drying of plants, brown discolouration in stems and pith and white cottony mycelial growth with orange sporodochia near the soil line. The pathogen produces microconidia, macroconidia and chlamydospores, surviving as soil- and seed-borne saprophytes. It spreads via water splash, contaminated tools, infected seeds and transplants. Wet, humid conditions (>80%) and moisture level during February-March promotes infection, while continuous monocropping favours endemic nature of the disease, resulting in patches of wilt affected plants leading to significant yield loss.

Screening for disease resistance

Procedure:

The fennel seeds should be sown in wilt affected field having a pathogen population of 1.3×10^4 cfu/g of soil or more. The infested soil is used since it permits the assessment of field resistance by facilitating the infection process under natural conditions, with realistic doses of naturally produced inocula. If there is no natural incidence of the disease in a particular location then, artificial inoculation of soil should be done. The culture of *Fusarium oxysporum f. sp. funiculi* should be mass multiplied on sterilized sorghum seeds in 500 ml flasks for seven days. The inocula should be mixed with soil before sowing the seeds in plots. The size of each plot should be 0.90 m × 4.0 m (2 rows of each genotype) with row spacing of 30 cm. Based on proportion of the plants exhibiting wilt symptoms in susceptible germplasm, the data will be recorded for healthy and wilted plants from different genotypes and per cent disease incidence will be calculated. The seeds sown in plots, in which inoculum was not added will be served as control. Record observations at regular intervals; 15, 30, 45, and 60 days after sowing or transplanting. The per cent wilt incidence should be calculated by following formula (Anonymous, 2004).

$$\text{Percent Disease Incidence (PDI)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Based on the PDI (%) the genotypes will be grouped under different categories.

Categorization based on reaction towards Fusarium wilt	
Categories	Percent Disease Incidence
Highly Resistant	0-10%
Resistant	11-20%
Moderately resistant	21-30%
Susceptible	31-50%
Highly susceptible	>50%

Selected references

Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research Calicut, Kerala. p. 62.

Root rot

Root rot of fennel caused by the soil-borne fungi such as *Fusarium spp., Rhizoctonia solani* and *Macrophomina phaseolina* affects plants at all growth stages.

Symptomatology

The seedlings may experience pre- or post-emergence damping-off, while older plants show stunted growth, yellowing, curling leaves and wilting. The roots and stem bases turn dark brown to black, with decayed feeder roots. The fungal structures may be visible as pinkish mycelium (*Fusarium*), black sclerotia (*Macrophomina*) or white web-like growth (*Rhizoctonia*). Severe infections during reproductive stage cause complete wilting, hollow stems and severe crop loss. The disease appears in patches and thrives in poorly drained soils, warm temperatures (25-30°C) and continuous cropping.

Screening for disease resistance

Procedure:

The fennel seeds should be sown in root rot affected field having a pathogen population of 1.3 x 10^4 cfu/g of soil or more. The infested soil is used since it permits the assessment of field resistance by facilitating the infection process under natural conditions, with realistic doses of naturally produced inocula. If there is no natural incidence of the disease in a particular location then, artificial inoculation of soil should be done. The culture of pathogens should be mass multiplied on sterilized sorghum seeds in 500 ml flasks for seven days. The inocula should be mixed with soil before sowing the seeds in plots. The size of each plot should be 0.90 m × 4.0 m (2 rows of each genotype) with row spacing of 30 cm. Based on the proportion of plants exhibiting root rot symptoms in susceptible germplasm, the data will be recorded for healthy and wilted plants from different genotypes and per cent disease incidence will be calculated.

The seeds sown in plots, in which inoculum was not added will be served as control. Record observations at regular intervals; 15, 30, 45, and 60 days after sowing or trans-planting. The per cent root rot incidence should be calculated by following formula (Anonymous, 2004).

$$\text{Percent Disease Incidence (PDI)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Based on the PDI (%) the genotypes will be grouped under different categories.

Categorization based on reaction towards root rot	
Categories	**Per cent Disease Incidence**
Highly Resistant	0-10%
Resistant	11-20%
Moderately resistant	21-30%
Susceptible	31-50%
Highly susceptible	>50%

Selected references

Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.

Powdery mildew

Powdery mildew caused by *Leveillula taurica var. languinosa*, is a major foliar disease of fennel, particularly during flowering (February-March) under cool, cloudy and humid conditions (20-25°C, RH>80%). The endophytic fungus grows intercellularly in leaf mesophyll, forming haustoria in parenchyma cells. Conidiophores emerge through stomata, producing hyaline, single conidia with papilla-like tips.

Symptomatology

The infection begins on leaves and spread to stem, branches and flowers, forming talc-like powder. Severe disease reduces photosynthesis, impedes seed development and can kill the plants. The conidia are primarily dispersed via soil and seed, with sec-ondary spread by wind or rain, causing significant yield loss.

Screening for disease resistance

Procedure:

The infector row (known highly susceptible variety/germplasm/breeding line) technique should be adopted to spread the disease intensively. The infector rows should be sown in 15 days advance of screening the test entries at after every 3rd pair row with susceptible check so as to establish and continuously supply of the pathogen inocula on to germinating genotypes. In addition, three rows of the susceptible check should also be raised all around the experimental plot to provide sufficient inoculum facilitating screening of the test entries under field conditions. Each of the test entries should be sown in paired rows of 3 m length with 30 x 15 cm spacing and replicated thrice. The screening disease data should be recorded when the disease incidence is maximum on the susceptible check. Observation on disease reaction should be made on ten randomly selected plants in each entry. Nine leaves should be scored in each plant, three each from the apical, middle and basal regions, and all should be graded. The disease intensity should be scored adopting the 0-4 grade (Anonymous, 2004).

Disease rating scale for powdery mildew infection (0-4 scale)	
Scale	**Symptoms on leaves**
0	Healthy
1	Whitish small spots on leaf
2	Whitish growth covering the entire leaf
3	Growth on leaf and stem
4	Growth on leaf, stem and umbel/pod
Anonymous (2004)	

Based on the observations, Per cent Disease Intensity (PDI) of the disease should be worked out using formula developed by Wheeler (1969).

$$\text{Per cent Disease Intensity (PDI)} = \frac{\text{Sum of all individual disease rating}}{\text{Total number of plants assessed x Maximum rating}} \times 100$$

Based on the PDI (%) the genotypes will be grouped in the different categories (Rathi and Tripathi, 1994).

Categorization based on reaction towards powdery mildew	
Categories	**Per cent Disease Intensity**
Immune/Highly Resistant	0
Resistant	1-10
Moderately Resistant	11-25
Moderately Susceptible	26-50
Susceptible	51-75
Highly Susceptible	>75

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.
- Rathi, A. S. and Tripathi, N. N. (1994). Assessment of growth reduction and yield losses in pea due to powdery mildew disease caused by *Erysiphe polygoni* DC. Crop Research (Hisar). 8(2): 371-376.
- Wheeler, B. E. J. (1969). An introduction to Plant Diseases. John Wiley and Sons Limited, London. p. 374.

Little leaf disease

Little leaf disease caused by phytoplasma was for the first time noticed on fennel in the experimental as well as commercial fields of CIMAP, Lucknow and its adjoining areas during 1998 (Samad et al., 2002).

Symptomatology

The typical symptoms of the disease are growth retardation with excessive proliferation of axillary shoots and production of small, narrow leaves which give rise to witches-broom appearance. The severely infected plants turn completely yellow and fail to produce inflorescence. The disease incidence is found to be in the range of 5-12% in the commercial fields. The symptoms of the disease were temporarily suppressed when treated with tetracycline hydrochloride.

Screening for disease resistance

Procedure:

The screening data should be recorded when the disease incidence is maximum in the susceptible check. No insecticides should be applied against the insect vectors to have the high natural inoculum pressure. The grown test entries should be exposed to natural infestation to leafhoppers. Data on disease incidence should be recorded in each accession thrice at 15 days interval by counting the number of symptomatic plants over total plants. Based on per cent disease incidence, the test entries will be graded into seven categories (Akhtar et al., 2013).

Categorization based on reaction towards little leaf disease	
Categories	**Per cent Disease Incidence**
Immune/ Highly resistant	0
Resistant	0.1-10
Moderately Resistant	10.1-20
Tolerant	20.1-30
Moderately susceptible	30.1-40
Susceptible	40.1-50
Highly susceptible	>50

Selected references

- Akhtar, K. P., Sarwar, G., Sarwar, N. and Elahi, M. T. (2013). Field evaluation of sesame germplasm against sesame phyllody disease. Pakistan Journal of Botany. 45: 1085-1090.

- Samad, A., Zaim, M., Ajayakumar, P. V., Khaliq, A. and Alam, M. (2002). Little leaf-A new disease of fennel (*Foeniculum vulgare* Mill.) caused by phytoplasma in India. Journal of Plant Diseases and Protection. 109(5): 506-511.

Aphids

Insects, particularly the aphid, *Hyadaphis coriandari,* is the major pest limiting fennel production in India.

Symptomatology

Both the nymphs and adults suck sap from leaves, stem, inflorescences and developing seeds, causing stunted growth, yellowing, curling and drying of foliage. Honeydew secretion promotes sooty mold, further weakening the plants. Severe infestation results in withered shoots, poor seed formation and shriveled seeds. The aphids reproduce rapidly, covering apical shoots quickly and can cause up to 50-80% yield loss, equivalent to 903 kg ha^{-1} in Gujarat, making them a key threat to fennel seed production (Kanjiya et al., 2018; Mittal and Butani, 1989; Ramalho et al., 2012).

Screening for resistance

Procedure:

The experiment should be laid out in a randomized block design (RBD). The seeds of test entries should be sown in second fortnight of November to first fortnight of December, each replicated thrice. The plot size should be maintained at 3.0 x 2.4 m^2 with the row to row and plant to plant distance of 30 and 5 cm, respectively. The test entries and the check varieties should be sown as 3 paired rows of test entries followed by check (susceptible/resistant/varieties). The observations on population of aphids should be recorded from ten randomly selected and tagged plants in plot at weekly intervals, starting from one month after germination to the harvest of crop. The aphid population should be estimated by adopting zero to four indexes through the observations made on 5 cm terminal twigs of ten randomly selected plants. The following indices should be used for estimation of aphid population.

Observation to be recorded: Number of aphids/5 cm twig

$$\text{Average aphid index} = \frac{0N + 1N + 2N + 3N + 4N}{\text{Total number of plants observed}}$$

Where,

0, 1, 2, 3 and 4 are aphid index

N = Number of plants showing respective aphid index

Rating scale for aphid infestation (1 to 4 scale) and categorization			
Aphid Index	**Degree of infestation**	**Approximate number of aphids/5 cm twig**	**Categories**
0	Plant free from aphid/No aphids	0	Immune/Highly Resistant
1	Isolated singly on few tender parts	1-5	Resistant
2	Singly on mature plant parts	6-10	Moderately Resistant
3	Colony countable	11-20	Susceptible
4	Uncountable colony on whole plant	21 and above	Highly susceptible
Anonymous (2004)			

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.
- Kanjiya, R. R., Shah, K. D., Talaviya, J. R., Patil, V. M. and Chudasama, K. A. (2018). Population dynamics of fennel aphid, *Hyadaphis coriandri* Das and occurrence of coccinellid predators on aphid in fennel. Journal of Entomology and Zoology Studies. 6(6):1150-1152.
- Mittal, V. P. and Butani, P. G. (1989). Evaluation of some insecticides against coriander aphid (*Hyadaphis coriandri*). Abstract: First National Seminar on Seed Spices, Jaipur, 24-25th October 1989. pp. 41-42.
- Ramalho, S. F., Fernandes, S. F., Nascimento, A. R. B. and Nascimento, L. J. (2012). Assessment of fennel aphids (Hemiptera: Aphididae) and their predators in fennel intercropped with cotton with colored fibers. Journal of Economic Entomology. 05(1): 113-119.

Seed midge/wasp

Among the insect pests, the chalcid or seed wasp, *Systole albipennis* is reported to occur as a regular pest in the country. Its damage cause both qualitative and quantitative losses in seed yield of fennel both in fields as well as in storage.

Symptomatology

The female chalcid wasp lay eggs in the embryo of grain and the developing larva feed, pupate inside the grain and adult emerge from the grains by boring a hole, ultimately resulting in both qualitative and quantitative losses besides reducing the germination percentage.

Screening for resistance

Procedure:

The experiment should be laid out in a randomized block design (RBD). The seeds of test entries should be sown in second fortnight of October, each replicated thrice. The plot size should be maintained at 2.0 x 2.25 m^2 with the row to row and plant to plant distance of 45 and 20 cm, respectively. The crop will be subjected to natural infestation of Systole albipennis. The observations on the incidence of *S. albipennis* should be recorded from seed setting to harvest of fennel umbels.

The seed damage due to seed midge should be recorded by selecting ten plants randomly in each sector. After seed setting at weekly interval, ten umbels should be selected randomly from each sector and 100 seeds from those umbels should be randomly collected and stored for 15 days and should be allowed for emergence of midge from the seeds. All the seeds should be thoroughly checked with the help of magnifying glass. The seeds with appearance of black spots or insect exit hole will be considered as damaged seed and per cent infestation will be calculated accordingly.

$$\text{Infestation (\%)} = \frac{\text{Infested seeds}}{\text{Total seeds}} \times 100$$

Categorization based on reaction towards seed midge	
Categories	**Seed midge infestation (%)**
Highly Resistant	0
Resistant	0.1-10
Moderately Resistant	10.1-25
Susceptible	25.1-50
Highly Susceptible	>50

Root knot nematode

Root knot is a common problem in fennel caused by *Meloidogyne javanica.*

Symptomatology

Root knot nematodes cause stunted growth where infected plants will be shorter and less vigorous than the healthy ones, yellowing of foliage wherein the leaves appear lighter in colour than healthy foliage. Visible swellings or knots on the roots are the sign of root-knot nematode infestation. The infected plants may also produce fewer and smaller seeds.

Screening for resistance

Procedure:

The experiment should be carried out in CRD design under pot conditions with three replications during Rabi season. The seeds should be sown in (21 x 17 cm) earthen pots having 5 kg naturally infested soil (2 larvae per gram of soil). The plants should be uprooted 60 days after germination and the observation should be recorded on root-knot index based on number of galls per plant. The test entries will be categorized as highly resistant, resistant, moderately resistant, susceptible and highly susceptible based on root-knot index 1-5 scale basis (Hartman and Sasser, 1985).

Categorization based on reaction towards root knot nematode	
Categories	**Number of galls**
Highly Resistant	0 (No Galls)
Resistant	1-10
Moderately Resistant	11-30
Susceptible	31-100
Highly Susceptible	>100

Selected references

- Hartman, K. M. and Sasser, J. N. (1985). Identification of *Meloidogyne* species on the basis of differential host test and perineal pattern morphology. In: An advanced treatise on *Meloidogyne*. pp. 69-77.

FENUGREEK

Fenugreek (*Trigonella foenum-graecum*) commonly known as 'Methi', is a diploid species which belongs to the family Fabaceae. Fenugreek is a native of South Eastern Europe and West Asia and extensively grown in India, especially in Madhya Pradesh, Rajasthan, Gujarat, Haryana, Uttaranchal and West Bengal. Fenugreek is a versatile crop cultivated for its leaves and seeds that are rich in calcium, iron, carotene, ascorbic acid and protein. The seeds are widely used in traditional medicine to treat digestive disorders, diabetes, respiratory issues and to enhance lactation.

Powdery mildew

Powdery mildew caused by *Erysiphe polygoni* and *Leveillula taurica* is an important disease, observed during flowering and pod formation stages which cause significant loss in grain quality as well as quantity (Prakash and Saharan, 2002).

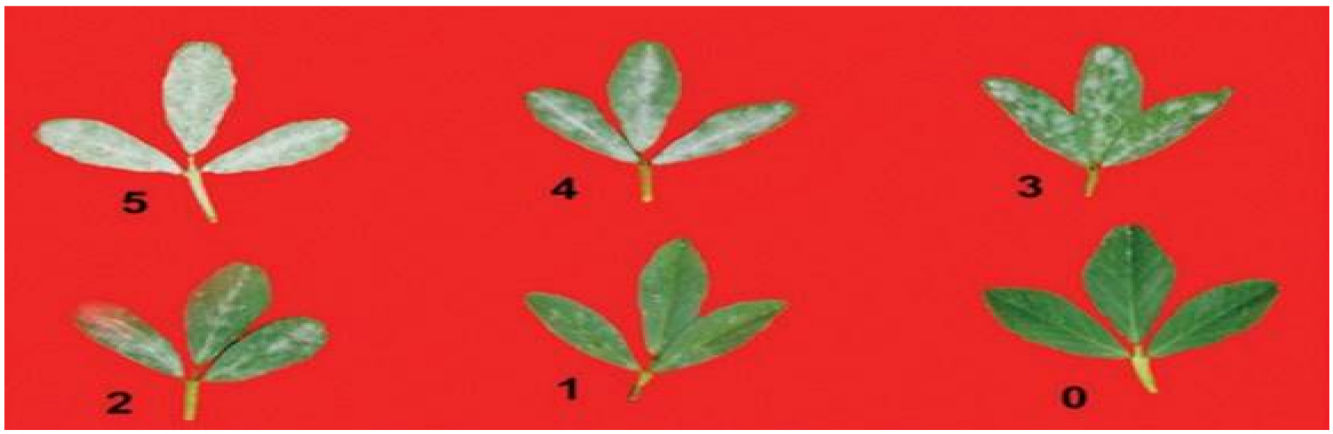
Symptomatology

The disease is characterized by white floury patches consisting of mycelium, conidiophores and conidia of the pathogen appearing on both sides of the leaves as well as on other above ground plants parts. Initially, the green foliage, tender stem and branches are affected. As the plant becomes older, the powdery growth spreads to the entire plant, turn more or less greyish brown thereby imparting a dirty appearance. In the advanced stage, powdery growth covers the pods thereby adversely affecting the seed set (Kumawat et al., 2017; Gupta et al., 2017).

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Complete Block Design (RCBD) with three replications or Augmented Design. The test entries should be sown during Rabi season (October-November) under field conditions on the beds with a dimension of 3 x 1 m^2 with a spacing 30 x 10 cm (row to row x plant to plant). The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. The crop should be observed regularly for foliar infections.



Different scales for scoring powdery mildew

The disease intensity should be recorded by examining 20 leaves from ten randomly selected plants in each plot starting from the initiation of the disease at weekly intervals. For disease scoring on leaves, 0-5 scale (Prakash and Saharan, 1999; Mayee and Datar, 1986) should be adopted. The Per cent Disease Intensity (PDI) should be calculated using the formula by Wheeler (1969). Based on average PDI during a particular year, the entries will be delineated into different categories of susceptibility or resistance which needs to be validated based on the observations recorded during subsequent two years.

Disease rating scale for powdery mildew (0-5 scale)	
Scale	**Description of symptoms**
0	No symptoms of powdery mildew disease (PMD) on leaf
1	1-10% leaf area showing PMD symptoms
2	11-25% area of leaf showing PMD colonies
3	26-50% area of leaf showing PMD and development of colonies on pods
4	51-75 % leaf area infected and yellowing and drying of le aves, stem highly and pods moderately infected
5	> 75% leaf area infected showing PMD colonies

Based on the observations, Per cent Disease Intensity (PDI) should be worked out using the formula developed by Wheeler (1969).

$$\text{Per cent Disease Intensity (PDI)} = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves examined x Maximum rating}} \times 100$$

Based on the Per cent Disease Intensity (PDI), the test entries will be placed into different categories (Rathi and Tripathi, 1994).

Categorization based on reaction towards powdery mildew	
Categories	**Per cent Disease Intensity (PDI)**
Immune/Highly Resistant	0
Resistant	1-10
Moderately Resistant	11-25
Moderately Susceptible	26-50
Susceptible	51-75
Highly Susceptible	>75

Selected references

- Gupta, S. K., Sharma, R. C. and Sharma, M. (2017). Diseases of vegetable, ornamental and spice crops. Scientific Publishers (India), New Delhi. p .192.
- Kumawat, R., Shekhawat, K. S. and Kumawat, K. (2017). Effect of sowing dates, crop geometry and host range on powdery mildew (*Erysiphe polygoni*) of fenugreek, *Trigonella foenum-graecum L.* Journal of Spices and Aromatic Crops. 26(2): 86-90.
- Mayee, C. D. and Datar, V. V. (1986). Phytopathometry. Technical Bulletin No.1, University of Agricultural Sciences, Marathawad, Parbhani, India. p. 146.
- Prakash, S. and Saharan, G. S. (1999). Source of resistance to downy mildew and powdery mildew of fenugreek. Journal of Mycology and Plant Pathology. 29(3): 383-384.
- Prakash S. and Saharan G. S. (2002). Estimation of losses in yield of fenugreek due to downy and powdery mildew. Haryana Journal of Horticultural Sciences. 31: 133-134.
- Rathi, A. S. and Tripathi, N. N. (1994). Assessment of growth reduction and yield losses in pea due to powdery mildew disease caused by *Erysiphe polygoni* DC. Crop Research (Hisar). 8(2): 371-376.
- Wheeler, B. E. J. (1969). An introduction to plant diseases. John Willey and Sons Ltd., London. p. 374.

Downy mildew

Downy mildew caused by *Peronospora trigonella* was first reported by Uppal et al. (1935) from Bombay and later from Himachal Pradesh by Sharma and Manjal (1977) and Thind (1942) from Punjab. The disease is more severe during cool and moist weather.

Symptomology

The disease is characterized by yellow patches on upper leaf surface and grayish growth on corresponding lower surface. The adaxial surface of leaves exhibits small chlorotic spots often along the leaf margin, while the abaxial surface exhibits a grayish violet, felty growth. The disease may also leads of stunted plant growth and wilting or distortion. The disease cause heavy yield loss if occurred during early stages of plant growth.

Healthy leaves and leaves with downy mildew symptoms
on lower and upper leaf surfaces

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Complete Block Design (RCBD) with three replications or Augmented Design. The test entries should be sown during Rabi season (October-November) under field conditions in 3 x 1 m^2 size beds with a spacing 30 x 10 cm (row to row x plant to plant). The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. The crop should be observed regularly for foliar infections. The disease intensity should be recorded by examining 20 leaves from ten randomly selected plants in each plot starting from the initiation of the disease at weekly intervals. The disease rating and Per cent Disease Intensity (PDI) should be calculated as per Mayee and Datar (1986). Based on average PDI during a particular year, the entries will be delineated into different categories of susceptibility or resistance which needs to be validated based on the observations recorded during subsequent two years.

Disease rating scale for downy mildew (0-9 scale)	
Scale	**Symptoms on leaves**
0	No infection
1	<1% leaf area infected
3	1-10% leaf area infected
5	11-25% leaf area infected
7	26-50% leaf area infected
9	>50% leaf area infected (severe infection, leaf heavily blighted/covered with mildew)

Based on these observations, Per cent Disease Intensity (PDI) should be worked out using the formula developed by Wheeler (1969).

$$\text{Per cent Disease Intensity (PDI)} = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves examined x Maximum rating}} \times 100$$

Based on the Per cent Disease Intensity (PDI), the test entries will be placed into different categories.

Categorization based on reaction towards downy mildew	
Categories	**Per cent Disease Intensity (PDI)**
Immune	0
Resistant	1-10
Moderately resistant	11-25
Moderately susceptible	26-50
Susceptible	51-75
Highly Susceptible	>75

Selected references

- Mayee, C. D. and Datar, V. V. (1986). Phytopathometry. Technical Bulletin No.1, University of Agricultural Sciences, Marathawad, Parbhani, India. p. 146.
- Sharma, A. D. and Munjal, R. L. (1977). The genus Peronospora in Himachal Pradesh, India. Indian Journal of Mycology and Plant Pathology. 7: 135-138.
- Thind, K. S. (1942). The genus *Peronospora* in the Punjab. Journal of Indian Botanical Society. 21: 197-225.
- Uppal, B. N., Patel, M. K. and Kamat, M. N. (1935). The fungi of Bombay. Bulletin of Department of Agriculture, Bombay. p. 176.
- Wheeler, B. E. J. (1969). An introduction to plant diseases. John Willey and Sons Ltd., London. p. 374.

Cercospora leaf spot

Cercospora leaf spot caused by *Cercospora traversiana* is a commonly occurring and harmful disease, which under conducive environmental conditions may lead to 80 per cent reduction in yield (Sillero et al., 2006).

Symptomatology

The disease initiates as small reddish brown spots which spread on the leaves, stem and young pods damaging the plants before maturity. The spots are amphigenous, round to semicircular about one centimeter in diameter, brown on the margin and white at the center. Later, large elongated spots develop on leaves, petioles and stem leading to severe premature defoliation. Under favourable conditions, the foliage appears completely blighted and later, the plants dry. The disease adversely affects the market quality of green leaves (Mishra, 2019).

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Block Design (RBD) with three replications for each entry and checks and the duration would be four years. The plot size should be of 2-3 rows of 3 m length per test entry with spacing of 30 cm between rows and 10 cm between plants. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centres. The test entries short-listed along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as per standard package and practices. The disease-free healthy seeds should be sown during second fortnight of October. The location/field should be endemic/conducive to natural infection of Cercospora leaf spot disease wherein, recurring infection is recorded/observed during the period of experiments and previous years.

Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than Cercospora leaf spot.
After the occurrence of initial symptoms, the data should be recorded at an interval of 10 days up to harvesting. For disease scoring, observations from 10 randomly selected plants per replication should be recorded. Per cent Disease Intensity (PDI) should be calculated for each replication for each month separately and average PDI should be calculated by combining data of other replications (average of two month data would represent the disease level of a particular entry/check for a particular year of screening). Based on average PDI during a particular year, the entries will be delineated into different categories of susceptibility or resistance which needs to be validated based on the observations recorded during subsequent years.

Disease rating scale for Cercospora leaf spot (0-5 scale)	
Scale	**Symptoms on leaves**
0	No visible infection
1	1-15% leaf area infected
2	16-40% leaf area infected
3	41-65% leaf area infected
4	66-90 % leaf area infected
5	91-100 % leaf area infected

Based on the observations, Per cent Disease Intensity (PDI) should be calculated using the formula developed by Wheeler (1969).

$$\text{Per cent Disease Intensity (PDI)} = \frac{\text{Sum of all numerical value}}{\text{Total number of leaves examined x Maximum grade}} \times 100$$

Based on the Per cent Disease Intensity (PDI), the test entries will be placed into different categories.

Categorization based on reaction towards Cercospora leaf spot	
Categories	**Per cent Disease Intensity (PDI)**
Highly resistant	No visible infection
Resistant	1-15% leaf area infected
Moderately resistant	16-40% leaf area infected
Moderately susceptible	41-65% leaf area infec ted
Susceptible	66-90 % leaf area infected
Highly susceptible	91-100 % leaf area infected

Selected references

- Iqbal, U., Iqbal, S. M., Afzal, R., Jamal, A., Farooq, M. A. and Zahid, A. (2011). Screening of mungbean germplasm against Mungbean Yellow Mosaic Virus (MYMV) under field conditions. Pakistan Journal of Phytopathology. 23(1): 48-51.
- Mishra, R. S. (2019). Diseases of vegetable, spices and plantation crops. Daya Publishing House, New Delhi. p. 259.
- Sillero, J. C., Fondevilla, S., Davidson, J., VazPatto, M. C., Warkentin, T. D., Thomas, J. and Rubiales, D. (2006). Screening techniques and sources of resistance to rusts and mildews in grain legumes. Euphytica. 147(1-2): 255-272.
- Wheeler, B. E. J. (1969). An introduction to plant diseases. John Willey and Sons Ltd., London. p. 374.

Root/collar rot/foot rot

Symptomatology

Root rot caused by *Rhizoctonia solani* can be identified by several symptoms including uneven crop growth, stunted growth and poorly developed roots. The major symptom of the disease is damping-off. The freshly emerged seedlings wither at pre or post soil emergence stages when severely infected. The affected plants may also develop foot rot and reddish brown cankers on root and stem near the ground level. The pathogen mainly attacks the root and underground parts and is also capable of infecting other plant parts like foliage, seeds and hypocotyls.

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Block Design (RBD) for test entries up to 30 and Augmented Block Design (ABD) for more than 30 test entries and the duration would be four years. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. The plot size should be 2-3 rows of 3 m length per test entry with spacing of 30 cm between rows and 10 cm between plants. Three replications should be maintained for each entries and checks. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as three test entries in paired rows followed by check (susceptible/resistant/varieties). The disease-free healthy fenugreek seeds should be sown during second fortnight of October. The location/field should be endemic/conducive to natural infection of root rot disease wherein, recurring infection is recorded/observed during the period of experiments and previous years. It should be designated as a sick plot or hot spot for the root rot disease occurrence. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than root rot.

The fenugreek seeds should be sown in root rot affected field having a root rot pathogen population of 1.3 x 10^4 cfu/g of soil or more. The infested soil should be used because it permits the assessment of field resistance by allowing the infection process to take place under natural conditions, with realistic doses of naturally produced inocula. If there is no natural incidence of disease in particular location then, artificial inoculation of soil should be done. The culture of Rhizoctonia solani should be mass multiplied on sterilized sorghum seeds in 500 ml flasks for seven days. The inoculum should be mixed with soil before sowing the seeds in plots. The size of each plot should be 0.90 m x 4.0 m (2 rows of each test entry) with row spacing of 30 cm. Each of the test entries should be alternated by a susceptible check. Based on the proportion of plants exhibiting root rot symptoms in susceptible check, the data should be recorded for healthy and affected plants from different test entries and per cent disease incidence should be calculated. The seeds sown in plots, in which inoculum was not added will be served as control. The observations should be recorded at regular intervals; 15, 30, 45, and 60 days after sowing or transplanting and the per cent wilt incidence should be calculated (Anonymous, 2004; Iqbal et al., 2005).

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Based on the Per cent Disease Incidence (PDI) the test entries will be grouped into different categories.

Categorization based on reaction towards root/collar/foot rot	
Categories	**Per cent Disease Incidence (PDI)**
Highly resistant	0-10
Resistant	11-20
Moderately resistant	21-30
Susceptible	31-50
Highly susceptible	>50

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.
- Iqbal, S. M., Haq, I. U., Bukhari, A. G. and Haqqani, A. M. (2005). Screening of chickpea genotypes for resistance against Fusarium wilt. Journal of Mycology and Plant Pathology. 3(1-2): 1-5.

Fusarium wilt

Symptomatology

Fusarium wilt is characterized by several symptoms, including stunting, yellowing and drooping of leaves, vascular discolouration and eventual death. The disease typically starts with stunting of the plants and yellowing of the lower leaves, followed by wilting and leaf curling. When stems are split, the vascular tissue exhibits dark streaks or discolouration. The symptoms appear in patches and may not spread in the entire field.

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Block Design (RBD) and three replications should be maintained for each entries and checks and the duration would be four years. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centres. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as per standard package and practices. The disease-free healthy fenugreek seeds should be sown during second fortnight of October.

The location/field should be endemic/conducive to natural infection of wilt disease wherein, recurring infection is recorded/observed during the period of experiments and previous years. It should be designated as sick plot or hot spot for the wilt disease occurrence. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than wilt. Based on the proportion of plants exhibiting wilt symptoms in susceptible varieties, the data should be recorded for healthy and wilted plants from different test entries and per cent disease incidence should be calculated. The per cent wilt incidence should be calculated by following formula (Anonymous, 2004; Iqbal et al., 2005).

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Based on the Per cent Disease Incidence (PDI) the test entries will be grouped into different categories.

Categorization based on reaction towards Fusarium wilt	
Categories	Per cent Disease Incidence (PDI)
Highly Resistant	0-10%
Resistant	11-20%
Moderately resistant	21-30%
Susceptible	31-50%
Highly susceptible	>50%

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.
- Iqbal, S. M., Haq, I. U., Bukhari, A. G. and Haqqani, A. M. (2005). Screening of chickpea genotypes for resistance against Fusarium wilt. Mycopathology. 3(1-2): 1-5.

Aphids

The experiment should be conducted at least for three years to screen the test entries against the aphids *Aphis craccivora*. Raise the crop as per recommended package of practices, spacing and adjust the date of sowing so that the test entries receive high aphid population during the vegetative stage.

Screening for resistance

Procedure:

Lay out the screening trial in Randomized Block Design (RBD) with three replications for each test entry. Tag at least ten plants randomly in each replication from each test entry for recording number of aphids per 10 cm apical twig at weekly intervals and till the harvest of crop and also calculate the mean number of aphids per 10 cm central shoot/apical twig for the particular test entry (Kalra et al., 2003; Patel et al., 2011). The test entries will be classified under different categories based on the number of aphids recorded from per 10 cm central shoot/apical twig per tagged plant (Sharma and Kalra, 2002; Kalra et al., 2003).

Categorization based on aphid population	
Categories	**Number of aphids per 5 cm central shoot**
Highly resistant	< 5
Moderately resistant	5-10
Least susceptible	10-20
Moderately susceptible	20-30
Highly susceptible	>30

Leaf miner

The experiment should be conducted for at least two years to screen the test entries against the leaf miner, *Liriomyza congesta.*

Screening for resistance

Procedure:

Raise the crop as per recommended package of practices, space and adjust the date of sowing so that the test entries receive high leaf miner populations during vegetative growth phase. Design the screening trial in randomized block design involving three replications for each test entry. Tag 10 plants randomly in each replication from each test entry for recording number of infested leaves and number of miners per plant at weekly intervals till harvest. Calculate the mean number of miners per plant or leaf infestation per cent for a particular test entry as per Kalra et al. (2003).

$$\text{Leaf infestation (\%)} = \frac{\text{Infested leaves per plant}}{\text{Total number of leaves per plant}} \times 100$$

Categorization based of per cent leaf infestation and leaf miner population		
Categories	**Leaf damage (%)**	**Number of miners per plant**
Highly resistant	Less than 1%	Less than 3
Moderately resistant	1-3%	3-6
Least susceptible	3-5%	6-9
Moderately susceptible	5-10%	9-12

Weevil

The experiment should be conducted for at least three years to screen the test entries against the weevil, *Hypera postica.*

Screening for resistance

Procedure:

Raise the crop as per recommended package of practices, spacing and adjust the date of sowing so that the test entries receive high weevil population during the vegetative stage. Lay out the screening trial in Randomized Block Design (RBD) with four replications for each test entry. Tag at least five plants randomly in each replication for each test entry for recording number of grubs per plant and plant damage (%) at weekly intervals till harvest. Calculate the mean number of grubs per plant and plant damage (%) for a particular test entry as per Kalra et al. (2003).

$$\text{Plant damage (\%)} = \frac{\text{Damaged plant}}{\text{Total number of plant}} \times 100$$

The test entries will be classified as resistant or susceptible based on the plant damage (%) (Kalra et al., 2003).

Categorization based of per cent plant damage	
Categories	**Plant damage (%)**
Moderately resistant	< 5%
Moderately susceptible	5-10%
Highly susceptible	> 10%

Selected references

- Kalra, V. K., Thakral, K. K. and Sharma, S. S. (2003). Reaction of various cultivars/varieties of fenugreek to different insect pests. Haryana Agricultural University Journal of Research. 33(5): 129-131.
- Patel, A. G., Patel, H. R. and Patel, R. K. (2011). Development of aphid infestation index for field evaluation of pest intensity in seed spices. Journal of Entomological Research. 35(2): 123-127.
- Sharma, S. S and Kalra, V. K. (2002). Assessment of seed yield losses caused by *Aphis craccivora* (Koch.) in fenugreek. Forage Research. 28(3): 183-184.

AJWAIN

Ajwain (*Trachyspermum ammi)* also known as 'carom seed', 'carom ajowan' and 'bishop's weed' is one of the most important seed spice representing the family Apiaceae which is a native of Egypt. It is widely grown in arid and semi-arid regions where soil contain high levels of salt. The essential oil possess various biological properties such as antioxidant, antibacterial, antimutagenic and antimicrobial and are generally recognized as safe natural substances.

Root rot

Root rot is the most common and destructive disease of ajwain and leads to loss in yield (10-100%) as well as quality. The disease is primarily caused by the soil-borne fungal pathogens such as *Rhizoctonia solani, Fusarium spp.* and *Macrophomina phaseolina*. The disease affects the plants at all growth stages, from seedlings to maturity.

Symptomatology

At seedling stage, the root rot typically manifests as damping-off. In pre-emergence damping-off, the seeds rot before sprouting while during post-emergence, the young seedlings emerge but collapse soon due to basal stem rot and decay of roots. The stem near the soil line often appears water-soaked and discoloured, ranging from brown to black. As the plant progresses to the vegetative stage, the affected plants exhibits stunted growth, yellowing of lower leaves and leaf curling or drooping. These symptoms are due to impaired water and nutrient uptake caused by decaying roots. Wilting initially occurs during the hotter period of the day and may recover during night, but over time it becomes permanent. The roots of affected plants exhibit dark brown to black discolouration, especially at the crown region. Secondary and fine feeder roots often rots and dry. In some cases, fungal growth can be observed on the decaying roots as pinkish in the case of *Fusarium*, black sclerotia with respect to *Macrophomina* or web-like white mycelium in case of *Rhizoctonia.* In severe infections during the reproductive stage, the disease causes complete wilting and death of the plant. The stem base may become hollow due to internal rotting and the plants often topple as the root system fails to anchor. The yield is significantly reduced due to poor flower development, shriveled seeds or failure to form umbels. The disease tends to appear in patches across the field and spreads gradually under favourable conditions such as poorly drained soils, continuous cropping and warm temperature between 25-30°C.

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Block Design (RBD)/ABD and the duration would be three years. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. Three replications should be maintained for each entries and checks. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as 3 paired rows of test entries followed by check (susceptible/ resistant/varieties). The disease-free healthy ajwain seeds should be sown during second fortnight of October. The location/field should be endemic/conducive to natural infection of root rot disease wherein, recurring infection is recorded/observed during the period of experiments and previous years. It should be designated as sick plot or hot spot for the root rot disease occurrence.

Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than root rot.

The ajwain seeds should be sown in root rot affected field having a pathogen population of 1.2×10^4 cfu/g of soil or more. The infested soil should be used because it permits the assessment of field resistance by allowing the infection process to take place under natural conditions, with realistic doses of naturally produced inocula. If there is no natural incidence of the disease in a particular location then, artificial inoculation of soil should be done. The culture of pathogens should be mass multiplied on sterilized sorghum seeds in 500 ml flasks for seven days. The inocula should be mixed with soil before sowing the seeds in plots. The size of each plot should be 1.0 m x 3.0 m (2 rows of each test entry) with row spacing of 50 cm. Based on the proportion of plants exhibiting root rot symptoms in susceptible varieties, the data should be recorded for healthy and wilted plants from different test entries and per cent disease incidence should be calculated. The seeds sown in plots, in which inoculum was not added will be served as control. The observations should be recorded at regular intervals; 15, 30, 45 and 60 days after sowing. The per cent root rot incidence should be calculated subsequently (Anonymous, 2004).

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Based on the Per cent Disease Incidence (PDI) the test entries will be grouped into different categories.

Categorization based on reaction towards root rot	
Categories	**Per cent Disease Incidence (PDI)**
Highly Resistant	0-10
Resistant	11-20
Moderately Resistant	21-30
Susceptible	31-50
Highly susceptible	>50

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.
- Iqbal, S. M., Haq, I. U., Bukhari, A. G. and Haqqani, A. M. (2005). Screening of chickpea genotypes for resistance against Fusarium wilt. Mycopathology. 3(1-2): 1-5.

Stem rot

Stem rot of ajwain is caused by *Sclerotinia sclerotiorum.*

Symptomatology

S. sclerotiorum causes more or less similar symptoms on leaves, stem and siliquae as fluffy white mycelia and sclerotia produced after mycelial growth, when the nutrition is not sufficient or other conditions are favourable for sclerotial development (Christias and Lockwood, 1973). Sclerotinia stem rot initiates as elongated, water soaked lesions on stem especially at base or at internodes and later white mycelial growth covers the lesions and affected plants appear whitish from a distance. The pathogen becomes air-borne and spreads through infected flower petals which fall and become lodged between the main stem and side branches. Large oval to round shaped holes are also formed on leaves due to air-borne infection. Under severe infection, defoliation, shredding of stem, wilting and drying of plants occurs. The infected plants will ripe earlier and stand out among the green plants (Meena et al., 2014).

Screening for disease resistance

Procedure:

The trial should be laid out in randomized block design (RBD)/ABD and the duration should be three years. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. Three replications should be maintained for each entries and checks. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as 3 paired rows of test entries followed by check (susceptible/resistant/varieties).

The disease-free healthy ajwain seeds should be sown during second fortnight of October. The location/field should be endemic/conducive to natural infection of stem rot disease wherein, recurring infection is recorded/observed during the period of experiments and previous years. It should be designated as a sick plot or hot spot for the stem rot disease occurrence. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than stem rot.

The ajwain seeds should be sown in stem rot affected field having a pathogen population of 1.2 x 10^4 cfu/g of soil or more. The infested soil should be used because it permits the assessment of field resistance by allowing the infection process to take place under natural conditions, with realistic doses of naturally produced inocula. If there is no natural incidence of the disease in a particular location then, artificial inoculation of soil should be done. The culture of pathogen should be mass multiplied on sterilized sorghum seeds in 500 ml flasks for seven days. The inocula should be mixed with soil before sowing the seeds in plots. The size of each plot should be 1.0 m x 3.0 m (2 rows of each test entry) with row spacing of 50 cm. Based on the proportion of plants exhibiting stem rot symptoms in susceptible varieties, the data should be recorded for healthy and rot plants from different test entries.

Fungal disc method for artificial inoculation: The test may conducted using cotton mycelium method in which cotton should be slightly moistened and a 5 mm mycelial mat from a fresh culture of the pathogen placed in the moistened cotton which may be placed in the nodal region of the stem and tightly covered with parafilm. After a week of inoculation, the collar region of stem may exhibit water soaked tiny specks which may enlarge rapidly in size, leading to girdling of the stem and advancing up and downwards. Later the affected parts may be covered with white mycelium and formation of sclerotia may also be observed inside the infected dried stem.

The crop should be monitored to record the initial appearance of the disease. Lesion length (cm) of 5 plants randomly selected from each inoculated test entry should be measured using a linear ruler at 20 days after inoculation. The observations should be recorded using a 0-4 scale as suggested by Garg et al. (2010) and converted into Per cent Disease Index to evaluate the disease reaction of each test entry. The test entries will be classified into different resistance groups based on mean lesion length (cm) as per the 0-4 scale.

Disease rating scale for stem rot (0-4 scale)	
Scale	Lesion length (cm)
0	<2.5
1	2.6-5.0
2	5.1-7.5
3	7.6-10.0
4	>10.0

Based on the observations, Per cent Disease Intensity (PDI) should be worked out using the formula developed by Wheeler (1969).

$$\text{Per cent Disease Intensity (PDI)} = \frac{\text{Sum of all numerical ratings}}{\text{Total number of main stems observed x Maximum disease rating}} \times 100$$

Based on the Per cent Disease Intensity (PDI), the test entries will be placed into different categories.

Categorization based on reaction towards stem rot	
Categories	Disease score
Highly Resistant	0
Resistant	1
Moderately resistant	2
Susceptible	3
Highly susceptible	4

Fungal mycelial disc method

Selected references

- Garg, H., Atri, C., Sandhu, P. S., Kaur, B., Renton, M., Banga, S. K., Singh, H., Singh, C., Barbetti, M. J. and Banga, S. S. (2010). High level of resistance to *Sclerotinia sclerotiorum* in introgression lines derived from hybridization between wild crucifers and the crop *Brassica* species *B. napus* and *B. juncea*. Field Crops Research. 117: 51-58.

- Meena, P. D., Rathi, A. S., Kumar, V. and Singh, D. (2014). Compendium of rapeseed-mustard diseases: Identification and management. Directorate of Rapeseed-Mustard Research (ICAR), Bharatpur (Rajasthan). p. 30.

- Wheeler, B. E. J. (1969). An introduction to plant diseases. John Willey and Sons Ltd., London. p. 374.

Aphids

The aphids (*Myzus persicae, Aphis gossypii* and *Hyadaphis coriandri*) has been reported as major pest of ajwain.

Symptomatology

The aphids colonize the apical shoots, causing withering and slight yellowing of leaves due to heavy feeding, along with the development of honey dew and sooty mold.

Screening for resistance

Procedure:

The experiment should be laid out in Randomized Block Design (RBD) or ABD. The seeds of varieties/genotypes/test entries (treatments) should be sown in second fortnight of October, each replicated thrice. The plot size should be maintained at 3.0 x 2.5 m2 with the row to row and plant to plant distance of 50 and 20 cm, respectively. The test entries and the check varieties should be sown as 3 paired rows of test entries followed by check (susceptible/resistant/varieties). The observations on population of aphids should be recorded from ten randomly selected and tagged plants in plot at weekly intervals, starting from one month after germination to the harvest of crop. The population of aphid should be estimated by adopting zero to four indexes through the observations made on 5 cm terminal twigs of ten randomly selected plants. The following indices should be used for estimation of aphid population (Patel et al., 2011).

Observation to be recorded: Number of aphids/5 cm twig

$$\text{Average aphid index} = \frac{0N + 1N + 2N + 3N + 4N}{\text{Total number of plants observed}}$$

Where,

0, 1, 2, 3 and 4 are aphid index

N = Number of plants showing respective aphid index

Pest rating scale for aphid (0-4 scale)	
Approximate number of aphids/5 cm twig	Aphid Index (AI)
0	0
1-5	1
6-10	2
11-20	3
21 and above	4
Anonymous (2004)	

The test entries will be categorized as highly resistant, resistant, moderately resistant, susceptible and highly susceptible based on aphid index 0-4 scale basis (Patel et al., 2011).

Categorization based on aphid index	
Categories	Aphid Index (AI)
Highly Resistant	0
Resistant	1
Moderately Resistant	2
Susceptible	3
Highly Susceptible	4

Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.

Patel, S. A., Patel, I. S., Patel, J. K. and Patel, P. S. (2011). Seasonal abundance of fennel aphid, *Hyadaphis coriandri* Das and associated bioagents in fennel crop. Trends in Biosciences. 4(1): 116-117.

Lygus bug

Lygus bugs are spindly legged small insects, which move rapidly when disturbed. The adults are 1/4 inch long, brown, flat-topped, with several angular black markings. The nymphs are small and greenish, with a few tiny dark spots. Their piercing-sucking mouthparts not only draw plant sap but also inject toxin.

Nymph **Adult**

Screening for resistance

Procedure:

The experiment should be laid out in Randomized Block Design (RBD) or ABD. The seeds of varieties/test entries should be sown in the second fortnight of October to first fortnight of November, each replicated thrice. The plot size should be maintained at 3.0 x 2.5 m^2 with the row to row and plant to plant distance of 50 and 20 cm, respectively. The test entries and the check varieties should be sown as 3 paired rows of test entries followed by check (susceptible/resistant/varieties). Five plants should be selected and tagged in each plot when the crop is at 30 days old. Three leaves (upper, middle and lower), each of the same five tagged plants should be labeled to record the lygus bug population. The test varieties/entries should be exposed to natural infestation.

The observations should be recorded at weekly intervals on five randomly selected and tagged plants from each plot by counting the number of lygus bug per plant, starting from the appearance of the lygus bug population and continued until crop maturity. The peak lygus bug population on test entries should be recorded during the crop season and the test entries will be categorized as highly resistant, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible.

Observation to be recorded:

Lygus bug population should be recorded on three leaves (upper, middle and lower)
Number of lygus bugs/leaf = Total lygus bugs/3

Categorization of test entries

The test entries will be categorized into highly resistant, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible categories. The scale used for categorizing different test entries is as per statistical tools in which mean value of individual test entry (Xi) will be compared with lygus bug infestation data of all test entries (X) and standard deviation (SD) following the scale adopted by Patel et al. (2002).

Categorization based on lygus bug infestation	
Categories	**Scale for resistance**
Highly Resistant	$X_i < X - 2SD$
Resistant	$X - 2SD < X_i < X - SD$
Moderately Resistant	$X - SD < X_i < X$
Moderately Susceptible	$X < X_i < X + SD$
Susceptible	$X + SD < X_i < X + 2SD$
Highly Susceptible	$X_i > X + 2SD$

Where, X = Mean value of all test entries, X i =Mean value of individual test entry and SD =Standard deviation

Selected references

Patel, I. S., Prajapati, B. G., Patel, G. M. and Pathak, A. R. (2002). Response of castor genotypes to caster semilooper *Achaea janata* Fab. Journal of Oilseed Research. 19(1): 153.

NIGELLA

Nigella (*Nigella sativa*), commonly known as 'black cumin' or 'kalonji', is an important annual medicinal and spice belonging to the Ranunculaceae family. Believed to have originated in the Mediterranean region, it is valued globally for both culinary and therapeutic uses. Its seeds, rich in protein, essential oils and bioactive compounds, are widely used in traditional medicine systems due to their anti-inflammatory, antioxidant and immune-boosting properties.

Alternaria blight

Alternaria blight caused by *Alternaria alternata* and *A. brassicae*, primarily affect the leaves, stem and pods, leading to reduced photosynthetic efficiency and seed quality. It is a major concern in nigella cultivation, particularly in regions with warm and humid climates.

Symptomatology

The symptoms includes, formation of small, circular, brown-to-black lesions with concentric rings on leaves leading to defoliation, dark elongated spots leading to stem weakening and blackened pods with shrivelled seeds, reducing seed viability. The favourable conditions for disease development includes an optimal temperature range of 20-28°C and high relative humidity (>80%). Prolonged wet conditions enhance disease spread.

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Block Design (RBD) for test entries up to 30 and Augmented Block Design (ABD) for more than 30 test entries and the duration would be four years. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. The plot size should be of 2-3 rows of 3 m length per test entry with a spacing of 30 cm between rows and 15 cm between plants. Three replications should be maintained for each entries and checks. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as three test entries in paired rows followed by check (susceptible/ resistant/varieties). The disease-free healthy nigella seeds should be sown during second fortnight of October. The location/field should be endemic/conducive to natural infection of Alternaria blight disease wherein, recurring infection is recorded/observed during the period of experiments and previous years. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than Alternaria blight.

If there is no natural incidence of the disease in a particular location then, artificial epiphytotic conditions should be created adopting artificial inoculation of the pathogen. For this method, prepare a spore suspension of 1 x 10^5 conidia/mL using sterile distilled water with 0.01% Tween-20 and inoculate the plants at 45-60 days after sowing (DAS). Spray uniformly during the evening hours using a knapsack sprayer. Maintain high humidity (≥85%) through overhead irrigation or misting for 48 hours post-inoculation. The disease should be recorded employing 0-4 scale (Anonymous, 2004). Commence the scoring at 7-10 days after inoculation. Repeat the observations weekly for 2-3 weeks. After disease appearance, the observations should be recorded at an interval of 10 days up to harvesting. For disease scoring, observations from 10 randomly selected plants per replication should be recorded. Per cent Disease Intensity (PDI) should be calculated for each replication for each month separately and average PDI should be calculated by combining data of other replications (average of two-month data would represent the disease level of a particular entry/check for a particular year of screening). Based on average PDI during a particular year, the entries will be delineated into different categories of susceptibility or resistance which needs to be validated based on the observations recorded during subsequent years.

Disease rating scale for Alternaria blight (0-4 scale)	
Scale	**Symptoms on leaves**
0	Healthy
1	Up to 25%
2	Up to 50%
3	Up to 75%
4	>75%
Anonymous (2004)	

Based on the observations, Per cent Disease Intensity (PDI) should be worked out using formula developed by Wheeler (1969).

$$\text{Per cent disease Intensity (PDI)} = \frac{\text{Sum of all individual disease rating}}{\text{Total number of plants assessed x Maximum rating}} \times 100$$

Based on the Per cent Disease Intensity (PDI), the test entries will be placed into different categories.

Categorization based on reaction towards Alternaria leaf blight	
Categories	**Per cent Disease Intensity (PDI)**
Immune/Highly Resistant	0
Resistant	0-10
Moderately Resistant	11-20
Moderately Susceptible	21-30
Susceptible	31-40
Highly Susceptible	>40

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.
- Wheeler, B. E. J. (1969). An introduction to plant diseases. John Willey and Sons Ltd., London. p. 374.

Fusarium wilt

Fusarium oxysporum causing Fusarium wilt is a devastating soil-borne pathogen of nigella which colonizes the vascular system thereby obstructing water and nutrient transport, leading to wilting and eventual plant death.

Symptomatology

The initial symptoms appear as yellowing of lower leaves, progressing upwards. In later stage of crop growth, dark brown streaks appear in vascular tissues that are visible upon stem dissection. Stunted growth, premature defoliation and plant death occurred in severe conditions. The pathogen is both soil and seed-borne and survives as saprophyte in the soil debris as mycelium and all spore types. The pathogen thrives under the optimal temperature range of 24-30°C and the favourable condition for disease development is sufficient water deposition on host during February-March. Wet and humid (>80 per cent) conditions predispose the conidia to germinate and light favours the infection and disease development.

Screening for disease resistance

Procedure :

The trial should be laid out in Randomized Block Design (RBD) for test entries up to 30 and Augmented Block Design (ABD) for more than 30 test entries and the duration would be four years. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. The plot size should be of 2-3 rows of 3 m length per test entry with spacing of 30 cm between rows and 15 cm between plants. Three replications should be maintained for each entries and checks. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as three test entries in paired rows followed by check (susceptible/resistant/varieties). The disease-free healthy nigella seeds should be sown during second fortnight of October. The location/field should be endemic/conducive to natural infection of wilt disease wherein, recurring infection is recorded/observed during the period of experiments and previous years. It should be designated as a sick plot or hot spot for the wilt disease occurrence. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than wilt.

The nigella seeds should be sown in wilt affected field having a wilt pathogen population of 1.3×10^4 cfu/g of soil or more. The infested soil should be used because it permits the assessment of field resistance by allowing the infection process to take place under natural conditions, with realistic doses of naturally produced inocula. If there is no natural incidence of disease in a particular location then, artificial inoculation of soil should be done. The culture of Fusarium oxysporum should be mass multiplied on sterilized sorghum seeds in 500 ml flasks for seven days. The inocula should be mixed with soil before sowing the seeds in plots. The size of each plot should be 0.90 m x 4.0 m (2 rows of each test entry) with row spacing of 30 cm. Each of the test entries should be alternated by susceptible check. Based on the proportion of plants exhibiting wilt symptoms in susceptible germplasm, the data should be recorded for healthy and wilted plants from different test entries and per cent disease incidence should be calculated. The seeds sown in plots, in which inoculum was not added will be served as control. Record observations at regular intervals; 15, 30, 45, and 60 days after sowing or transplanting. The per cent wilt incidence should be calculated by following formula (Anonymous, 2004).

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Based on the Per cent Disease Incidence (PDI) the test entries will be grouped into different categories.

Categorization based on reaction towards Fusarium wilt	
Categories	Per cent Disease Incidence (PDI)
Highly Resistant	0-10%
Resistant	11-20%
Moderately resistant	21-30%
Susceptible	31-50%
Highly susceptible	>50%

Selected references

- Anonymous. (2004). Proceedings of the XVII workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.

Root rot

Root rot caused by *Rhizoctonia solani* is an economically important disease that affects crop establishment and yield.

Symptomatology

The disease is characterized by reddish-brown to dark lesions on roots and stem bases, cortical decay, poor seedling emergence, stunting, chlorosis, wilting and in severe cases, plant death. The pathogen is a soil-borne that survive for long periods as sclerotia or mycelium in soil and crop residues and under warm, moist and poorly drained conditions, the sclerotia germinate to produce hyphae that penetrate root tissues, causing necrosis and girdling.

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Block Design (RBD) for test entries up to 30 and Augmented Block Design (ABD) for more than 30 test entries and the duration would be four years. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. The plot size should be of 2-3 rows of 3 m length per test entry with spacing of 30 cm between rows and 15 cm between plants. Three replications should be maintained for each entries and checks. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as three test entries in paired rows followed by check (susceptible/resistant/varieties). The disease-free healthy nigella seeds should be sown during second fortnight of October. The location/field should be endemic/conducive to natural infection of root rot disease wherein, recurring infection is recorded/observed during the period of experiments and previous years. It should be designated as a sick plot or hot spot for the root rot disease occurrence. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than root rot.

The nigella seeds should be sown in root rot affected field having a root rot pathogen population of 1.3 x 10^4 cfu/g of soil or more. The infested soil should be used because it permits the assessment of field resistance by allowing the infection process to take place under natural conditions, with realistic doses of naturally produced inocula. If there is no natural incidence of disease in particular location then, artificial inoculation of soil should be done. The culture of Rhizoctonia solani should be mass multiplied on sterilized sorghum seeds in 500 ml flasks for seven days. The inocula should be mixed with soil before sowing the seeds in plots. The size of each plot should be 0.90 m x 4.0 m (2 rows of each test entry) with row spacing of 30 cm. Each of the test entries should be alternated by a susceptible check. Based on the proportion of plants exhibiting root rot symptoms in susceptible germplasm, the data should be recorded for healthy and affected plants from different test entries and per cent disease incidence should be calculated. The seeds sown in plots, in which inoculum was not added will serve as control. Record observations at regular intervals; 15, 30, 45, and 60 days after sowing or transplanting. The per cent wilt incidence should be calculated as per Anonymous (2004).

$$\text{Per cent Disease Incidence (PDI)} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Based on the Per cent Disease Incidence (PDI) the test entries will be grouped into different categories.

Categorization based on reaction towards root rot	
Categories	Per cent Disease Incidence (PDI)
Highly Resistant	0-10%
Resistant	11-20%
Moderately resistant	21-30%
Susceptible	31-50%
Highly susceptible	>50%

Selected references

- Anonymous. (2004). Proceedings of the XVII workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.

Powdery mildew

Powdery mildew is a common and economically important foliar disease of nigella caused by *Erysiphe polygoni*. The pathogen is endophytic and consists of hyphae which are intercellular and occupy the spongy parenchyma of the mesophyll.

Symptomatology

The major symptoms include formation of white, powdery coating on leaves, stems, and flowers. Initially, small, white, round spots appear on the upper side of older leaves. Primary dispersal of conidia is through soil and seed and secondary dispersal of conidia is through wind, rain splashes. Favourable conditions for disease are cool high humid weather (20-25ºC) and cloudy weather which favours conidial germination and disease development.

Screening for disease resistance

Procedure:

The trial should be laid out in Randomized Block Design (RBD) and the duration would be four years. The recommended package of practices should be adopted to raise the crop which should be uniformly adopted in all the centers. Three replications should be maintained for each entries and checks. The test entries shortlisted along with known/reported susceptible and resistant checks should be used to screen for disease resistance. The test entries and the check varieties should be sown as per standard package and practices. Timely sprays/soil application of recommended plant protection chemicals should be adopted to manage insect pests and diseases other than powdery mildew.

Infector row (known highly susceptible variety/germplasm/breeding line) technique should be followed to spread the disease intensively. The infector rows should be sown 15 days in advance of screening material at after every fourth row with susceptible check so as to establish and continuously supply of the inocula on to germinating test entries. In addition, four rows of the susceptible check should also be raised around the experimental plot to provide the inocula facilitating screening of the test entries under field conditions. Each of the test entries should be sown in two rows of 3 m length with 30 x 15 cm spacing and replicated thrice. The crop should be raised adopting the all recommended package of practices. The screening data should be recorded when the disease incidence will be at the maximum on the susceptible check. Observation on disease reaction should be made on ten randomly selected plants in each entry. Nine leaves should be scored in each plant, three each from the apical, middle and basal regions and all should be graded. The disease intensity should be scored adopting the 0-4 grade (Mayee and Datar, 1986).

Disease rating scale for powdery mildew (0-4 scale)	
Scale	**Description of symptoms**
0	Healthy
1	Whitish small spots on leaf
2	Whitish growth covering the entire leaf
3	Growth on leaf and stem
4	Growth on leaf, stem and umbel/pod

Based on the observations, Per cent Disease Intensity (PDI) should be worked out using formula developed by Wheeler (1969).

$$\text{Per cent Disease Intensity (PDI)} = \frac{\text{Sum of all individual disease rating}}{\text{Total number of plants assessed x Maximum rating}} \times 100$$

Based on the Per cent Disease Intensity (PDI) the test entries will be grouped into different categories (Rathi and Tripathi, 1994)

Categorization based on reaction towards powdery mildew	
Categories	**Per cent Disease Incidence (PDI)**
Immune/Highly Resistant	0
Resistant	1-10
Moderately Resistant	11-25
Moderately Susceptible	26-50
Susceptible	51-75
Highly Susceptible	>75

Selected references

- Anonymous. (2004). Procedure for grading disease and pest severity of various pests and diseases in seed spices. Proceedings of the XVII Workshop of All India Coordinated Research Project on Spices. 3-5 February 2004, ICAR-Indian Institute of Spices Research, Calicut, Kerala. p. 62.
- Mayee, C. D. and Datar, V. V. (1986). Phytopathometry. Technical Bulletin No.1, University of Agricultural Sciences, Marathawad, Parbhani, India. p. 146.
- Rathi, A. S. and Tripathi, N. N. (1994). Assessment of growth reduction and yield losses in pea due to powdery mildew disease caused by *Erysiphe polygoni* DC. Crop Research (Hisar). 8(2): 371-376.
- Wheeler, B. E. J. (1969). An introduction to plant diseases. John Willey and Sons Ltd., London. p. 374.

Aphids

Among the insect pests, the primary aphid species reported to infest nigella is *Aphis fabae* (Black bean aphid).

Symptomatology

The aphids cause maximum damage to the crop as it sucks the cell sap from leaves, stem inflorescences and developing grains due to which the plants become weak and stunted. Due to the rapid reproduction rate, the aphids cover the entire surface of apical shoots within a short span. As a consequence of the continuous feeding by the extensive population, the leaves turn yellowish, curl and eventually dries. In case of severe infestation, the growing points and flower stalks wither and dries and at flowering and fruiting stage, the seeds are not formed and if formed, they are shrivelled and of poor quality.

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