



Identification of multiple diseases resistance in faba bean germplasm under assured inoculum in field condition.

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ABSTRACT

Faba bean (*Vicia faba* L.) plays a crucial role in global food security and sustainable agriculture. However, its cultivation faces challenges due to various diseases that can significantly impact crop yield and quality. This study focuses on exploring the multifaceted aspects of disease resistance in faba beans, with a particular emphasis on developing cultivars with strong defense mechanisms against multiple pathogens. This study investigates the resistance of forty-six faba bean (*Vicia faba* L.) germplasm lines against three major pathogens: root-knot nematode (*Meloidogyne incognita* race-1), Alternaria blight (*Alternaria alternata*), and leaf curl virus (family-Begomoviridae). The primary aim was to identify germplasm with significant resistance for potential use in breeding programs. Under controlled conditions, each germplasm line was inoculated with nematode juveniles and assessed for root gall formation. Five varieties (FLIP15-139FB, S2011,134, FLIP19-207FB, L2014-010, HB-19-13) demonstrate resistance/tolerance to root-knot nematode, Alternaria blight, and leaf curl virus. These varieties are highly recommended for commercial production in regions where multiple diseases co-exist, ensuring robust crop performance. These findings underscore the critical importance of diverse germplasm screening to enhance the disease resilience of faba beans, contributing to sustainable agricultural practices.

Keywords: Disease resistance, pathogens, global food security and sustainability.

INTRODUCTION

One of the world's first domesticated dietary legumes the faba bean, botanically known as *Vicia faba*, is also known by common names such as horse bean, field bean, broad bean, fava bean and tic bean. It was most likely domesticated around the Neolithic era (Metayer, 2004). In the plains of India, it is primarily a *rabi* pulse though it can be grown successfully in hilly and mountainous area during the kharif (rainy) season (Singh and Bhatt 2012). It's also cultivated extensively as garden crop. After garden peas, faba beans are the fourth most significant food legume in the world (Toresset *al.*, 2006). By fixing nitrogen, faba bean also contribute significantly to the restoration of soil fertility and make an excellent crop to rotate

with cereals and other crops (Al-Abdalall, 2010, Teshome and Taggen, 2013). The faba bean (*Vicia faba* L) is a native of Southwest Asia and North Africa. It is mostly grown for its dried seeds and green pods, which are high dietary fibre, minerals, vitamins, proteins and secondary metabolites including phenolics. It is therefore a crucial part of the food that human eat (Randhret *et al.*, 2002, Sahileet *et al.*, 2011). The faba bean has a high nutritional content and is significant to the country's economy. Among all temperate and tropical pulse crops, such as lentil (*Lens culinaris*), common bean (*Phaseolus vulgaris*), Chickpea (*Cicer arietinum*) and pea (*Pisum sativum*) this crop yields the highest percentage of protein (20-41%) per unit land (Crepona *et al.*, 2010, FAOSTAT, 2013). Maturated faba bean seeds are high in nutritional value, with 26.1% proteins, 58.3% carbohydrates and 25.0% dietary fiber (Anonymous, 2021).

In terms of total production, the faba bean came in sixth place globally in 2018-19, behind the common bean, pea, chickpea, cowpea and lentil, with 4.5 million tonnes produced, while area 2.5 million hectares were harvested. In both area and production, China is the faba bean growing nation choice (Khazaei and Vandenberg, 2020). Bihar has the largest area of faba beans in India because it is the state's traditional legume crop. Madhya Pradesh, Odisha, Jharkhand and Uttar Pradesh (Primarily the eastern part) are the Indian states where faba beans are grown (Singh *et al.*, 2012).

Numerous biotic and abiotic stressors affect faba beans, significantly lowering their ultimate yields (El-Hendawy *et al.*, 2010). The faba bean is affected with numerous harmful illnesses. In the Mediterranean region, different pathogens attack it. In the production of faba beans, diseases can cause significant losses. The Alternaria leaf spot disease, which is caused by *Alternaria alternata*, has been causing significant harm to plants over past few years. This is because the temperature has been rising above natural levels. (Honda *et al.*, 2001, Reis *et al.*, 2007, Juroszek and von Tiedemann, 2011). Fungi represent the most extensive and potentially significant groups in the faba bean, affecting every part of the plant throughout its life cycle (Nigussie *et al.*, 2008).

Like other pulse crops, faba bean also suffers from various diseases caused by fungus, bacterial, nematodes and viral. However, among the fungal disease, Alternaria leaf spot caused *Alternaria alternata* is a serious disease causing heavy losses during all the stages of the plant growth. The first symptoms of Alternaria leaf spot of faba bean initially manifested as a tiny, brownish-coloured circular spot at the leaf edge. It then moved towards the midrib or the spots combined to form an irregular, elongated, dark brown necrotic lesion.

Materials and Methods

The experiment was conducted during the Rabi season of 2022-23 & 2023-24 at the Genetics and Plant Breeding Farm within the Department of Plant Pathology, College of Agriculture, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). The experiment's specifics are outlined below:

Geographical and climatic conditions of the location:

The Ayodhya district is situated at a geographical location of approximately 26.47 °N latitude and 82.12 °E longitude, with an altitude of 113 meters above mean sea level. The area experiences a sub-humid, sub-tropical climate with an average annual rainfall of around 1200 mm. Approximately 80% of the total rainfall occurs from mid-June to the end of September, constituting the monsoon months. Winters are characterized by very cold temperatures, while summers are extremely hot and dry. Generally, hot winds prevail from the end of April until the onset of the monsoon.

Screening of Faba bean germplasm against root-knot nematode Alternaria leafspot and leaf curl Virus disease:

A total of 46 germplasms of faba bean were acquired from the department of Genetics and Plant Breeding Farm at Acharya Narendra Deva University of Agriculture and

Technology, located in Kumarganj, Ayodhya (U.P). The details of these germplasms screened in the experiments are presented in Table.

At ANDUA&T Ayodhya, screening 46 germplasms of faba bean were screened against root-knot nematode (*Meloidogyne incognita* race-1), Alternaria blight disease (*Alternaria alternata*) and leaf curl Virus disease (family- *Begomo*).

Screening of faba bean germplasm against major diseases		
Trial		Faba Bean
Season		Rabi 2022-23& 2023-24
Experimental Details		
1	No. of Entries	46+03
2	No. of Reps.	3
3	Design	RBD
4	Row x Row (cm.)	50
5	Plant x Plant (cm.)	15
6	No. of rows/ plot	2
7	Row length (m)	2
8	Date of sowing	10.11.2022, - 16.11.2023
9	Date of harvesting	05.04.2023, - 20.04.2024
10	Plot Size	1.50 m ²

Disease Rating Scales:

1. Root-knot Nematode Disease in Faba bean (Rating scale used in AICRP on Nematode)

Gall Index	No. of galls/plant	Reaction
0	NO GALLS	IMMUNE
1	1-2 GALLS	HIGHLY RESISTANT
2	3-10 GALLS	RESISTANT
3	11-30 GALLS	MODERATELY REISTANT
4	31-100 GALLS	SUSCEPTIBLE
5	MORE THAN 100 GALLS	HIGHLY SUSCEPTIBLE

2. Alternaria blight Disease in Faba bean (Rating Scale by Mayee and Datar,1986)

All the Faba bean varieties were screened against *Alternaria alternata* using (0-9) scale in field in field condition. Per cent disease intensity was calculated using formula given by McKinney (1923).

$$PDI = \frac{\text{Sum of all numerical rating}}{\text{Total number of leaves examined} \times \text{Maximum grade}} \times 100$$

All faba bean varieties were screened against *Alternaria alternata* in the field condition by the following disease rating scale:

Rating scale	Disease intensity (%)	Reaction
0	No symptoms on the leaf	Immune
1	Small, irregular brown spots covering 1 per cent or less of the leaf area	Resistant
3	Small, round to irregular brown spots with concentric rings covering 1-10 percent of the leaf area.	Moderately resistant
5	Round to irregular brown lesions enlarging, with concentric rings covering 11-25 percent of the leaf area.	Tolerant
7	Lesions enlarging and coalescing to form irregular brown patches with concentric rings and covering 26-50 per cent of the leaf area. Lesions also appeared on stem, petioles and pods.	Susceptible

9	Lesions enlarged coalesced to forming irregular, dark brown patches with concentric rings covering 51 percent or more of the leaf area. Lesions on stem, petioles and pods.	Highly susceptible
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3. Leaf Curl Disease in Faba bean (Using in AICRP on MULLaRP Crops)

Infected Plants (%)	Reaction
0	Free (F)
0.1-5	Highly Resistant (HR)
5.1-10	Resistant (R)
10.1-20 %	Moderately Resistant (MR)
20.1-50 %	Susceptible (S)
More than 50 %	Highly Susceptible (HS)

RESULTS & Discussion

Screening of Faba Bean germplasm for resistance against Root-knot Nematode, Alternaria leaf spot and leaf curl Virus disease:

Total Forty-six germplasm of faba bean were screened against root-knot nematode (*Meloidogyne incognita* race-1), Alternaria blight disease (*Alternaria alternata*) and leaf curl Virus disease (family- Begomo) under assured inoculum in field condition.

Screening of Faba bean germplasm against root-knot nematode, *Meloidogyne incognita* race-1, *Alternaria* blight disease, *Alternaria alternata* and leaf curl Virus disease, family- Begomo under assured inoculum field conditions.

Sr No.	Germplasm	Root-Knot Disease						Alternaria Blight						Leaf Curl Disease					
		2022-23		2023-24		Pooled Data		2022-23		2023-24		Pooled Data		2022-23		2023-24		Pooled Data	
		Gall Index	Reaction	Gall Index	Reaction	Gall Index	Reaction	Mean PDI	Reaction	Mean PDI	Reaction	Mean PDI	Reaction	Mean PDI	Reaction	Mean PDI	Reaction	Mean PDI	Reaction
1	FLIP19-198FB	4.00	S	5.00	HS	5.00	HS	52.60	HS	63.07	HS	57.83	HS	3.50	HR	1.50	HR	2.50	HR
2	FLIP19-183FB	4.00	S	4.00	S	4.00	S	22.20	T	32.60	S	27.40	S	1.75	HR	1.75	HR	0.87	HR
3	FLIP19-193FB	5.00	HS	4.00	S	5.00	HS	20.30	T	23.97	T	23.13	T	2.25	HR	1.83	HR	2.04	HR
4	FLIP19-219FB	4.00	S	4.00	S	4.00	S	17.45	T	28.87	S	23.16	T	1.83	HR	0.00	F	0.91	HR
5	FLIP19-216FB	4.00	S	4.00	S	4.00	S	46.10	S	48.47	S	47.28	S	3.42	HR	1.75	HR	2.58	HR
6	FLIP19-211FB	3.00	MR	3.00	MR	3.00	MR	20.66	T	36.43	S	28.54	S	4.16	HR	1.75	HR	2.95	HR
7	FLIP19-149FB	4.00	S	5.00	HS	5.00	HS	51.15	HS	49.70	S	50.42	HS	6.50	R	2.92	HR	4.71	HR
8	FLIP19-221FB	4.00	S	5.00	HS	5.00	HS	57.05	HS	56.20	HS	56.62	HS	6.33	R	1.08	HR	3.70	HR
9	FLIP19-218FB	4.00	S	4.00	S	4.00	S	46.60	S	49.57	S	48.08	S	25.08	S	20.25	S	22.66	S
10	Hashbenge	5.00	HS	4.00	S	5.00	HS	15.20	T	28.63	S	21.81	T	32.92	S	31.75	S	32.33	S
11	Syn 6 (3)	5.00	HS	4.00	S	4.00	HS	21.20	T	29.37	S	25.28	S	2.62	HR	1.75	HR	2.18	HR
1	FLIP15-	3.00	MR	3.00	MR	3.00	MR	15.	T	21.	T	18.	T	3.3	HR	1.75	HR	2.54	HR

2	139FB			0		0		75		97		86		3					
1 3	FLIP15- 156FB	4.00	S	4.0 0	S	4.0 0	S	51. 10	HS	39. 77	S	45. 43	S	5.6 7	R	1.50	HR	3.58	HR
1 4	FLIP15- 158FB	3.00	MR	3.0 0	MR	3.0 0	MR	49. 25	S	50. 22	HS	49. 73	S	5.9 2	R	5.17	R	5.54	R
1 5	FLIP15- 159FB	3.00	MR	4.0 0	S	3.0 0	S	49. 60	S	41. 17	S	45. 38	S	3.5 0	HR	2.58	HR	3.04	HR
1 6	FLIP15- 164FB	3.00	MR	3.0 0	MR	3.0 0	MR	43. 05	S	41. 95	S	42. 50	S	3.1 7	HR	3.17	HR	3.17	HR
1 7	FLIP15- 169FB	4.00	S	5.0 0	HS	5.0 0	HS	40. 60	S	50. 95	HS	45. 77	S	8.5 0	R	6.25	R	7.37	R
1 8	FLIP15- 172FB	4.00	S	4.0 0	S	4.0 0	S	43. 15	S	28. 73	S	35. 94	S	32. 58	S	23.92	S	28.25	S
1 9	S2011,104	5.00	HS	5.0 0	HS	5.0 0	HS	54. 90	HS	50. 83	HS	52. 86	HS	34. 75	S	8.42	R	21.58	S
2 0	S2011,116	5.00	HS	5.0 0	HS	5.0 0	HS	15. 10	T	20. 53	T	17. 81	T	12. 92	MR	5.08	R	9.00	R
2 1	S2011,134	3.00	MR	3.0 0	MR	3.0 0	MR	14. 60	T	23. 30	T	18. 95	T	12. 00	MR	7.17	R	9.58	R
2 2	Syn11	4.00	S	3.0 0	MR	4.0 0	S	15. 60	T	21. 57	T	18. 58	T	10. 25	MR	6.67	R	8.46	R
2 3	FLIP15- 163FB	3.00	MR	3.0 0	MR	3.0 0	MR	41. 05	S	46. 00	S	43. 52	S	6.6 7	R	3.83	HR	5.25	R
2 4	FLIP19- 202FB	5.00	HS	5.0 0	HS	5.0 0	HS	43. 11	S	50. 13	HS	46. 62	S	4.9 2	HR	5.92	R	5.42	R
2 5	FLIP19- 196FB	3.00	MR	3.0 0	MR	3.0 0	MR	32. 20	S	40. 77	S	36. 48	S	32. 33	S	7.75	R	20.04	S
2 6	FLIP19- 207FB	3.00	MR	3.0 0	MR	3.0 0	MR	20. 15	T	21. 27	T	20. 71	T	11. 83	MR	10.75	MR	11.29	MR
2 7	L2014-043	4.00	S	4.0 0	S	4.0 0	S	30. 40	S	22. 03	T	26. 21	S	41. 83	S	13.17	MR	27.50	S
2	L2014-010	3.00	MR	3.0	MR	3.0	MR	23.	T	18.	T	21.	T	16.	MR	10.17	MR	13.25	MR

8				0		0		55		63		09		33					
29	L2014-089	3.00	MR	3.00	MR	3.00	MR	30.60	S	41.93	S	36.26	S	45.50	S	22.33	S	33.91	S
30	L2014-136	4.00	S	4.00	S	4.00	S	19.75	T	32.10	S	25.92	S	41.92	S	21.25	S	31.58	S
31	L2014-108	3.00	MR	3.00	MR	3.00	MR	20.70	T	40.10	S	30.40	S	14.75	MR	30.42	S	22.58	S
32	GIZA-4	5.00	HS	5.00	HS	5.00	HS	45.65	S	36.97	S	41.31	S	8.50	R	10.67	MR	9.58	R
33	HB-18-10	5.00	HS	5.00	HS	5.00	HS	15.65	T	38.95	S	27.30	S	4.97	HR	1.92	HR	3.44	HR
34	HB-18-15	5.00	HS	4.00	S	5.00	HS	54.65	HS	16.33	T	35.49	S	5.35	R	1.53	HR	3.44	HR
35	HB-19-04	4.00	S	4.00	S	4.00	S	24.70	T	16.47	T	20.58	T	6.76	R	5.63	R	6.19	R
36	HB-19-10	3.00	MR	3.00	MR	5.00	MR	57.10	HS	30.87	S	43.98	S	5.35	R	0.00	F	4.11	HR
37	HB-19-11	3.00	MR	4.00	S	4.00	S	45.55	S	29.15	S	23.85	T	8.95	R	5.87	R	7.41	R
38	HB-19-12	4.00	S	5.00	HS	5.00	HS	19.30	T	21.75	S	20.52	T	15.12	MR	5.30	R	10.21	MR
39	HB-19-13	3.00	MR	3.00	MR	3.00	MR	12.00	T	33.55	S	22.77	T	11.57	MR	3.53	HR	7.55	R
40	HB-18-14	4.00	S	5.00	HS	5.00	HS	31.55	S	24.00	S	27.77	S	13.17	MR	6.00	R	9.58	R
41	HB-16-15	4.00	S	4.00	S	4.00	S	15.65	T	40.63	S	28.14	S	4.97	R	7.33	R	6.15	R
42	HB-14-31	5.00	HS	5.00	HS	5.00	HS	18.85	T	29.37	S	24.11	T	5.97	R	9.00	R	7.48	R
43	HB-15-38	5.00	HS	4.00	S	5.00	HS	11.10	T	44.37	S	27.73	S	5.35	R	0.00	F	2.67	HR
44	HFB-1	4.00	S	4.00	S	4.00	S	31.	S	34.	S	32.	S	16.	MR	25.33	S	21.05	S

4				0		0		05		07		56		77					
4 5	HFB-2	4.00	S	4.0 0	S	4.0 0	S	26. 60	S	44. 73	S	35. 66	S	23. 28	S	20.10	S	21.69	S
4 6	Vikrant(Check)	5.00	HS	5.0 0	HS	5.0 0	HS	45. 30	S	45. 94	S	45. 62	S	21. 23	S	24.75	S	22.99	S

Multiple disease resistance of Faba bean germplasm against root-knot nematode, *Meloidogyne incognita* race-1, Alternaria blight disease, *Alternaria alternata* and leaf curl Virus disease, family-Begomo under assured inoculum field conditions.

Sr. No.	Germplasm	Root-Knot Disease	Alternaria Blight	Leaf Curl Disease	N+AB	N+LC	AB+LC	N+AB+LC
		Reaction	Reaction	Reaction				
1	FLIP19-198FB	HS	HS	HR	HS			
2	FLIP19-183FB	S	S	HR	S			
3	FLIP19-193FB	HS	T	HR			T/HR	
4	FLIP19-219FB	S	T	HR			T/HR	
5	FLIP19-216FB	S	S	HR	S			
6	FLIP19-211FB	MR	S	HR		MR/HR		
7	FLIP19-149FB	HS	HS	HR	HS			
8	FLIP19-221FB	HS	HS	HR	HS			
9	FLIP19-218FB	S	S	S				S
10	Hashbenge	HS	T	S	S	S		
11	Syn 6 (3)	HS	S	HR	S			
12	FLIP15-139FB	MR	T	HR				R
13	FLIP15-156FB	S	S	HR	S			
14	FLIP15-158FB	MR	S	R		MR/R		
15	FLIP15-159FB	S	S	HR	S			
16	FLIP15-164FB	MR	S	HR				
17	FLIP15-169FB	HS	S	R				
18	FLIP15-172FB	S	S	S				S
19	S2011,104	HS	HS	S				HS/S
20	S2011,116	HS	T	R			T/MR	
21	S2011,134	MR	T	R			T/MR	
22	Syn11	S	T	R			T/R	
23	FLIP15-163FB	MR	S	R		MR/R		
24	FLIP19-202FB	HS	S	R	HS/S			
25	FLIP19-196FB	MR	S	S			S	
26	FLIP19-207FB	MR	T	MR		MR		R
27	L2014-043	S	S	S				S
28	L2014-010	MR	T	MR				MR/T/MR
29	L2014-089	MR	S	S			S	
30	L2014-136	S	S	S			S	
31	L2014-108	MR	S	S				S
32	GIZA-4	HS	S	R	HS/S			
33	HB-18-10	HS	S	HR	HS/S			
34	HB-18-15	HS	S	HR	HS/S			
35	HB-19-04	S	T	R			T/R	
36	HB-19-10	MR	S	HR		MRHR		
37	HB-19-11	S	T	R			T/R	
38	HB-19-12	HS	T	MR			T/MR	
39	HB-19-13	MR	T	R				MR/T/HR
40	HB-18-14	HS	S	R		HS/S		
41	HB-16-15	S	S	R		S		

42	HB-14-31	HS	T	R			T/R	
43	HB-15-38	HS	S	HR		HS/S		
44	HFB-1	S	S	S				S
45	HFB-2	S	S	S				S
46	Vikrant(Check)	HS	S	S				HS/S

Screening for disease resistance

In order to study the response of Faba bean germplasms or varieties against the important diseases of Faba bean i.e. Root-knot nematode, *Meloidogyne incognita*, Alternaria leaf blight, *Alternaria alternata* and leaf curl, family- Begomoviridae causing considerable yield loss to faba bean growers, disease screening in field under inoculated conditions was carried out in the cage-houses of Genetics & Plant breeding research farm, Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, U.P., India. The observation recorded on disease incidence, disease severity and root knot index indicated that root-knot nematode disease, Alternaria leaf blight and leaf curl disease was able to develop on the Fava during the *rabi* session where the temperature ranges between 18-28 degree during crop growth. The disease development remains variable in all the varieties or germplasm. Out of 46 varieties tested for the resistance response against Root-knot nematode, *Meloidogyne incognita*, Alternaria leaf blight, *Alternaria alternata* and leaf curl, 13 germplasm (FLIP19-211FB, FLIP15-139FB, FLIP15-158FB, FLIP15-164FB, S2011,134, FLIP15-163FB, FLIP19-196FB, L2014-010, L2014-089, L2014-108, FLIP19-207FB, HB-19-10, HB-19-13) of faba bean was observed to be showed moderately resistant reaction against root-knot nematode disease, 14 varieties was tested as tolerant (FLIP19-193FB, FLIP19-219FB, Hashbenge, FLIP15-139FB, S2011,116, S2011,134, Syn11, L2014-010, Flip19-207FB, HB-19-04, HB-19-11, HB-19-12, HB-19-13, HB-14-31 against Alternaria leaf blight disease) and 3 varieties (L2014-010, HB-19-12, FLIP19-207FB) showed moderate reaction, 15 showed resistant reaction (FLIP15-158FB, FLIP15-169FB, S2011,116, S2011,134, Syn11, FLIP15-163FB, FLIP19-202FB, HB-19-04, HB-18-15, GIZA-4, HB-19-04, HB-19-11, HB-19-13, HB-18-14, HB-16-15) and 17 germplasm showed highly resistant reaction (FLIP19-198FB, FLIP19-183FB, FLIP19-193FB, FLIP19-219FB, FLIP19-216FB, FLIP19-211FB, FLIP19-149FB, FLIP19-221FB, Syn 6 (3), FLIP15-139FB, FLIP15-156FB, FLIP15-159FB, FLIP15-164FB, HB-18-10, HB-18-15, HB-19-10, HB-15-30) against leaf curl disease. When all these 46 germplasms were when tested against the multiple disease reaction, the observations indicated that 5 germplasm i.e. FLIP15-156FB, S2011,134, FLIP19-207FB, L2014-010, HB-19-13 showed HR/R/MR/T reaction root-knot disease and Alternaria leaf blight disease while 9 germplasms (FLIP19-211FB, FLIP15-139FB, FLIP15-158FB, FLIP15-164FB, S2011,134, FLIP19-207FB, L2014-010, HB-19-10, HB-19-13) showed F/HR/R/MR reaction for the Root-Knot Nematode & Leaf Curl Virus Disease, 13 germplasm (FLIP19-193FB, FLIP19-219FB, FLIP15-139FB, S2011,116, S2011,134, Syn11, FLIP19-207FB, L2014-010, HB-19-04, HB-19-11, HB-19-12, HB-19-13, HB-14-31) showed F/HR/R/MR/T reaction however only 05 germplasm (FLIP15-139FB, S2011,134, FLIP19-207FB, L2014-010, HB-19-13) was observed to be showed F/HR/R/MR/T reaction against all above said three diseases under field and inoculated conditions.

Disease development of Alternaria leaf spot of faba bean

Alternaria leaf spot, caused by the fungus *Alternaria alternata*, can significantly impact faba bean crops. Here's a day-to-day summary of its disease development:

1. Initial Infection:

- i. Spores from *Alternaria* spp. land on faba bean leaves, especially in warm and humid conditions.
- ii. Spores germinate and penetrate the leaf surface, infecting the plant tissues.

2. Incubation Period (Days 1-5):

- i. After infection, there is an initial period where the fungus grows within the leaf tissues without showing visible symptoms.
- ii. This phase typically lasts from 1 to 5 days, depending on environmental conditions such as temperature and humidity.

3. Symptom Development (Days 5-10):

- i. Small, dark brown to black spots appear on the leaves.
- ii. These spots gradually enlarge, becoming circular or irregular in shape.
- iii. Centers of the spots may turn gray or tan as the disease progresses.
- iv. Infected leaves may yellow and eventually die if the infection is severe.

Day 1-3:

- i. **Initial Infection:** Spores of *Alternaria* land on faba bean leaves.
- ii. **Incubation:** No visible symptoms initially; fungus begins to invade leaf tissues.

Day 4-5:

- i. **Early Symptoms:** Small, dark brown to black spots start to appear on leaves.
- ii. **Lesion Development:** Spots enlarge, often with a concentric ring pattern.

Day 6-7:

- i. **Lesion Expansion:** Spots continue to grow in size, becoming more distinct.
- ii. **Color Changes:** Centers of lesions may turn gray or tan, surrounded by darker edges.

Day 8-10:

- i. **Increased Lesion Density:** More leaves show symptoms as the disease spreads.
- ii. **Leaf Yellowing:** Infected leaves start to yellow around the lesions.

Day 11-14:

- i. **Progression to Lower Leaves:** Disease spreads to lower leaves of the plant.
- ii. **Leaf Drop:** Severely infected leaves may begin to drop prematurely.

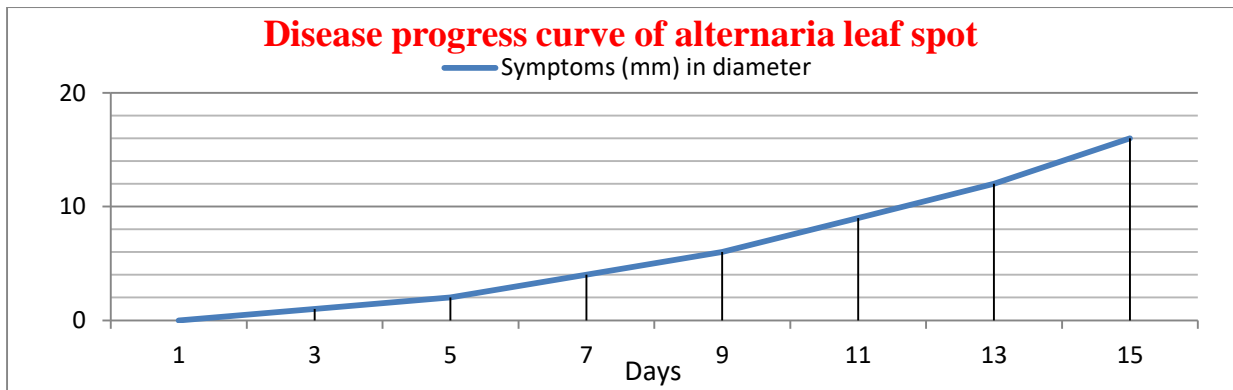
Day 15 onwards:

- i. **Severe Infection:** If conditions remain favorable (warm and humid), disease can rapidly spread throughout the crop.
- ii. **Defoliation:** Severe cases can lead to extensive defoliation, reducing photosynthesis and impacting yield.

Day to day disease development table for *Alternaria* leaf spot of faba bean involves detailing the progression of symptoms typically observed over time. Here a disease symptom table.

Day	Symptoms (mm) in diameter
1	0
4	1
6	2
8	4
10	6
12	9
14	13
15	15

Disease progress curve *Alternaria* leaf spot of faba bean.



Disease development of Alternaria leaf spot of faba bean.



Disease development (Root-Knot of faba bean)

After the first appearance of root knot nematode symptoms in faba beans, changes that may be observed at 15-day intervals include:

1. Increase in Root Galls: Initially, small galls may appear on the roots. Over subsequent 15-day intervals, these galls can increase in size and number as nematode populations grow and continue to feed on the root tissues.

2. Worsening of Root Deformation: The distortion and swelling of roots due to nematode feeding intensify with time. Roots may become more visibly deformed and knotted, affecting their ability to function properly in water and nutrient uptake.

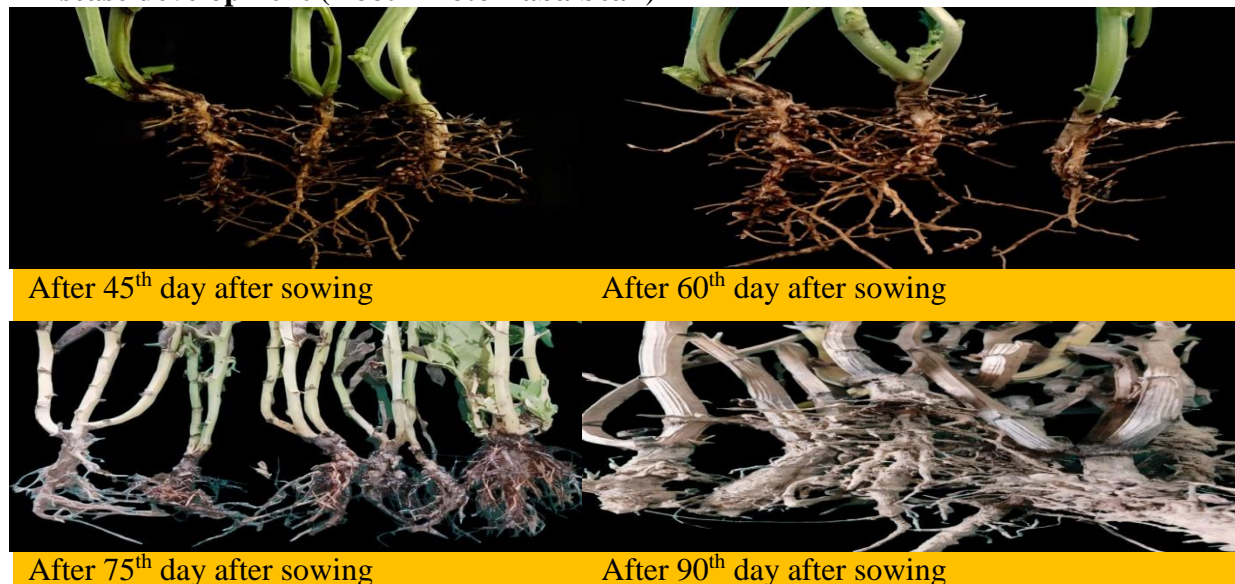
3. Development of Secondary Symptoms: As root damage progresses, secondary symptoms such as stunted growth and yellowing of leaves (Chlorosis) may become more pronounced. This is because the compromised root system cannot adequately support the plant's nutrient needs.

4. Impact on Plant Growth: The overall growth of faba bean plants may be noticeably affected over 15-day intervals. Infected plants may appear more stunted compared to healthy plants, with reduced vigour and potentially lower yield potential.

5. Spread of Infestation: If not managed, nematode populations can spread further within the soil, affecting more roots and potentially neighbouring plants within the field.

Monitoring these changes at regular 15-day intervals is crucial for assessing the progression of root knot nematode infestation in faba beans and implementing appropriate management strategies to mitigate their impact.

Disease development (Root-Knot of faba bean)



CONCLUSION:

Based on the pooled data screening of Faba bean germplasm against root-knot nematode (*Meloidogyne incognita* race-1), Alternaria blight disease (*Alternaria alternata*), and leaf curl virus disease (family- Begomoviridae), the following conclusions can be drawn for a breeding program aimed at developing resistant varieties:

Root-Knot Nematode Disease Resistant		
Reaction	Total number	Germplasm/Variety
Moderately Resistant (MR)	13	FLIP19-211FB, FLIP15-139FB, FLIP15-158FB, FLIP15-164FB, S2011,134, FLIP15-163FB, FLIP19-196FB, L2014-010, L2014-089, L2014-108, FLIP19-207FB, HB-19-10, HB-19-13
Alternaria Blight Disease Resistance		
Tolerant (T)	14	FLIP19-193FB, FLIP19-219FB, Hashbenge, FLIP15-139FB, S2011,116, S2011,134, Syn11, L2014-010, Flip19-207FB , HB-

		19-04, HB-19-11, HB-19-12, HB-19-13, HB-14-31
Leaf Curl Virus Disease Resistance		
Moderately Resistant (MR)	3	L2014-010, HB-19-12, FLIP19-207FB
Resistant (R)	15	FLIP15-158FB, FLIP15-169FB, S2011,116, S2011,134, Syn11, FLIP15-163FB, FLIP19-202FB, HB-19-04, HB-18-15. GIZA-4, HB-19-04, HB-19-11, HB-19-13, HB-18-14, HB-16-15
Highly Resistant (HR)	17	FLIP19-198FB, FLIP19-183FB, FLIP19-193FB, FLIP19-219FB, FLIP19-216FB, FLIP19-211FB, FLIP19-149FB, FLIP19-221FB, Syn 6 (3), FLIP15-139FB, FLIP15-156FB, FLIP15-159FB, FLIP15-164FB, HB-18-10, HB-18-15, HB-19-10, HB-15-30
Root-Knot Nematode + Alternaria Blight Disease Resistance		
HR/R/MR/T	5	FLIP15-156FB, S2011,134, FLIP19-207FB, L2014-010, HB-19-13
Root-Knot Nematode + Leaf Curl Virus Disease Resistance		
F/HR/R/MR	9	FLIP19-211FB, FLIP15-139FB, FLIP15-158FB, FLIP15-164FB, S2011,134, FLIP19-207FB, L2014-010, HB-19-10, HB-19-13
Alternaria Blight + Leaf Curl Virus Disease Resistance		
F/HR/R/MR/T	13	FLIP19-193FB, FLIP19-219FB, FLIP15-139FB, S2011,116, S2011,134, Syn11, FLIP19-207FB, L2014-010, HB-19-04, HB-19-11, HB-19-12, HB-19-13, HB-14-31
All Three Diseases		
F/HR/R/MR/T	5	FLIP15-139FB, S2011,134, FLIP19-207FB, L2014-010, HB-19-13

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