ANNUAL PROGRESS REPORT

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Department of Plant Pathology

College of Agriculture

Chaudhary Sarwan Kumar

Himachal Pradesh Krishi Vishvavidyalaya

PALAMPUR-176062 (HP)

ACKNOWLEDGEMENT

The 31st Annual Progress Report of the department has been brought out with the co-operation of the professors/ scientists/ extension specialists deployed/ placed in the department, different Research and Extension Centers, Research-substations and Krishi Vigyan Kendras of the university located at different regions of the state. I express my appreciation to all of them. I am especially thankful to the committee comprising of Dr S K Rana (Chairman), Dr B R. Thakur, Dr A K Sud, Dr Amar Singh and Dr Suman Kumar for editing and compilation of the report.

I express my deep sense of gratitude to the honorable Vice-Chancellor for the motivation and encouragement rendered to the scientists of the department. The sincere advice and guidance provided by Director of Research, Dean Post Graduate Studies, Dean College of Agriculture, and Director of Extension Education in the spheres of research, teaching and extension education is duly acknowledged.

I am grateful to the faculty members of the department for their necessary help and scientific co-operation whenever required. My thanks are also due for the staff of the department for their co-operation in printing/ photo stating and binding of the report.

Head of the Department

CONTENTS

INTRODUCTION

The Department of Plant Pathology has the mandate of teaching, research and extension education pertaining to plant diseases and mushrooms. Scientists work in different areas of specialization and the students admitted to M Sc and Ph D programmes are assigned research problems on different aspects of diseases of cereals, pulses, oilseeds and vegetable crops including mushrooms.

The research work in various projects is being carried out in the main department at Palampur, Hill Agriculture Research & Extension Centres (Bajaura, Dhaulakuan and Kukumseri), Mountain Agriculture Research & Extension Centre (Sangla), Shivalik Agriculture Research & Extension Centre (Kangra), Rice & Wheat Research Centre (Malan) and Research Stations (Berthin and Akrot). Research on wheat diseases is carried out at Malan, Dhaulakuan and Bajaura, on rice diseases exclusively at Malan and on maize diseases at Bajaura and Dhaulakuan, whereas, the research on diseases of pulses is carried out at Palampur, Sangla, Berthin and Dhaulakuan and on oilseed crops at Kangra and Palampur. Among the diseases of vegetable crops, bacterial wilt and canker, late blight and fruit rots of solanaceous crops; powdery mildew, white rot and root rot/wilt complex diseases of peas; fungal, bacterial and viral diseases of French bean and Phomopsis leaf blight & fruit rot of brinjal receive special attention.

The department also carries out research on different aspects of mushroom cultivation. The spawn laboratory at present is meeting the demand of Horticulture Department and private mushroom growers. Teachers/scientists/students of the department are actively participating in the various seminars and symposia conducted by different scientific societies from time to time.

Several *ad-hoc* research projects are being carried out in the department with financial support from different agencies viz., Government of Himachal Pradesh, ICAR, CSIR, DST, DBT and fungicide companies.

The department is engaged in various extension education activities such as advisory service to farmers for diagnosis and management of diseases, conducting on farm trials & field demonstrations, participation in district/ state level workshops/ seminars/ field days/ kisan melas and on & off campus trainings etc. The scientists of the department are also actively involved in training and disseminating mushroom cultivation technology to the mushroom growers.

STAFF POSITION

Position/ Designation	Name	E-mail
Department of Plant Pathology, Palampur - 176062		
Professor & Head	Dr P N Sharma	pns1960@gmail.com
Principal Scientist cum Dean PGS	Dr A K Basandrai	**bunchy@rediffmail.com**
Professor	Dr S Dhancholia	**dhancholias1960@gmail.com**
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Principal Extension Specialist	Dr A K Sud	**arunsud7217@gmail.com**
Principal Scientist	Dr D K Banyal	**dkbanyal@gmail.com**
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Senior Scientist	Dr Suman Kumar	**sumanhpkv@gmail.com**
Hill Agricultural Research & Extension Centre, Bajaura – 175125		
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Senior Scientist	Vacant	-
Hill Agricultural Research & Extension Centre, Dhaulakuan – 173031		
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Hill Agricultural Research & Extension Centre, Kukumseri - 175142		
Senior Scientist	Vacant	-
Scientist	Vacant	-
Shivalik Agricultural Research & Extension Centre, Kangra – 176001		
Principal Scientist cum SI	Dr Ashok Kumar	**ashokumar59@yahoo.com**
Rice & Wheat Research Station, Malan – 176047		
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Scientist	Vacant	-
Research Sub-Station, Salooni - 176320		
Scientist	Vacant	-
Research Sub-Station, Lari - 172113		
Scientist	Vacant	-
Directorate of Extension Education, Palampur - 176062		
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Krishi Vigyan Kendra, Dhaulakuan - 173031		
Principal Extension Specialist cum PC	Dr Akhilesh Singh	**asingh1962@rediffmail.com**
Krishi Vigyan Kendra, Bara - 177044		
Extension Specialist	Dr Pardeep Kumar	**drpardeep1968@gmail.com**
Krishi Vigyan Kendra, Kangra - 176001		
Extension Specialist	Dr Deepika Sood	**deepika_agri@rediffmail.com**

FINANCIAL OUTLAY AND STAFF POSITION IN DIFFERENT SCHEMES OF THE DEPARTMENT

Name of the Scheme	**Budget allocation (Lac Rs.)**	**Expenditure (Lac Rs.)**	**Staff**
APL-001-17 "Creation of facilities for Postgraduate Studies in the Department of Plant Pathology", CSK HPKV, Palampur		29.29	Dr. A.K. Basandrai (Dean, PGS) Sh. Harbans Lal, Senior Assistant (Biotechnology) Sh. Kehar Singh, Clerk Sh. Ravi Kumar, Senior Assistant Sh. Shakti Chand, Junior Technician (COBS)
APL-010-17 "Facilities for teaching in the College of Agriculture and creation of facilities for Postgraduate Studies" in the Plant Pathology, CSK HPKV, Palampur		90.27	Dr. S. Dhancholia, Professor Dr. S. K. Rana, Principal Scientist Dr. A. K. Sud, Principal Extension Specialist Sh. Partap Chand , Junior Technician Sh. Kishori Lal, Junior Technician Sh. Vijay Kumar, Chowkidar (Security Cell)
APL-21-17 "Strengthening of facilities for research of Plant Pathology" CSK HPKV, Palampur		32.15	Dr. Suman Kumar, Senior Scientist Sh. Ramesh Kumar, Beldar Sh. Dalip Kumar, Beldar Sh. Desh Raj, Beldar Sh. Rattan Chand, Beldar
APL-59-17 "Facilities for research in the department of Plant Pathology" CSK HPKV, Palampur		4.97	Sh. Subhash Chand, Beldar
ICAR-017-17 Pt.-II" All India Coordinated Research Project on Seed Technology Research" under NSP		50.17	Dr. P. N. Sharma, Professor &Head Sh. Jyoti Swaroop, Senior Technical Assistant G-I

FINANCIAL OUTLAY OF AD HOC PROJECTS FOR THE YEAR 2016-2017

Project No. & Funding Agency	**Name of the Scheme & Duration**	**Allocation Rs. Lakh**	**Expdt Rs. Lakh**	**Staff**
State Ad - hoc Misc 2169-17 (i) (RKVY – HP Govt)	Technological Interventions for Protected Cultivation of Vegetable Crops in Himachal Pradesh (Fungal Pathology) 2015-16 (Extended till 31.03.2017)	2.65	2.59337	Dr Amar Singh (PI) Dr D K Banyal (CoPI) Mr Munish Kumar (FA)
State Ad - hoc Misc 2169-17(ii) (RKVY – HP Govt)	Technological Interventions for Protected Cultivation of Vegetable Crops in Himachal Pradesh (Viral Pathology) 2015-16 (Extended till 31.03.2017)	4.28	4.02423	Dr P N Sharna (PI) Dr Suman Kumar (CoPI) Mr Anoop Kumar (FA) Ms Nisha Kumari (SPF)
State Ad - hoc Misc 2156-17 (HP Govt)	Eco-friendly Management of Sudden Wilt of Bottle Gourd 2015-17	4.00	1.98672 (3.99992)	Dr Suman Kumar (PI) Mr Sanjeet Kumar (PA)
State Ad - hoc Misc 2160-17 (RKVY – HP Govt)	Management strategies for Yellow Rust of wheat in Himachal Pradesh 2015-16 (Extended till 31.03.2017)	3.35168	3.20864	Dr S K Rana (PI) Ms Kavita Rana (SRF)
GOI Ad - hoc Misc 5016-17 (DST)	Deciphering Diversity at Loci for Diversification of Powdery Mildew Resistance in Pea 2014-17	31.69	8.73353 (17.74190)	Dr D K Banyal (PI) Ms Jaya Chaudhary (SRF) Mr Ranjeet Singh (FH)
GOI Ad - hoc Misc 5023-17 (UGC)	Molecular Characterization of *Pepper Mild Mottle Virus PMMoV*) and its Management through host Resistance 2016-19	13.85	4.85637	Dr P N Sharma (PI) Dr S K Sharma (CoPI) Ms Nidhi Kumari (PF)
GOI Ad - hoc Misc 5022-17 (DBT)	Fine mapping of *Co-Ind* gene in common bean land race KRC5 possessing resistance to different races of *Colletotrichum lindemuthianum* 2016-19	49.38	13.68783	Dr P N Sharma (PI) Dr Anju Pathania (CoPI) Dr R Rathore (Co PI) Dr S K Sharma (CoPI) Ms Prakriti Kashap (JRF)
Misc 626-17 Pesticide Companies	Fungicides testing – New molecules/ brands under testing (2001- Cont.)	30.00	7.79548	Dr D K Banyal (PI)

COURSES TAUGHT

FIRST SEMESTER			
Course No	**Course title**	**Cr Hr**	**Name of Instructor**
Pl Path 111 (O)	Plant Pathogens and Principles of Plant Pathology	3+1	Dr Amar Singh
Pl Path 233	Diseases of Field Crops and their Management	2+1	Dr Suman Kumar
Pl Path 364 (O)	Diseases of Horticultural Crops and their Management	2+1	Dr Amar Singh
Pl Path 475	IPM and IDM	2+2	Dr A K Sud
Pl Path 477	Bio-control Agents and Bio-pesticides	1+2	Dr A K Sud
Ent 477	Pesticides and Plant Protection Equipment	1+2	Dr A K Sud
VSF 474	Protected Cultivation of Horticultural Crops and Seed Production of Vegetables and Flowers	1+3	Dr Amar Singh
Pl Path 501	Mycology	2+1	Dr S Dhancholia
Pl Path 502	Plant Virology	2+1	Dr Anand Singh
Pl Path 504	Principles of Plant Pathology	3+0	Dr B R Thakur
Pl Path 505	Detection and Diagnosis of Plant Diseases	0+2	Dr S K Rana
Pl Path 507 (O)	Diseases of Field and Medicinal Crops	2+1	Dr Amar Singh
Pl Path 513 (O)	Disease Resistance in Plants	2+0	Dr S K Rana
Pl Path 518	Epidemiology and Forecasting of Plant Diseases	2+1	Dr D K Banyal
Pl Path 591	Master`s Seminar	1+0	Dr S K Rana
Pl Path 603	Advanced Bacteriology	2+1	Dr Suman Kumar
Pl Path 604	Molecular Basis of Host-Pathogen Interaction	2+1	Dr P N Sharma
Pl Path 605	Principles and Procedures of Certification	1+0	Dr D K Banyal
Pl Path 606	Plant Bio-Security and Bio-Safety	2+0	Dr B R Thakur
Pl Path 691/ 692	Doctoral Seminar I/ II	1+0	Dr S K Rana
SECOND SEMESTER			
Pl Path 121	Fundamentals of Plant Pathology	3+1	Dr Amar Singh
Pl Path 233 (O)	Diseases of Field Crops and their Management	2+1	Dr Suman Kumar
Pl Path 241	Crop Protection-I (Plant Pathology)	0+1	Dr A K Sud
Pl Path 364	Diseases of Horticulture Crops and their Management	2+1	Dr Amar Singh
RAWE Programme	Mushroom Plant Clinic	0+2 0+2	Dr S Dhancholia Dr A K Sud
Pl Path 503	Plant Bacteriology	2+1	Dr Suman Kumar
Pl Path 506	Principles of Plant Disease Management	2+1	Dr B R Thakur
Pl Path 509	Diseases of Vegetable and Spices Crops	2+1	Dr S K Rana
Pl Path 510/ SST 512	Seed Health Technology	2+1	Dr P N Sharma/ Dr Sachin Upmanyu
Pl Path 511	Chemicals in Plant Disease Management	2+1	Dr D K Banyal
Pl Path 513	Disease Resistance in Plants	2+0	Dr S K Rana
Pl Path 591	Master`s Seminar	1+0	Dr S K Rana
Pl Path 601	Advanced Mycology	2+1	Dr S Dhancholia/ Dr S K Rana
Pl Path 602	Advanced Virology	2+1	Dr P N Sharma
Pl Path 691/692	Doctoral Seminar I/ II	1+0	Dr S K Rana

STUDENTS ADMITTED DURING 2016-17

Name of the Student	Admission No.	Major Advisor
M Sc		
Mr Bikramjeet Singh	A-2016-30-060	Dr S Dhancholia
Ms Gurpreet Kaur	A-2016-30-061	Dr D K Banyal
Mr Rahul Pathania	A-2016-30-062	Dr B R Thakur
Ms Richa Bahman	A-2016-30-063	Dr A K Sud
Mr Siddesh SK	A-2016-30-064	Dr S K Rana
Ms Sonali Chauhan	A-2016-30-065	Dr P N Sharma
Mr Vishal Sharma	A-2016-30-066	Dr Suman Kumar
Ph D		
Mr Anudeep B Mallannavara	A-2016-40-017	Dr D K Banyal

STUDENTS COMPLETED M Sc / Ph D PROGRAMME DURING 2016-17

Name of the Student	Admission No.	Major Advisor
M Sc		
Mr Abhishek Negi	A-2014-30-052	Dr Amar Singh
Mr Anudeep B Malannavar	A-2014-30-054	Dr S Dhancholia
Ms Arushi	A-2014-30-055	Dr D K Banyal
Ms Nisha Kumari	A-2014-30-056	Dr B R Thakur
Ms Sneha Chaudhary	A-2014-30-057	Dr P N Sharma
Ph D		
Ms Jaya Chaudhary	A-2012-40-009	Dr D K Banyal

ABSTRACTS

M Sc

Name of the student: Abhishek Negi (A-2014-30-052)
Title of thesis: Biology and management of target spot of tomato caused by *Corynespora cassiicola* (Berk. & Curt.) Wei under protected cultivation
Major advisor: Dr Amar Singh
Abstract: The present investigation entitled "Biology and management of target spot of tomato caused by *Corynespora cassiicola* (Berk. & Curt.) Wei under protected cultivation" was undertaken to study the status of disease in Himachal Pradesh and its biology, factors affecting the disease development and components of IDM for disease management. Different polyhouses surveyed during 2014-15 in five districts of the state revealed that target spot of tomato caused by *C. cassiicola* has emerged one of the most important diseases under protected cultivation. The disease severity ranged between 10.5- 45.0 per cent, being maximum average disease severity in Kangra district (34.3%) followed by Mandi (30.2%), Hamirpur (15.8%), Kullu (12.8%) and Bilaspur (12.5%). On the basis of morphological characteristics of the pathogen and disease symptomatology, causal agent was identified as *C. cassiicola.* The identity of the pathogen was also confirmed through molecular characterization by analysing rDNA of ITS region using primer pair ITS-1 and ITS-4. The symptoms of target spot were thoroughly studied and on the basis of comparative account of symptoms produced by *C. cassiicola, Alternaria solani* and *Stemphylium lycopersici* were distinguished from each other to avoid confusion with early blight and gray leaf spot of tomato. Pathogen isolates; CC-01 (Tomato-I), CC-02 (Tomato-II), CC-06 (Capsicum) CC-07 (Pecanut) and CC-10 (Cucumber) of *C. cassiicola* cross infected brinjal, tomato, sesame, capsicum, cucumber, cowpea and pecanut. The isolate CC-01 was found most aggressive followed by CC-10, CC-02, CC-07 and CC-06 on the basis of incubation and latent period developed on different hosts. Maximum mycelial growth and sporulation of *C. cassiicola* was observed on PDA medium at 25±1°C temperature. Optimum pH for growth and sporulation of pathogen was found to be pH 7.0. Effect of different temperature on disease development revealed that symptoms were developed at 20-35°C temperature and sporulation was found at 20-30°C on detached leaves. Under polyhouse conditions, temperature range of 24-28^{0}C and high RH 82-92% favoured high disease severity (77.4%), AUDPC (322.23) and infection rate (0.49/week) in July planted crop and in comparison less disease severity (50.02%), AUDPC (211.12) and infection rate (0.37/week) was observed in September planted crop when temperature and RH remained 24-18^{0}C and 70-52%, respectively while no disease developed on March planted tomato. Target spot was observed at all stages of plant growth. Under *in vitro* testing of bioagents *Trichoderma viride* resulted in 85.2 per cent mycelial inhibition of pathogen and 70.5 per cent disease control under *in vivo* testing. Among 7 fungicides tested against the *C. cassiicola* under *in vitro,* tebuconazole and copper oxychloride gave 100 per cent inhibition of mycelial growth at 1500 and 2000 ppm followed by hexaconazole, carbendazim, difenoconazole, mancozeb and azoxystrobin. Under polyhouse conditions, three sprays of tebuconazole (0.05%), carbendazim (0.1%), hexaconazole (0.05%), difenoconazole (0.05%) at 15 days interval and four sprays of copper oxychloride (0.3%) at 10 days interval were found effective in providing 85.5 to 76.9 per cent disease control with 50.0 to 61.8 percent increase in fruit yield over check.

Name of the student: Anudeep B Malannavar (A-2014-30-054)
Title of thesis: Characterisation of *Colletotrichum* species and their pathogenic behaviour on different hosts

Major advisor: Dr S Dhancholia

Abstract: The present investigations on the characterization of *Colletotrichum* species were undertaken to establish the identity and prevalence of *Colletotrichum* species on different hosts in and around Palampur based on morpho-cultural, pathogenic behaviour and molecular characters. The difference in host range between the species and among the species was also studied. Occurrence of different species of *Colletotrichum viz., C. truncatum (*syn *C. capsici)* on soybean and chilli, *C. acutatum* on guava, *C. gloeosporioides* on chilli and Banana, *C. orbiculare (*syn *C. lagenarium)* on cucumber, *C. coccodes* on chilli and *C. lindemuthianum* on beans have been established. The identities of species associated with different hosts were established by combining morphological, cultural characteristics as well as molecular analysis. The molecular analysis helped in confirming the morphological identification up to species complex as well as species level. *C. acutatum* on Guava is recorded for the first time from Himachal Pradesh. The isolates of soybean showed wide variation in cultural characteristics as well as conidial-setal morphology and infection pattern leading to question the validation of using *C. capsici* as synonym of *C. truncatum.* Though both isolates were phylogenetically clustered under a single group, morphologically they were exhibiting completely different characters under *in vitro* conditions on potato dextrose agar medium. Hence, it is suggested that the use of *C. capsici* as synonym of *C. truncatum* should no longer exists and both the species may be treated independently to each other. The cross pathogenicity study on different economic hosts including weeds showed a wide variation of infection potential within and between the species. The isolates from soybean i.e. Cs-1 and Cs-2 showed difference in infecting ability. *C. acutatum* isolated from guava found to infect almost all the hosts which may pose a threat in future, it also affected ageratum, the problematic weed in the area and may be exploited can be used as potential mycoherbicide. *C. orbiculare (*syn *C. lagenarium)* and *C. lindemuthianum* showed high degree of specificity towards hosts.

Name of the student: Arushi (A-2014-30-055)

Title of thesis: Biology and management of powdery mildew of tomato under protected cultivation

Major advisor: Dr D K Banyal

Abstract: The present investigation entitled "Biology and management of powdery mildew of tomato under protected cultivation" was undertaken to identify the associated pathogen(s) & study their biology, factors affecting the disease development and management of disease. Powdery mildew caused by *Oidium neolycopersici* L. Kiss and *Leveillula taurica* (Lev.) G. Arnaud is one of the most important disease of tomato under polyhouse conditions. During 2014-15, polyhouses of Kangra district were surveyed and the disease severity was observed between 5.0 to 89.5 per cent in different polyhouses with overall average disease severity of 51.2 per cent. Maximum disease severity (89.5 per cent) was recorded in Kunsal whereas, minimum in Amtrar (5 per cent). On the basis of symptomatology and morphological characteristics, the test pathogens 'A' and 'B' were identified as *O. neolycopersici* and *L. taurica,* respectively. The identity of test pathogens were also confirmed through rDNA analysis by using *Erysiphe* specific primers EryF and EryR. Incubation period of 4 to 5 days and latent period of 5 days were observed *in vitro* and *in vivo* conditions. Disease severity was positively and negatively correlated with temperature and relative humidity, respectively in 30th March transplanted crop whereas, it was negatively and positively correlated with temperature and relative humidity, respectively in 30th August transplanted crop. Low temperature and high relative humidity were found most favourable environmental factors for disease development. Among 14 evaluated hybrids/cultivars of tomato, 11 were found

susceptible and 3 were found moderately susceptible. None of the evaluated tomato hybrid/cultivar was found resistant to powdery mildew under polyhouse conditions. In 30th March transplanted crop, disease severity was observed less as compared to 30th August transplanted crop. The disease severity was observed more in narrow spaced plants (45x30 cm) as compared to wider spaced plants (75x30 cm). The yields were also observed high in 30th March transplanted crop and wider spaced crop as compared to 30th August transplanted crop and narrow spaced crop. *In vivo* evaluation of bioagents *viz., Trichoderma harzianum*-1 (TH-1), *T. harzianum*-2 (TH-2), *T. viride*-1 (TV-1), *T. viride*-2 (TV-2) and *Pseudomonas fluorescence*-1 (PF-1) @ 10 g/l showed 63.9-75.41 per cent disease control. Among all tested bioagents, both strains of *T. harzianum* (TH-1 & TH-2) were found highly effective in controlling tomato powdery mildew disease. *In vivo* evaluation of 3 botanicals *viz., Eupatorium adenophorum*, *Melia azedarach* and *Azadirachta indica* showed that aqueous extract of all the tested botanicals at 100 per cent concentration provided more than 50 per cent disease control being maximum *i.e.* 65.1 per cent was provided by *E. adenophorum*. Three sprays of eight fungicides at 10 days interval were evaluated for the management of disease under protected cultivation. Hexaconazole 5EC @ 1 ml/l and difenoconazole 23EC @ 0.5 ml/l were found highly effective with 91.0 & 89.2 per cent disease control and 42.0 & 39.0 per cent increase in yield as compared to check, respectively. Triadimefon 25WP and dinocap 48EC with 86.0 & 85.7 per cent disease control and 34.0 & 32.1 per cent increase in yield, respectively were also found effective. Azoxystrobin 23EC, mancozeb 75WP and propineb 70WP were found less effective whereas, captan 50WP was found least effective with 19.5 per cent disease control as compared to check.

Name of the student: Nisha Kumari (A-2014-30-056)
Title of thesis: Studies on pea root rot/wilt complex disease
Major advisor: Dr B R Thakur
Abstract: The present investigations entitled “Studies on pea root rot/wilt complex disease” had been undertaken in the Department of Plant Pathology, College of Agriculture, CSK HPKV, Palampur during 2014-2016. Pea root rot /wilt complex had been noticed as an emerging problem in pea growing regions of Himachal Pradesh. The disease has been observed at different intensity levels in different pea growing areas of the state. In Zone IV, the highest disease incidence of 54.7 % was recorded at HAREC, Kukumseri whereas, in Zone III, the disease incidence remained in moderate form ie. 19.7%. However, in Zone II, highest disease incidence of 35.3% was recorded at Palampur. The two species of *Fusarium viz., F. solani* f.sp. *pisi* and *F. oxysporum* f.sp. *pisi* were found associated with pea root rot/wilt complex in the state. Both species produced distinct symptoms when inoculated on pea seedlings in test tubes containing Hoagland's solution. *F. solani* f.sp. *pisi* was solely responsible to cause root rots of pea resulting in yellowing of leaves from basal leaf to upward whereas, *F. oxysporum* f.sp. *pisi* was responsible to cause wilting without root rots by clogging of xylem vessels. For disease management different components *viz.,* composts, bioagents, botanicals, chemicals and germplasm were evaluated *in vitro* to frame the management strategies. Vermicompost showed the maximum mycelial inhibition of 39.7% against *F. oxysporum* f. sp. *pisi* and 36.3% against *F. solani* f. sp. *pisi* followed by Farm Yard Manure with 29.7 and 30.0%, respectively. SMA-5 strain of *Trichoderma harzianu*m showed the maximum mycelial inhibition of 77.4 and 75.9 % against *F. oxysporum* f. sp. *pisi* and *F. solani* f. sp. *pisi* respectively. The plant extracts of test botanicals proved to be effective against both the pathogens at 25% concentration resulting in >60% inhibition of mycelial growth. However, *Eupatorium adenophorum* showed maximum

inhibition of 83.8 % against *F. oxysporum* f. sp. *pisi* and 77.5% against *F. solani* f. sp. *pisi* followed by *Eucalyptus* sp. resulting 83.1 and 76.1% inhibition respectively. All the test fungicides were found effective even at 50 ppm with >70 % inhibition of mycelial growth against *Fusarium oxysporum* f. sp. *pisi* except Vitavax (carboxin 75 WP). Vitavax power and Bavistin (carbendazim 50 WP) gave cent per cent mycelial inhibition even at 500 ppm followed by Tilt (propiconazole 25 EC) and Raxil (tebuconazole 2 DS) with 93.3 and 90.4 % respectively. In case of *F. solani* f. sp. *pisi*, Bavistin (carbendazim 50 WP), Raxil (tebuconazole 2 DS) and Vitavax power (carboxin 37.5%+ thiram 37.5%) yielded cent per cent mycelial inhibition at 1000 ppm. Out of one hundred thirteen elite pea lines, five pea genotypes *viz.*, EC-329570, EC-329573, DPP-127-R, DPP-100, KS-268 were remained resistant against pea root rot complex.
Management module comprised of soil amendment with vermicompost carrying *Trichoderma* @ 5kg/q and seed treatment with *E. adenophorum* @ 5.0 ml/kg seed was found most effective in the management of pea root rot /wilt complex pathogens giving maximum increase in yield i.e. 80.7 % as compare to control.

Name of the student: Sneha Chaudhary (A-2013-30-057)
Title of thesis: Molecular characterization of BCMV NL-7n strain and yield loss assessment in common bean.
Major advisor: Dr P N Sharma
Abstact: Common bean, a widely grown legume crop that belongs to the genus *Phaseolus* species *vulgaris*is vulnerable to the attack of diseases like anthracnose, wilt, white rot, bacterial bligts and leaf spots. Along with these, viral diseases also account for considerable yield losses. *Bean common mosaic virus* (BCMV), a member of family *Potyviridae* is economically most important due to its regular occurrence and ubiquitous seed borne nature. In India, five strains of BCMV *viz.*, NL-1, NL-1n, NL-4, NL-7 and NL-7n have been reported from north-western Himalayas, of which NL-7n is of wide prevalence along with NL-1n. The present study on BCMV NL-7n strain was undertaken with the view to obtain complete genome sequence, identify the resistant sources and assessment of yield losses. Characteristic symptoms in plant raised from infected seeds and artificial inoculated plants consisted of mosaic, downward leaf rolling, blistering, green vein banding, leaf deformation and stunting, however, they were more severe in former than latter. The identity of virus as BCMV was confirmed through DAS-ELISA and RT-PCR amplification. Whereas the reaction pattern on International differential set of bean varieties established its strain identity as NL-7n. This strain NL-7n differed from the NL-7 strain due its necrotic reaction on differential bean cv. Jubila (*I, bc-1* gene). The genome of the test strain comprises single ORF of 10.045 kb and encodes a single polypeptide of 3222 amino acids whichis self- cleaved into ten proteins typical of *Potyvirus*.Phylogenetic analysis, per cent similarity indices and multiple alignment based on nucleotide and amino acid sequences clustered NL-7n strain along with BCMV NL-1 and BCMV NL-1n. However, the restriction pattern differentiated it from the two. The recombination analysis revealed BCMV-Az and BCMV-NY15p as major and minor parents of NL-7n. Out of 209 common bean accessions, forty-nine were found resistant to strain BCMVNL-7n. Using tightly linked SCAR markers the presence of three resistance genes *viz., I, bc-1*^{2} and *bc-3* were present in 40, 16 and 08 common bean accessions, respectively. The yield loss assessed both under field and protected conditions revealed positive correlation of plant growth parameters with the seed yield and it was observed that the effects of virus infection decreased with the delay in inoculations. The virus affects the yield most when, plants were inoculated at primary leaf stage or originated from infected seeds. Yield reduction of 44.71 per cent and 47.13 per cent was observed in 2015 and 2016, respectively, under protected conditions whereas the average losses in field conditions were upto 37.14 per cent.

Ph D

Name of student: Jaya Chaudhary (A-2012-40-009)
Title of thesis: Genetics of resistance and virulence analysis in *Erysiphe pisi* - pea pathosytem.
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Abstact: The investigation entitled "Genetics of resistance and virulence analysis in *Erysiphe pisi* - pea pathosytem" was conducted at Department of Plant Pathology, CSKHPKV Palampur during 2013-2016. Powdery mildew of pea caused by *Erysiphe pisi* DC ex. Saint-Amans is one of the most destructive diseases occurring widely in different parts of the world. Twenty-four isolates of *E. pisi* were collected from 7 districts of Himachal Pradesh *i.e.* one isolate each from district Hamirpur, Bilaspur, Una, Kinnaur, 2 from Kangra, 3 from Mandi and 15 isolates from Lahaul & Spiti. On the basis of morphological and molecular identification it was established that *E. pisi* is the only cause of pea powdery mildew. It was also established that *E. trifolii* is not the cause of pea powdery mildew in North west Himalayas. To identify the resistant sources 310 pea germplasm lines were evaluated under net house and *in vitro* conditions and 31 lines *viz.*, HFPU, P-1797, P-1783, P-1052, HFP-7, HFP-8, P-1808, P-1820, P-1813, P-1377, P-1422-1, P-1811, IPF-99-25, KMNR-400, LFP-566, LFP-569, LFP-552, LFP-573, JP-501-A/2, PMR-21, KMNR-894, P-1280-4, P-1436-9, P-200-11, IPFD-99-13, HVDP-15, DPP-43-2, LFP-517, LFP-570, JP Ajjila and JP-15 were found to be highly resistant. AUDPC was also observed as important component to evaluate the resistance in addition to disease severity. Differential set was refined and final set of 11 lines *i.e.* JI-2302, EC- 329561, NIC-11181, EC-292164, PB-29B, JI-2480, EC-334160, Palam Priya, PMR-10, VN-53 and EC-381866 with Lincoln as check was developed to study the pathogenic variability of pea powdery mildew. Pathogenic variability among 24 isolates was determined on differential set and 17 pathotypes were observed and designated as PMP-1 to PMP-17. On the basis of study of slow mildewing components *viz.*, incubation period/latent period, size of colonies, sporulation as represented by numbers of 'conidiophores bearing conidia' per colony, AUDPC and infection rate pea lines *viz.*, IC-219028 (A), DPP-54, EC-292166 and VRP-12 were categorized slow mildewers as compared to Lincoln. Pattern of inheritance of resistance was studied in eleven test crosses (resistant x susceptible) with four pathotypes of powdery mildew. F_2 population of each cross exhibited a segregation ratio of 1 resistant to 3 susceptible (1:3) which confirmed the monogenic recessive nature of resistance in pea powdery mildew. To carry out the allelic relationship studies, three resistant lines were crossed with known *er* gene lines and it was found that resistance in line Acacia is conferred by *er2* while in PMR-10 and EC-381866-1 is conferred by *er1*.

RESEARCH

A. Survey and Surveillance of diseases

Cereals

Rice: An overall low disease severity (< 3 on 0-9 scale) of blast was recorded in majority of areas in districts Kangra and Mandi except few locations where it was moderate to high (>3) on local and old varieties. Sheath blight was also recorded at many locations and its incidence varied from 5-70% and severity ranged from 10-60%. The incidence of false smut varied from 1-7%. Survey of major rice growing districts of Himachal Pradesh namely, Kangra, Solan and Sirmour was also conducted under Production Oriented Survey (POS) programme of AICRIP during *kharif* 2016 and intensity of rice diseases is recorded in Table 1.

Table 1. Prevalence of diseases of rice in Himachal Pradesh during *kharif* 2016

District	Diseases									
	LBL	**NBL**	**BS**	**GD**	**FS**	**LS**	**NBLS**	**SHBL**	**SHR**	**BLB**
Kangra	L-M	L-M	L-M	L-M	L-M	L	L	L	L	-
Sirmour	L-M	L-M	L-M	L	L-M	L-M	L	L-M	T	-
Solan	L	L	L-M	L	L-M	L	L	L	L	-

LBL: Leaf blast, NBL: Neck blast, BS: Brown spot, GD: Grain discolouration, FS: False smut, LS: Leaf scald, NBLS: Narrow brown leaf spot, SHBL: Sheath blight, SHR: Sheath rot, BLB: Bacterial leaf blight, L: Low, M: Moderate, S: Severe, T: Traces

Disease Intensity: L = 2-5%; L-M = 6-15%; M = 16-25%; M-S = 26-50%; S = 51-100%.

Maize: Maize crop was monitored for the prevalence of different diseases in parts of districts Kangra and Mandi during *kharif* 2016 and the severity of Maydis Leaf Blight (MLB), Brown Spot and Banded Leaf and Sheath Blight (BLSB) varied from 10-70%, 30-90% and 10-50% respectively. However, moderate severity of Turcicum Leaf Blight, MLB and BLSB was recorded at different parts of Kullu district.

Wheat: High disease severity (> 40S) of yellow rust was recorded on susceptible wheat varieties like VL 829, HS 240, HD 2967, PBW 621, Sonalika etc. whereas, low to moderate severity (< 40S) was recorded on resistant varieties like HPW 349, HS 507, HPW 360, HPW 368 etc., during the surveys of districts Kangra and Mandi in *rabi* 2016-17. An overall low to moderate powdery mildew severity (< 5 on 0-9 scale) was recorded on majority of cultivated varieties in different areas. Loose smut incidence varying from 0.1 to 5.0 % was also recorded at few locations. Low to moderate intensity (<5 on 0-9 scale) of Septoria blotch was recorded on cultivated wheat varieties at majority of locations except few locations where high disease intensity (>5) was observed. However, moderate severity of yellow rust and low incidence of loose smut and hill bunt were recorded in different parts of district Kullu.

Barley: A moderate severity of yellow rust and low incidence of covered smut was recorded in different areas of Kullu district.

Pulses

Rajmash: The incidence of root rot was less during 2016-17 in district Kinnaur as compared to the previous year. The incidence of bean common mosaic in two promising lines, SR5-3 and SR6-9 ranged from 15-20 %. The overall incidence of BCMV in Baspa varied from 30-40 % at

Sangla, 20-30 % in Jawala at Leo including Pooh valley and 10-15 % at Lari in Spiti. The severity/ intensity of angular leaf spot in Baspa, was 3 in 0-9 scale at Sangla.

Urd Bean: Low to moderate severity of cercospora leaf spot and low severity of leaf crinkle virus were recorded on urd bean at Bajaura.

Pea: The severity of powdery mildew was moderate (3-5 on 0-9 scale) at Sangla and Chitkul whereas, the incidence of root rot complex ranged between 20-30 % at Sangla & Pooh valley and 40-50 % at Nako and Chango. In Hangrang valley (Hango & Chulling) the severity of powdery mildew was found > 5 in 0-9 scale.

Oilseeds

Soybean: Mainly four diseases *viz*., frog eye leaf spot (*Cercospora sojina*), pod blight (*Colletotrichum truncatum*), bacterial pustule (*Xanthomonas campestris* pv. *Glycines*) and yellow mosaic virus (YMV) were found to occur in soybean growing areas of districts Kangra and Mandi, surveyed during mid September. Diseases were scored on 0-9 scale and location wise per cent disease index (PDI) is presented in Table 2.

Table 2. Location wise per cent disease index (PDI) of important soybean diseases

District/ village	Variety grown	Per cent disease index			
		Frogeye leaf spot	Pod blight	YMV	Bacterial pustule
Kangra district					
Pantehar	Hara soya	55.55	11.11	0.0	0.0
	Him Soya	55.5	11.11	0.0	0.0
Kangra	Hara soya	33.33	11.11	33.3	11.11
	Shivalik	77.77	33.33	00	0.0
Nagri	Hara soya	55.55	33.33	0.0	0.0
Baijnath	Hara soya	55.55	11.11	0.0	0.0
Bir	Hara soya	55.55	11.11	0.0	0.0
Palampur	Hara soya	55.55	33.33	0.0	0.0
	Bragg	33.33	55.55	0.0	0.0
	Shivalik	77.77	33.33	0.0	0.0
Mandi district					
Chauntra	Hara soya	77.77	11.1	0.0	0.0
	Palam soya	11.11	33.3	0.0	0.0
Dohag	Hara soya	55.55	11.11	0.0	0.0
	Him soya	33.33	11.11	0.0	0.0
Jogindernagar	Hara soya	33.3	11.11	0.0	0.0

Frog eye leaf spot (*Cercospora sojina*), pod blight (*Colletotrichum truncatum*) and bacterial pustule (*Xanthomonas campestris* pv. *glycines*) were mainly observed on Hara Soya, Palam Soya and Bragg varieties of soybean in Himachal Pradesh. Brown spot (*Septoria glycines*) and Powdery mildew (*Microsphaera diffusa*) diseases were observed in moderate intensity while collor rot (*Sclerotium rolfsii*) in low intensity only at Palampur, from experimental farm. Incidence of soybean mosaic virus (SMV) was also noticed at low intensity at Palampur and YMV was prevalent in Kangra area.

Sesame: *Phytophthora* blight, *Cercospora* blight and phyllody were the major disease problems in sesame at the farmer's fields (Table 3).

Table 3. Occurrence of diseases in Sesame during *Kharif* 2016

Locations	Variety	Disease severity (%)		
		***Cercospora* blight**	***Phytophthora* blight**	**Phyllody**
District Kangra				
Kangra	Brajeshwari	60	25	25
Dehrian	Local	50	10	5
Bharoli	Local	50	10	5
Gahlian	Local	60	10	2
Lanj	Local	50	5	2
District Hamirpur				
Nadoun	Local	50	10	2
Galore	Local	30	10	5

Rapeseed-Mustard: *Alternaria* blight and white rust remained the serious diseases of rapeseed-mustard crops in different regions of Himachal Pradesh and their severity ranged from 10-60% and 5-30% respectively (Table 4) during the crop season 2016-17.

Table 4. Occurrence of diseases in rapeseed-mustard during 2016-17

Locations	Crop/Variety	Disease severity (%)	
		***Alternaria* blight**	**White rust**
District Kangra			
Kangra	Mustard	60	30
Patta Jattiyan	Gobhi sarson	10	0
Bagga	Brown sarson	25	5
Kuthera	Gobhi sarson	20	0
Amblela	Gobhi sarson	10	0
Dehrian	Gobhi sarson	20	0
District Chamba			
Malara	Brown sarson	20	0
Bassa	Brown sarson	20	0
District Hamirpur			
Bela	Gobhi sarson	30	0
Kangoo	Mustard	30	20
Badaran	Brown sarson	20	10
District Una			
Nandpur	Mustard	40	30
Basol	Mustard	20	20

Linseed: Rust, wilt and powdery mildew were observed to affect the crop in major linseed growing areas of districts Kangra and Mandi (Table 5) during the crop season 2016-17.

Table 5. Occurrence of diseases in linseed during 2016-17

Locations	Variety	Disease severity (%)		
		Rust	**Wilt**	**Powdery mildew**
District Kangra				
Kangra	Local	70	50	0
Rajiana	Local	25	10	25
Palampur	Local	10	10	75
Yol	Local	10	5	10
Rait	Local	20	5	0
District Mandi				

Ahju	Local	10	10	20
Harabag	Local	10	5	30

Vegetable crops

Bottle gourd: Sudden wilt with average incidence of 45-90% was recorded at different locations of districts Kangra, Una, Hamirpur and Bilaspur during 2016-17.

The intensity of diseases recorded on different vegetable crops in the command area of HAREC, Bajaura is given in the Table 6.

Table 6: Intensity of diseases on different vegetable crops

Crop	Disease	Disease Intensity	Area Surveyed
Tomato	Early Blight and Alternaria fruit Rot	Moderate	Kelhali, Garsa, Jia, Ruaru, Bhuntar, Nagwain, Panarsa, Aut, Haat, Jhiri, Jwalapur, Manikaran, Katrain, Seobagh
	Late Blight and fruit Rot, Buck Eye Rot	Moderate - High	
	Septoria Blight, Bacterial Spots, Bacterial wilt,	Low - Moderate	
	Virus diseases and Disorders.		
Capsicum	Blight and Fruit Rot, Anthracnose	Moderate	Kelhali, Garsa, Jia, Ruaru, Bhuntar, Nagwain, Panarsa, Aut, Haat, Jhiri, Jwalapur, Manikaran, Katrain, Seobagh
	bacterial wilt and virus diseases	Low	
Cabbage and Cauliflower	Black rot	High	Kelhali, Garsa, Jia, Ruaru, Bhuntar, Nagwain, Panarsa, Aut, Haat, Jhiri, Jwalapur, Manikaran, Katrain, Seobagh
	Alternaria leaf spot	Low - Moderate	
French Bean	Angular leaf spot	Low - Moderate	Kelhali, Garsa, Jia, Ruaru, Bhuntar, Nagwain, Panarsa, Aut, Haat, Jhiri, Jwalapur, Manikaran, Katrain, Seobagh
Peas	Wilt & root rot, Powdery Mildew,	Low-Moderate	Kelhali, Garsa, Jia, Ruaru, Bhuntar, Nagwain, Panarsa, Aut, Haat, Jhiri, Jwalapur, Manikaran, Katrain, Seobagh
	Bacterial blight	Moderate	
Cucumber	Powdery mildew, Downey mildew.	Moderate- High	Kelhali, Garsa, Jia,Ruaru, Nagwain, Panarsa, Aut, Haat, Piridi, Mohal, Khokhan
Garlic	Stemphylium blight & purple blotch in garlic.	Moderate	Nahalach, Pirdi, Khokhan, Chheol, Garsa, Mohan, Dhaman, Shalouri, Ratwa, Targali, Sai Ropa, Banjar
	Rust	Low	
Onion	Purple blotch, downy Mildew.	Moderate	HAREC, Bajaura
	Bulb rot	Low	

Protected cultivation

The prevalence of different diseases along with their incidence/ severity on capsicum, tomato and cucumber under protected condition in Kangra, Hamirpur, Bilaspur and Kullu districts of Himachal Pradesh is given in Tables 7 and 8.

Table7. Prevalence of diseases in capsicum under protected cultivation in different districts

District	Diseases	No of polyhouses surveyed	Incidence (%)	Severity (%)
Kangra		4		

	Powdery mildew		5-100	10-75 (25.0)
	Root rot		5-50	5-50 (22.2)
	Cercospora leaf spot		5-100	5-25 (11.0)
	Gray mould		0-25	5-25(8.0)
Hamirpur		3		
	Powdery mildew		25-100	5-75(38.6)
	Root rot		1-25	1-25 (15.2)
	Cercospora leaf spot		5-100	5-50 (16.2)
Bilaspur		2		
	Powdery mildew		50-100	1-75(19.2)
	Root rot		1-10	1-10(4.2)
	Cercospora leaf spot		10-50	1-20(6.2)
Kullu		3		
	Powdery mildew		5-75	10-50(35.0)
	Root rot		5-50	5-50 (25.0)
	Cercospora leaf spot		25-100	5-25(13.3)

Table 8. Prevalence of diseases in different vegetables under protected cultivation

Crop	Disease(s)	Poly-houses infested (%)	Disease Severity (%)
Tomato	Blights (Early, gray and target spots)	20	10-25 (20)
	Fruit rots (target, gray mould and sunscald)	24	5-20 (15)
	Powdery mildew	20	20-30 (25)
	Fusarium wilt	7.5	5-10 (7.5)
	Bacterial wilt	5	5-20 (7.5)
Capsicum	Root/collar rot	15	5-25 (15)
	Bacterial wilt	6	5-15 (7.5)
	Blights (Cercospora leaf spot)	20	10-25 (15)
	Viruses	25	5-25 (10)
	Powdery mildew	35	10-50 (20)
Cucumber	Powdery mildew	15	20-30 (25)
	Downy mildew (summer)	5	5-10 (7.5)
	Downy mildew (August-November)	50	10-50 (25)

Pepper mild mottle: The polyhouse grown capsicum crop was monitored to assess the prevalence and the isolates of *Pepper mild mottle virus* were collected from different districts of Himachal Pradesh. The surveys showed the presence of virus like infections in almost all the districts on capsicum. The diseased plants showed symptoms like mosaic, mottling, puckering and deformation of the leaves along with stunting of the plants.

In Kangra district the viral incidence ranged from 5- 60%. In Bilaspur district upto 90% virus incidence was observed in Capsicum crop. The range of incidence was 5-50 % in Mandi district. While the virus incidence was highest in Kullu district where 90-100 % incidence was observed. Average incidence of viral like symptoms of different locations surveyed within the districts is given in Fig 1.

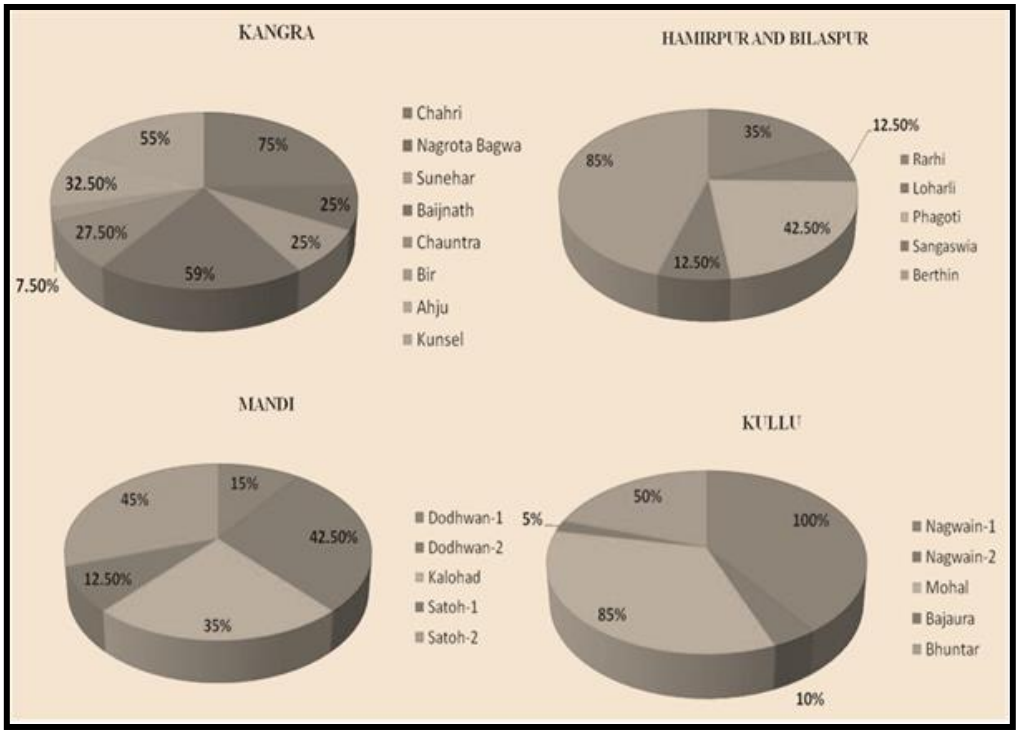

Fig. 1: Average Incidence of viral like symptoms in different districts

Organic farming

Disease incidence/ severity of diseases recorded on different crops/ vegetables under organic farming are given in Table 9.

Table 9: Disease scenario in different crops under organic farming

Crops	Disease	Incidence
Tomato	Buck Eye rot and other fruit rot diseases	Moderate
	Alternaria Blight	Moderate
	Late Blight	Moderate
	Septoria Leaf spot	Low
	Bacterial spot/ canker	Low- Moderate
Peas	Rot rot	Low
French Bean	Angular leaf spots	Moderate
Cauliflower	Curd Rot	Low
	Black Rot	Moderate
Black Gram	Cercospora leaf spot	Moderate
	Leaf crincle	Low
Okra	Powdery mildew	Moderate

Fodder crops

Status of diseases of fodder crops like cowpea, maize, sorghum and bajra during 2016-17 is given in Table 10.

Table 10. Diseases of different *Kharif* & *Rabi* fodder crops

Crop	Diseases and insect pest	Incidence/ Severity (%)
***Kharif* 2016**		

Cowpea	Wilt/root rot (*Fusarium, Rhizoctonia*)	72
	Leaf spot and blight (*Ascochyta, Phyllostricta*)	30
	Phytophthora Blight	20
	Anthracnose	5
	CMV	7
	Aphids	5
Maize	Blight (*Helminthosprium maydis* and *H. Tercecium*)	7
	Banded leaf & sheath blight (*Rhizoctonia*)	15
	Maize stem borer	6
Sorghum	leaf blight (*Helminthosporium*)	14
	Zonate leaf spot (*Gloeocercospora sorghi*)	20
Bajra	leaf blight (*Helminthosporium*)	15
***Rabi* 2016-17**		
Oats	Powdery mildew	95
	Leaf blights	15
	Loose smut	3
	Aphids & Thrips	16
Berseem	Root rot	5
	Leaf spot	12
	Defoliating beetles	20
Lucerne	Leaf spot	18
	Defoliating beetles	20

B. Cereals

Rice

Identification of resistance sources:

Blast: Rice germplasm consisting of 1376 entries from various screening nurseries viz. National Screening Nursery 1 (NSN1=373), National Screening Nursery 2 (NSN2=663), National Screening Nursery-Hills (NSN-H=86), National Hybrid Screening Nursery (NHSN=145) and Donor Screening Nursery (DSN=109) were screened under natural epiphytotic conditions at RWRC, Malan. Two sets of all the 1376 entries were prepared of which one set was sown for leaf blast screening under Uniform Blast Nursery (UBN) Pattern and the other was transplanted for neck blast screening. The test entries were scored based on leaf blast severity following Standard Evaluation System for Rice (SES) scale as per the technical programme of All India Coordinated Plant Pathology Trials (2016-17). Of these, 73 entries from NSN-1, 120 from NSN-2, 29 from NSN-H, 36 from NHSN and 37 entries from DSN were found promising against leaf blast. Whereas, 37 entries from NSN1, 2 from NSN-2, 28 from NSN-H, 21 from NHSN and 12 from DSN were found promising against neck blast.

Monitoring of virulences in *Pyricularia oryzae*:

Virulence spectrum in the population of *Pyricularia oryzae* in different rice ecosystems was characterized by planting a set of 25 differentials comprising of international differentials, donors and commercial cultivars across 23 centres adopting UBN pattern. Differentials viz., C101 LAC, BL-122, C101 PKT, Raminad str-3, NP 125, Tetep, Tadukan and IR 64 showed resistant reaction while rest of the differentials were found susceptible to leaf blast. The difference in disease reaction score of susceptible and resistant checks revealed a shift in the pathogen population. The reaction pattern of genotypes at all test locations was grouped into six distinct groups wherein reaction pattern of Malan was included in group two.

Disease Observation Nursery:

To observe the time of occurrence and intensity of leaf blast, a trial was conducted during *kharif* 2016 at RWRC, Malan by sowing a blast susceptible variety namely, 'HPU 2216' on three dates i.e. early (21.05.2016), normal (05.06.2016) and late (20.06.2016). Similarly, transplanting was done when seedlings were 25 days old on 15.06.2016, 30.06.2016 and 15.07.2016, respectively at 20 x 10 cm spacing in 14 m^2 plot. Application of fertilizers was done as per the technical programme of All India Coordinated Rice Pathology Trials. Observations on leaf blast severity were recorded at 7 days interval starting from July 30, 2016 till flowering stage (27.08.2016) beyond which leaf blast ceased to progress. The perusal of data (Table 11) showed that leaf blast severity was very high both in the normal (58.0 %) and the late (>95 %) sown/ planted crop while the early crop escaped leaf blast with very low disease intensity (14% at flowering) which shows that delayed planting favours the disease development under prevailing environmental conditions at Malan and disease escapes in early planted susceptible variety.

Table 11. Effect of dates of sowing on leaf blast severity

Sowing/ planting time	Leaf Blast Severity (%) on different dates				
	30.07.2016	06.08.2016	13.08.2016	20.08.2016	27.08.2016
Early	0	0	5.9	14.3	-
Normal	4.7	13.7	21.8	40.1	58.0
Late	12.3	26.0	52.6	77.1	95.2

Management of diseases

Blast: A replicated field trial was conducted during *kharif* 2016 in randomized block design to evaluate the efficacy of some new fungicide formulations against blast using a susceptible variety 'HPU 2216'. Fungicides namely, tricyclazole 20% + tebuconazole 16% SC, tricyclazole 75 WP, tebuconazole 25%, hexaconazole 5% EC and carbendazim 50 WP were evaluated for their efficacy against leaf and neck blast. The new fungicide molecule namely tricyclazole 20% + tebuconazole 16% SC was evaluated at two doses viz., 2.0 ml and 2.25 ml/ litre of water. In all, two sprays were applied first on August 19, 2016 and second on September 03, 2016 at the time of panicle emergence. Observations on leaf blast severity were recorded till flowering and that on neck blast incidence were recorded a week before harvest by counting the infected over total panicles from 3 sampling units of 1 x 1 m area in each plot in case of neck blast. However, severity was calculated from 10 hills/ plot following 0-9 scale of Standard Evaluation System for Rice, Philippines (2013). The grain yield was recorded on plot basis and was converted to q/ha.

A perusal of the data (Table 12) revealed that all the fungicides significantly reduced the disease as compared to control during *kharif* 2016. Of these, tricyclazole 20% + tebuconazole 16% SC proved to be the most effective and reduced leaf blast severity to 24.1 and 25.7 per cent when applied at the dose of 2.25 ml and 2.0 ml/ l resulting in 62.6 and 60.2 per cent reduction over control, respectively. Tricyclazole 75 WP was at par with the new molecule restricting leaf blast severity to 25.2 per cent followed by carbendazim 50 WP while hexaconazole was the least effective against leaf blast. Similarly, combination of tricyclazole 20% + tebuconazole 16% SC also proved quite effective in minimizing the neck blast incidence. The new molecule reduced neck blast incidence to 10.9 per cent at higher dose (2.25 ml/ l) and 12.6 per cent at lower dose (2.0 ml/ l) with 85.4 and 83.2 per cent reduction over control. However, it was statistically at par with tricyclazole 75 WP which was the most effective with 86.2 per cent reduction in neck blast incidence. All the fungicides except hexaconazole 5% EC significantly enhanced the grain yield over control but tricyclazole 20% + tebuconazole 16% SC at both the doses resulted in maximum (4.1 and 4.2 q/ ha, respectively) grain yield being statistically at par with tricyclazole 75 WP.

Table 12. Evaluation of new fungicides for the management of rice blast

Fungicide	Dose / L	Leaf blast severity (%)	Reduction in LB (%)	Neck blast incidence (%)	Reduction in NB (%)	Grain yield (q/ha)
Tricyclazole 20% + tebuconazole 16% SC	2.0 ml	25.7 (30.5)	60.2	12.6 (20.7)	83.2	40.7
Tricyclazole 20% + tebuconazole 16% SC	2.25 ml	24.1 (29.3)	62.6	10.9 (19.2)	85.4	42.0
Tricyclazole 75 % WP	0.6 g	25.2 (30.1)	60.9	10.3 (18.6)	86.2	40.7
Tebuconazole 25%	1.5 ml	42.4 (40.6)	34.3	46.3 (42.8)	38.1	34.6
Hexaconazole 5% EC	2.0 ml	48.3 (44.0)	25.1	53.2 (46.8)	28.9	27.8
Carbendazim 50% WP	1.0 g	33.3	48.4	35.4	52.7	35.8

		(35.2)		(36.5)		
Control	-	64.5 (53.4)	-	74.8 (59.8)	-	24.1
CD (*P = 0.05*)		2.2		3.2		4.18

Figures in parentheses are arcsine transformed values

Integrated disease management: The efficacy of best disease management practices was tested against blast on high yielding commercial susceptible/ resistant varieties, by conducting a trial in split plot design with three replications during *kharif* 2016. The treatments comprised of cultivation of a highly susceptible variety, HPU 2216, a moderately resistant variety, HPR 2612 and a locally released hybrid, Arize 6129 with two levels of management, DM where management practices were followed as recommended in the technical programme and NDM where no management or farmers practice (FP) was followed. Seedlings (25 days old) of all the varieties were transplanted and the application of fertilizer was done as per the requirement of treatments. Spray application of tricyclazole @ 0.06 % was done on 26th August and 12th September, 2016 at maximum tillering and panicle emergence stage, respectively after the first appearance of disease symptoms. In the other management level, NDM which was represented by farmers' practice no fungicide spray was done. Observations on leaf blast severity were recorded from 10 hills/ plot following 0-9 scale of Standard Evaluation System for Rice, Philippines (2013) at flowering and that on neck blast incidence were recorded a week before harvest by counting the infected over total panicles from 3 sampling units of 1 x 1 m area in each plot. The grain yield was recorded on plot basis and was converted to q/ha.

Table 13. Integrated management of leaf and neck blast of rice

Main plot	**Leaf blast severity (%)**			**Neck blast incidence (%)**			**Grain yield (q/ ha)**		
Variety	**DM**	**NDM**	**Mean**	**DM**	**NDM**	**Mean**	**DM**	**NDM**	**Mean**
Himalaya 2216	29.0 (32.5)	63.3 (54.5)	46.2 (43.5)	8.6 (17.0)	64.2 (53.3)	36.4 (35.1)	37.8	29.1	33.4
HPR 2612	0 (0)	2.3 (8.6)	1.2 (4.3)	6.0 (14.1)	26.4 (30.9)	16.2 (22.5)	43.8	41.7	42.8
Arize 6129	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	66.0	61.6	63.8
Mean	14.5 (10.8)	32.8 (21.1)		7.3 (10.3)	45.3 (28.1)		49.2	44.1	
CD (5%)	Management Level = 0.6 Varieties = 1.8 Interaction = 1.0			Management Level = 1.7 Varieties = 3.2 Interaction = 3.0			Management Level = 2.4 Varieties = 2.3 Interaction = NS		

Figures in parentheses are arcsine transformed values
DM = Disease management; NDM = No disease management

The perusal of data (Table 13) revealed that leaf blast severity was reduced to 29.0 per cent when susceptible variety, 'HPU 2216' was applied two sprays of tricyclazole as against 63.3 per cent in the plots where no disease management practices were followed resulting 54.2 per cent disease control over FP.

Maize

Identification of resistance sources

Turcicum leaf blight (TLB): A total of 778, maize and 68 specialty corn (QPM, Pop Corn, Sweet Corn and Baby Corn) genotypes in 9 different trials comprising of various maturity groups

were evaluated against TLB during *kharif*, 2016 at HAREC, Bajaura. Screening of these genotypes was carried out under artificial epiphytotic conditions. The resistant stocks under different nurseries are given in Table 14.

Table 14. Maize stocks resistant to Turcicum leaf blight

Name of trial	Total stocks (No.)	Resistant stocks (No.)	Some of the promising stocks
IVT late maturity	98	43	SYN616734, DKC 9178, HT 16607, OMH 14-55 , CCH 9241, HM16305, SYN617328, ADV 9233, BLH 114, IMHBG-2016-3, PM16102L, VaMH 13024, PM16101L, CMH11-586, GK3202,MM 2626, VNR 33051
IVT medium maturity	140	44	MM9222, VaMH 14020, IQ8319, GH-150114, IMHBG-2016-2, JKMH 4157, IQ8712, IIMRNH 2016-1, WH-1003, IQ8627, OMH 14-30, GOLD-1155, IMHBG-2016-4, FCH-11267, JKMH 1414, WH-2006
IVT early and extra early maturity	40	6	IH-0901, MH 21, FH 3763, DH-304 (early Maturity) and FH 3765, FH 3771 (Extra Early maturity).
AET (I & II) late maturity	24	9	DKC8161, PM15103L, PM15104L, DKC9163, CMH12-686, DAS-MH-111, CMH12-688 (AVT-I Late) and DKC9151, DMH192 (AVT-II Late)
AET (I & II) medium maturity	17	6	JH 13348, LMH 615, VaMH 12014 (AVT-I Medium) and JH 31605, C.P 201, JKMH 4848 (AVT-II Medium)
AET early and extra early maturity	8	3	FH 3754, AH-7006, DMRH 1305
Speciality corn (QPM, Pop Corn, Sweet Corn, Baby Corn)	27	17	QPM-MH-27, IIMRQPMH 1501, VEHQ-16-1, IMHQPM 1530, IIMRQPMH 1608, IIMRQPMH 1603, FQH 106, IIMRQPMH 1606
	14	7	DPCH-306, IMHP-1535, AP6005, IMHP 1540, IHPC-1203, SJPC1, DMRHP-1402
	13	8	FSCH 91, ASKH 4, VEHS-16-1, ASKH 6, FSCH 55*, FSCH 75, BSCH 6, MITHAS
	14	7	IMHB 1537, DMRHB 1305, AH-7043, IMHB 1538, IMHB 1529, IMHB 1531, IMHB 1532
Association panel	337	182	BML 7, DML-346, CML 29, CML 40BBB, CML 452, CM 108, CML 278, CML 549 W, HKI 1128, UMI 1210, HKI 193-2, HKI 1378, CML 175, HKI 4C4B, IML12-10, IML12-180, IML 15-65, IML16-6, UMI 1210
Inbred lines	114	36	BGS 4,21, 22, 27, 28, 30, 32, 35, 37, 38, 39, 41, 42, 47,58, 59, 68, 73, 76, 77, 78, 79, 80, 81, 86, 94, 95, 97, 100, 4840, CM117-3-4-1, CML420, JCY2-1-2-1, PAC745, PFSR9

Maydis and Turcicum leaf blights: Nineteen maize hybrids of public and private sectors were screened against MLB and TLB under artificial epiphytotic conditions at HAREC, Bajaura. All the maize hybrids were found resistant/ moderately resistant against both the diseases. Maize hybrids LG.34.05, Kanak-51, DEKALB 9179, SIRI 5455, P 3542, P 3436 and Star-9 were found better in yield (> 70 q/ha) and resistance to both diseases and can be suitable for commercial cultivation (Table 15).

Table 15. Evaluation of maize hybrids against Turcicum leaf blight and Maydis leaf blight

Hybrid	TLB		MLB		Yield (q/ha)
	Disease Score (1-9 scale)	Reaction Type	Disease Score (1-9 scale)	Reaction Type	
DEKALB 7173	2.5	R	2	R	73.47
Palam Sankar Makka 2	2	R	2	R	69.90

LG.34.05	2	R	2	R	93.73
Kanak-51	2	R	2	R	70.82
DEKALB 8164	2	R	2	R	66.61
DEKALB 9179	2.5	R	2	R	80.96
DEKALB 9164	2	R	2	R	61.28
SIRI 5455	2.5	R	2	R	76.84
P 3542	2.5	R	2.5	R	76.93
Kohinoor Deluxe	2	R	2	R	57.73
DEKALB 8174	2.5	R	2	R	58.39
VNR 4001	2	R	2	R	68.35
P 3436	2	R	3.5	MR	71.39
Star-40	2	R	3	R	62.79
Star-23	3.5	MR	2	R	67.16
Star-22	2.5	R	2	R	59.41
Star-35	2.5	R	2	R	51.34
Star-9	3	R	2	R	84.91
Kranthi	2.5	R	3.5	MR	45.57

Bacterial stalk rot (BSR) and banded leaf & sheath blight (BLSB): A total of 324 entries/ genotypes of maize hybrids and composites received from IIMR, Delhi were evaluated against bacterial stalk rot (BSR) and banded leaf and sheath blight (BLSB) under artificial epiphytotic conditions at HAREC, Dhaulakuan. None of the maize entries were found free from *Erwinia* stalk rot where as, 50 entries were resistant (disease incidence 11-25%) under artificial inoculated conditions (Table 16). However, 35 entries namely DH-291, LMH 616, IMH 1604, IMH 1605, EH-2906, DMRH 1410, BH 414351, HKH 353, LMH 1016, INDAM-1122, IMH 1527, CMH 08-292 (C), BIO 9544 (C), JH 31801, JH 31783, JH 31816, JH 31794, AH9002, WH-2096, JH 31780, AH-7154, FH 3768, IH-0702, AH-7007, HKH 352, DKC 7074 (C), DH-305, C.P 802, DKC9164 (IP9002, DKC9151(IN8902), JH 31785, DMRH 1305, Prakash (C), KDQH-51 and IIMRQPMH 1609 were resistant to both the BLSB and BSR.

Table 16: Maize genotypes free/ resistant to bacterial stalk rot (BSR)

Name of trial	Total entries (No.)	Entries free from BSR (No.)	Entries resistant (Incidence 11-25%) to BSR (No.)
NIVT (L-A Maturity)	50	0	0
NIVT (L-B Maturity)	50	0	0
NIVT (M-A Maturity)	39	0	DH-291, BLH 112, BLH 111 (3 Nos.)
NIVT (M-B Maturity)	40	0	LMH 616, IMH 1604, IMH 1605, EH-2906, DMRH 1410, BH 414351, HKH 353, LMH 1016, INDAM-1122, IMH 1527, CMH 08-292, BIO 9544 (12 Nos.)
NIVT- EARLY & E EARLY Maturity	40	0	LMH 616, IMH 1604, IMH 1605, JH 31784, JH 31801, JH 31783, JH 31816, JH 31794, AH9002, AH-7009R, WH-2096, KMH-14-50, JH 31780, AH-7154, FH 3768, IH-0702, AH-7007, HKH 352, PMH 5 (19 Nos.)
75 L Maturity (AVT-I-II)	24	0	DKC8161, CP 802, DKC9164, DKC9151 (4 Nos.)
76 M Maturity (AVT-I-II)	17	0	0
77 M Maturity (AVT-I-II)	9	0	0

QPM I-II-III	27	0	VEHQ-16-1, IIMRQPMH 1608, IIMRQPMH 1605, IIMRQPMH 1603, FQH 106, IIMRQPMH 1606, IIMRQPMH 1508, KDQH-51, IIMRQPMH 1601, IIMRQPMH 1609, HQPM 1 (C) (11 Nos.)
SWEET CORN I-II-III	13	1	VEHS-16-1 (1 No.)
BABY CORN I-II-III	14	0	0
POP CORN I-II-III	10	0	0

Disease trap nursery: Maize disease trap nursery consisting of 14 lines was planted to determine the prevalence of different diseases of maize. Maximum disease incidence of TLB and MLB was recorded on CM129 and CM202, whereas Curvularia leaf spot was observed on CM129.

Assessment of losses: A field trial was conducted to determine avoidable losses due to Turcicum leaf blight (TLB) of maize using variety Early Composite during *kharif*, 2016. The experiment comprised of two treatments viz. protected and unprotected with 10 replications. The crop was inoculated once with TLB at 30 DAS. In protected plot, Dithane M-45 @ 0.25% was sprayed two times at 3 DAI and 15 DAI. In non-protected plot, plain water was sprayed after inoculation of the plants with pathogen. Avoidable losses to the tune of 10.8 % were recorded (Table 17).

Table 17. Assessment of avoidable yield losses due to Turcicum Leaf Blight in maize

Replication	Treatment	Disease Score/ Incidence (1-9 scale)	PDI (%)	Yield (q/ha)	Yield Loss (%)
R1	Protected	4	44.4	42.6	13.5
	Unprotected	6.5	72.2	36.9	
R2	Protected	3.8	42.2	40.3	15.5
	Unprotected	6.2	68.9	34.1	
R3	Protected	3.8	42.2	47.5	10.4
	Unprotected	6.1	67.8	42.6	
R4	Protected	3.5	38.9	55.5	10.4
	Unprotected	6	66.7	49.8	
R5	Protected	4.1	45.6	45.2	12.4
	Unprotected	6.5	72.2	39.6	
R6	Protected	3.6	40.0	53.2	6.4
	Unprotected	6.6	73.3	49.8	
R7	Protected	3.8	42.2	45.9	4.4
	Unprotected	6.5	72.2	43.8	
R8	Protected	3.9	43.3	46.0	9.5
	Unprotected	6.9	76.7	41.6	
R9	Protected	3.5	38.9	45.1	1.0
	Unprotected	6.3	70.0	44.7	
R10	Protected	3.9	43.3	25.0	24.6
	Unprotected	6.7	74.4	18.9	
Mean	Protected	3.8	42.1	44.6	
	Unprotected	6.4	71.4	40.2	
Disease control (%)		41.0			
Avoidable Loss (%)		10.8			

CD (5%)		0.2	1.2	1.3	

Management of diseases

Banded leaf & sheath blight (BLSB): A field trial consisting of eight treatments including check was conducted for the management of BLSB using variety Early Composite in RBD with 3 replications during *Kharif*, 2016. All the treatments were found superior over the control (Table 18) however, a single spray of Trifloxystrobin 25%+Tebuconazole 50% @ 0.05 % at 35 days old crop was found most effective in controlling BLSB giving 53.5 % disease control and 47.8% increase in yield.

Table 18. Efficacy of fungicides against banded leaf and sheath blight of maize

Treatment	Mean disease score	PDI*	Disease control (%)	Yield (q/ha)	Yield increase (%)
T1: Difenconazole @ 0.1 %	4.8	53.3 (46.8)	27.3	46.8	23.5
T2: Hexaconazole @ 0.1%	5.0	55.9 (48.4)	23.7	47.9	26.4
T3: Carbendazim @ 0.1%	5.3	59.3 (50.3)	19.1	46.7	23.2
T4:Validamycin @ 0.1%	3.1	34.4 (35.9)	53.1	50.9	34.3
T5:Tebuconazole @ 0.05%	4.3	48.1 (43.9)	34.4	50.8	34.0
T6:Trifloxystrobin 25% + Tebuconazole 50% @ 0.05%	3.1	34.1 (35.6)	53.5	56.0	47.8
T7:Azoxystrobin @ 0.05%	4.1	45.9 (42.6)	37.4	51.1	34.8
T8:Untreated check (water spray)	6.6	73.3 (58.8)	-	37.9	-
CD 0.05	0.3	2.2	-	6.9	-

*Transformed values (angular transformation) in the parentheses

Turcicum leaf blight (TLB): Effect of seed priming and spray of salicylic acid on the incidence of TLB in maize variety Early Composite was assessed by conducting a field trial which consisted of five treatments in RBD with 4 replications during *kharif*, 2016. All the treatments were found effective as compared to untreated check giving 12.0 - 32.8% disease control and 2.7 – 23.0% increase in yield (Table 19). Salicylic acid (SA) spray @ 200 ppm, 24 hrs before inoculation was most effective giving 32.8% disease control and 23.0% increase in yield. No toxic/ synergetic effect of seed priming was observed on germination.

Table 19. Effect of salicylic acid on incidence of Turcicum leaf blight

Treatment	Disease Score (1-9 scale)	PDI* (%)	Disease control (%)	Yield (q/ha)	Yield increase over control (%)	Germination (%)
T1: 50 ppm SA as seed priming (SP)	5.1	56.4 (48.6)	12.4	41.6	2.7	81.8
T2: 100 ppm SA (SP and Foliar spray 24 hrs after inoculation)	4.7	52.2 (46.2)	18.9	44.5	9.9	80.0
T3: 150 ppm SA (Foliar spray 24 hrs before inoculation)	4.2	46.9 (43.2)	27.2	48.5	19.8	83.1
T4: 200 ppm SA (Foliar spray 24 hrs before inoculation)	3.9	43.3 (41.1)	32.8	49.8	23.0	81.2
T5: Check (seed dipping in water and water spray)	5.8	64.4 (53.4)	-	40.5	-	80.6
CD 0.05	0.2	1.3	-	6.9	-	NS

*Transformed values (angular transformation) in the parentheses

Effect of botanicals/ natural products on TLB: A field trial consisting of seven treatments viz., aqueous extract @10% of *Melia Azedarach* leaves, dry rhizomes of Sweet Flag (*Acorus calamus*), dry Ginger Powder, cloves of Garlic (*Allium sativum*) and Cow Urine @15% with fungicidal check was conducted using maize variety Early Composite in RBD with 3 replications during *kharif*, 2016. Two sprays of bioextracts and fungicide were given at 15 days interval. All the treatments were found effective as compared to untreated check (Table 20). Among plant extracts, aquous extract of *Melia Azedarach* leaves @10% was found most effective giving 28.8% disease control and 33.7% increase in yield. However, none of the plant extracts was found effective as compared to fungicidal check which gave 47.8% disease control and 58.0 % increase in yield.

Table 20. Effect of botanicals/ natural products on Turcicum leaf blight

Treatment	Disease score	PDI* (%)	Disease Control (%)	Yield (q/ha)	Increase in Yield (%)
T1: Aqueous extract of *Melia Azedarach* leaves @10%	4.4	48.5 (44.1)	28.8	38.6	33.7
T2: Aqueous extract of dry rhizomes of Sweet Flag (*Acorus calamus*) @10%	5.1	56.7 (48.8)	16.8	37.5	29.7
T3: Aqueous extract of dry Ginger Powder @10%	5.3	59.3 (50.3)	13.0	36.3	25.6
T4: Aqueous extract of cloves of Garlic (*Allium sativum*) @10%	4.6	50.7 (45.4)	25.5	37.4	29.3
T5: Cow Urine @15%	4.6	51.1 (45.6)	24.9	36.4	25.9
T6: Fungicidal Check (Two sprays of Dithane M45 @2.5gm/l)	3.2	35.6 (36.6)	47.8	45.7	58.0
T7: Control (water Spray)	6.1	68.1(55.6)		28.9	
CD 5%	0.5	3.2		4.6	

Transformed values (angular transformation) in the parentheses

Wheat

Identification of resistance sources

Wheat stocks/ entries constituting various plant pathological nurseries under All India Coordinated Wheat and Barley Improvement Project were screened against major diseases under artificial inoculation conditions at HAREC Dhaulakuan. The results are summarized in Table 21.

Table 21. Wheat stocks resistant to yellow rust, powdery mildew, Karnal bunt and head scab in various plant pathological nurseries

Sr. No.	Name of nursery	Total entries	No. of free entries			
			Yellow rust	Powdery mildew	Karnal bunt	Head scab
1	IPPSN	1390	565			
2	PPSN					
	Avt 2nd yr	60	60	-	-	-
	Avt 1st yr	91	22	-	-	-
	NIVT	345	108	-	-	-
3	NIVT (KB)	345	95	-	-	-
4	MDSN(KB)	69	0	-	63	-
5	MDSN (AVT-II)	69	22	-	-	-
6	PMSN	159	0	88	-	-

7	KBSN	151	0	-	86	-
8	HSSN					
	AVT-I	91	0	-	-	77
	AVT-II	59	0	-	-	53
9	Released varieties	417	35	-	-	-
10	SAARC	20		-	-	-
11	TPN	20		-	-	-
Total		3286	907	88	149	130

From these nurseries, 907 entries remained free from yellow rust, 88 from powdery mildew, 149 from Karnal bunt and 130 from head scab.

Yellow rust: A total of 496 entries/ genotypes constituting PPSN (AVT I & II and NIVT/ Special Trials) were screened under artificial inoculation condition against yellow rust at HAREC, Bajaura. The promising genotypes with yellow rust resistance are given in Table 22.

Table 22. Resistant entries/ genotypes in PPSN (AVT-I & II and NIVT/ Special Trials)

Nursery	Total entries (No.)	Resistant entries (No.)	Promising entries
PPSN (AVT-II)	60	17	DBW 173, HD 3043 (C), WH 1080 (C), WH 1105 (C), WH 1124 (C), WH 1142 C), HI 1612, K 0307 (C), K 1317 (I) (C), DBW 110 (C), MP 3288 (C), HI 8777 (d), MACS 6222 (C), UAS 446 (C), DBW 14 (C), TL 2942 (C), TL 2969 (C)
PPSN (AVT-I)	91	64	HPW 439, 440, 448, HS 611, 629, 630, 644, 645, 646, 647, UP 2993, 2942, VL 1011, 1012, 1013, 3013, 3014, 3015, 4002, BRW 3773, 3775, CG 1023, DBW 187, 189, 196, 246, 247, 248, 250, 251, HD 3219, 3226, 3237, 3271, HI 1617, 1619, 1620, 1621, 8791 (d), HP 1963, MACS 6677, PBW 750, 752, 777, 778, 779, WH 1202, 1232, 1233, 1316, UAS 462 (d), KRL 370, 384, 386, TL 3011, 3012, 3013, 3014, 3015, VHA-01, 03, 06, 09 and 10
PPSN (NIVT/ Special Trials)	345	194	N-1A-101, 102, 106, 110, 113, 114, 115, 117, 120, 122, 123, 124, 125, 126, 128, 129, 130, 131, 132, 133, 134, 135, 138, 139, 140, 142, 144, 145, 146, 147, 148, 149, N-1B-201, 204, 205, 206, 207, 209, 211, 212, 213, 214, 216, 218, 220, 223, 225, 227, 228, 231, 235, 236, 237, 238, 239, 240, 241, 245, 246, 249, N-2-304, 307, 308, 313, 317, 320, 323, 325, 327, N-3A-405, 406, 407, 408, 412, 413, 415, 417, 418, 419, 421, 423, 424, 427, 430, 431, N-3B-501, 502, 504, 506, 508, 513, 515, 521, 523, 528, 529, 530, N-4-601, 602, 603, 604, 605, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, N-5A-701, 704, 705, 707, 708, 710, 715, 719, 724, 728, 729, 735, 736, N-5B-803, 806, 807, 808, 810, 811, 812, 813, 814, 816, 817, 818, 819, 820, 821, 822, 823, 824, NHIVT 1601, 1602, 1603, 1604, 1605, 1606, 1607, 1609, 1610, 1611, 1612, 1613, 1614, 1615, 1616, 1617, 1618, 1619, 1620, 1621, 1622, 1623, 1624, SHIVT 106, 111, 112 and 114

Hill bunt: Thirty one wheat genotypes were screened against hill bunt under artificially inoculated conditions at Bajaura. Genotypes viz., HPW 251 (C), HS 490 (C), UP 2993, VL 1012 andVL 3013 remained free from disease whereas, HS 644 and UP 2992 were resistant (< 5% infection).

Powdery mildew: PMSN consisting of 159 genotypes was screened against powdery mildew under artificial inoculation conditions at HAREC Bajaura and Dhaulakuan. Nine genotypes viz. TL 2942 (C), TL 2969 (C), TL 3011, TL 3012, TL 3013, TL 3014, TL 3015 TL 3007 and TL

3008 remained free from the disease while, 16 genotypes were resistant and 85 were moderately resistant at Bajaura. At Dhaulakuan, 88 genotypes were found resistant to powdery mildew.

Karnal bunt: Under All India Coordinated Wheat and Barley Improvement Project, 151 wheat entries were evaluated against local isolates of *Tilletia indica* under artificial inoculation conditions. Eighty six entries were found free from karnal bunt.

Head scab: Out of 91 entries screened against head scab pathogen *(Fusarium graminarium*) by artificial inoculation at Dhaulakuan, 77 entries were found resistant to head scab.

Glume blotch: One hundred forty one varieties/ genotypes were evaluated for resistance against *Septoria nodorum* (SN) under natural infection at Palampur. Six genotypes viz. HPW 89, HPW 309, HPW 314, HPW 373, HS 490 and VL 907 recorded resistant score (0-3) while, 124 stocks recorded moderately resistant/ moderately susceptible reaction (< 5 score) on 0-9 scale.

Management of diseases

Yellow rust: A new fungicide BAS 751 04 F EC was evaluated for its bioefficacy at 1.0, 1.2, 1.4 and 1.6 ml/ l by conducting a trial in RBD with three replications and using a susceptible variety PBW343. Two sprays of test fungicide at 1.6 ml/ l were found most effective for the management of the disease giving 92.1% disease control and 85.8% increase in yield over check (Table 23). However, test fungicide @ 1.6 ml/ l was at par with Propiconazole 25% EC in controlling yellow rust of wheat.

Table 23. Evaluation of BAS 751 04 F EC against yellow rust of wheat

Treatment	Dose (ml/ l)	Rust Severity (%)	Disease Control (%)	Yield (q/ha)
T1: BAS 751 04 F EC	1.0	9.0 (17.4)	87.6	40.9
T2: BAS 751 04 F EC	1.2	8.2 (16.5)	88.7	50.6
T3: BAS 751 04 F EC	1.4	8.0 (16.4)	88.9	52.7
T4: BAS 751 04 F EC	1.6	5.7 (13.7)	92.1	54.8
T5: BAS 750 02 F SC	0.35	12.7 (20.8)	82.5	35.4
T6: Propiconazole 25 EC	1.0	5.6 (13.7)	92.2	54.8
T7: Untreated control		72.7 (58.4)	-	29.5
CD (0.05)		2.8		10.0

Another fungicide, BAS 750 02 F SC was tested for its bioefficacy against YR @ 0.5, 0.6, 0.75 and 0.8 ml/ l in RBD with three replications and using susceptible variety PBW343. Two sprays of test fungicide @ 0.8 ml/ l were found most effective giving 92.2% disease control and 82.7% increase in yield over check (Table 24). However, test fungicide @ 0.8 ml/ l was at par with Propiconazole 25 EC in controlling stripe rust of wheat.

Table 24. Evaluation of BAS 750 02 F SC against yellow rust of wheat

Treatment	Dose (ml/ l)	Rust Severity (%)	Disease Control (%)	Yield (q/ha)
T1: BAS 750 02 F SC	0.5	8.7 (17.1)	89.8	41.7
T2: BAS 750 02 F SC	0.6	7.8 (16.2)	89.4	48.1
T3: BAS 750 02 F SC	0.75	6.7 (14.9)	90.9	49.8
T4: BAS 750 02 F SC	0.8	5.7 (13.6)	92.2	53.9
T5: Propiconazole 25EC	1.0	5.7 (13.6)	92.2	54.8
T6: Untreated control		74.0 (59.4)	-	29.5

CD (0.05)		4.7		13.4

Karnal bunt: A trial in RBD with 3 replications was conducted to evaluate the efficacy of Tebuconazole 6% FS against Karnal bunt. The perusal of data (Table 25) indicated that test fungicide @ 3.5 ml per 10 kg of seed as a seed dresser was most effective giving 77.5% disease control and 64.5% increase in yield over check and was closely followed by tebuconazole 6% FS @ 3.0 ml/ 10 kg seed which was statistically at par with tebuconazole 2% DS @ 10 g per 10 kg of seed giving 70.0% disease control and 67.7% increase in yield over check.

Table 25. Evaluation of Tebuconazole 6% w/v FS against Karnal bunt of wheat

Treatment	Dose (ml or g/ 10 kg of seed)	Disease Incidence (%)	Disease Control (%)	Yield (q/ha)	Yield Increase (%)
Tebuconazole 6% FS	2.5	**1.60** (7.26)	60.0	49.00	58.06
Tebuconazole 6% FS	3.0	**1.20** (6.28)	70.0	52.00	67.70
Tebuconazole 6% FS	3.5	**0.90** (5.43)	77.5	51.00	64.50
Tebuconazole 2% DS	10.0	**1.20** (6,28)	70.0	48.00	54.80
Carboxin 75% WP	25.0	**1.90** (7.91)	52.5	44.00	41.90
Untreated control	-	**4.00** (11.53)	-	31.00	-
CD (P=0.05)		**0.49**	**-**	**3.34**	**-**

*Data in the parentheses are arc sin transformed values

Loose smut: A replicated field trial with nine treatments (Table 26) including check was conducted in RBD with three replications for evaluating efficacy against loose smut in variety HPW 349. Seed treatment with reference fungicides viz. Benomyl and Carbendazim both applied @ 2.0g/ kg seed were found most effective giving maximum 99.9 and 99.3% disease control respectively. Test fungicide Thiophanate methyl 450 g/l + Pyraclostrobin 50 g/l (**Xelora 500 g/l FS**) was inferior to reference fungicides in disease control however, its highest test dose i.e. 2.5 ml/ kg seed gave 72.9% disease control and followed by Xelora 50 FS at 2.0 and 1.5 ml/ kg seed which gave 66.6 and 59.6% control, respectively. The highest grain yield was obtained with Benomyl and closely followed by Bavistin and Xelora 50 FS (4 ml/ kg seed) respectively.

Table 26. Evaluation of Xelora 500 g/ l FS against loose smut of wheat

Treatment	Dosage (ml or g/ kg seed)	Loose Smut		Grain Yield	
		Incidence (%)	Control (%)	(q/ha)	Increase (%)
Xelora 50 FS	1.50	3.94 (11.44)	59.6	45.3	3.7
Xelora 50 FS	2.00	3.26 (10.40)	66.6	45.7	4.6
Xelora 50 FS	2.50	2.55 (9.19)	72.9	45.8	4.8
Thiophanate Methyl 50 WP	3.00	6.10 (14.29)	37.5	44.0	0.7
Pyraclostrobin 20 WG	0.75	6.97 (15.30)	28.6	44.4	1.6
Carbendazim 50 WP	2.00	0.10 (1.81)	99.9	46.0	5.3
Benomyl 50 WP	2.00	0.07 (1.51)	99.3	46.2	5.7
Xelora 50 FS	4.00	1.00 (5.74)	89.8	45.9	5.0
Control	-	9.76 (18.18)		43.7	
CD (0.05)		0.58		1.6	

Figures within brackets are angular transformed values

Loose smut and Karnal bunt: A new seed dresser Sedaxane 2.5 % + Fludioxonil 2.5 % + Thiamethoxam 26.25% (312.5) FS was tested for its bioefficacy against loose smut (*Ustilago nuda tritici*) and Karnal bunt (*Tilletia indica*) of wheat in RBD with three replications (Table 27). Seed dressing with test formulation @ 2 g/ kg seed was significantly effective in controlling

loose smut and Karnal bunt giving 64.2 and 62.1% disease control over check respectively, along with 50.0% increase in the grain yield.

Table 27. Evaluation of Sedaxane 2.5 % + Fludioxonil 2.5 %+ Thiamethoxam 26.25% (312.5) FS against loose smut and Karnal bunt of wheat

Treatment	Dosage (g/ml per kg of seed)	Disease incidence				GrainYield	
		KB	Control %	LS	Control (%)	(q/ha)	Increase (%)
Untreated control	-	3.7		2.8		3.4	
Sedaxane2.5 % + Fludioxonil 2.5 %+ Thiamethoxam 26.25% (312.5) FS	1.0	1.6	56.7	1.4	50.0	4.0	17.6
Sedaxane2.5 % + Fludioxonil 2.5 %+ Thiamethoxam 26.25% (312.5) FS	2.0	1.4	62.1	1.0	64.2	5.1	50.0
Sedaxane2.5 % + Fludioxonil 2.5 %+ Thiamethoxam 26.25% (312.5) FS	3.0	2.0	45.9	1.2	57.1	4.8	41.1
Sedaxane 500 FS	0.2	2.6	29.7	1.3	53.5	4.8	41.1
Fludioxonil 100 FS (Maxim)	2.0	2.4	35.1	1.0	64.2	4.8	41.1
Thiamethoxam 30 FS (Cruiser)	3.3	3.0	18.9	1.5	46.4	3.9	14.7
Tebuconazole 5.36% FS (Raxil)	0.33	2.7	27.0	1.8	35.7	4.0	20.5
Carboxin 27.5%+ Thiram 37.5% DS	3.0	1.6	56.7	0.9	67.8	4.8	41.1
CD (0.05)		0.55		0.51		0.44	

Barley

Identification of resistanace sources

Yellow rust: A total of 625 barley lines/ genotypes constituting Initial Barley Disease Screening Nursery (IBDSN), National Barley Disease Screening Nursery (NBDSN) and Elite Barley Disease Screening Nursery (EBDSN) were screened against yellow rust under artificial inoculation at HAREC Bajaura and Dhaulakuan. The results are summarized in Table 28.

Table 28. Barley stocks/ genotypes resistant to yellow rust

Nursery name	Total Entries	Resistant Entries	Some of the promising entries
HAREC, Bajaura			
IBDSN	400	208	UPBM 2, UPBM 11, UPBM 15, PKB 1605, PKB 1618, PKB 1628, PKB 1636, PKB 1640, BK 1603, BK 1610, BK 1617, BK 1622, BK 1629, BK 1634, HBL 789, HBL 795, HBL 805, HBL 814, HBL 819, HBL 825, JB 353, JB 359, JB 364, JB 371, BL 1216, BL 1237, BL 1165, BL 1279, BL 1296, PL 887, PL 890, NDB 1677, NDB 1683, NDB 1698, BBM 745, BBM 752, BBM 759, BBM 766, HUBL 1609, VB 1601, VB 1612, VB 1628, VB 1632, BD 1719, BD 1727, BD 1733, BD 1742, BD 1750, BH 1601, BH 1618, BH 1627, BH 1639, BH 1646, DWRFB 8, DWRFB 15, DWRFB 23, DWRNB 17, DWRNB 30.
NBDSN	176	91	NBDSN 1, NBDSN 9, NBDSN 16, NBDSN 25, NBDSN 31, NBDSN 38, NBDSN 47, NBDSN 52, NBDSN 57, NBDSN 61, NBDSN 67, NBDSN 74, NBDSN 80, NBDSN 88, NBDSN 93, NBDSN 99, NBDSN 106, NBDSN 118, NBDSN 129, NBDSN 135, NBDSN 142, NBDSN 148, NBDSN 154, NBDSN 158, NBDSN 160, NBDSN 164, NBDSN 171, NBDSN 176
EBDSN	49	41	DWRB 127, DWRB 147, DWRB 152, BK 1508, BK 1518, BK 1525, HBL 113, HBL 757, BH 1009, BH 1014, BH 995, KB 1318, HUB 246, HUB 247, BCU 7621, BCU 7719, BCU 7748, BCU 7811, BH 981,

			BHS 430, DWRB 137, PL 874, RD 2900, RD 2909, RD 2913, RD 2930, RD 2941, PL 890, PL 891
HAREC, Dhaulakuan			
IBDSN	400	336	-
NBDSN	176	158	-
EBDSN	49	49-	

C. Pulses

Chickpea

Resistance sources

Blight (*Aschochta rabiei*): A total of 235 accessions received from ICAR-NBPGR were evaluated for *Ascochyta* blight at HAREC, Dhaulakuan under natural infection. Of these, accessions viz., IC-269073, IC-348562, IC-506915, IC-485905, IC-487371, IC-249572, IC-269247, IC-261223, IC-251732, IC-244267, IC-244515, IC-244624, IC-372689, IC-485668, IC-209670, IC-376248, IC-327416, IC-240830, IC-275535, IC-372351, IC-269690, IC-327779, IC-546326, IC-327960, IC-328009, IC-327580, IC-561350, IC-396753, IC-223042, EC-223490, EC-223067, EC-267301, ICC -3117, ICC -2271 and ICC -328 gave resistant reaction **(**Disease Rating <1**)** to *Ascochyta* blight.

Management

Wilt and dry root rot: Bioagents were evaluated against wilt & dry root rot (*Fusarium oxysporum* f sp.*ciceri* and *Macrophomina phaseolina)* as seed priming and soil application. The minimum pre emergence mortality was observed in *Trichoderma viride* PAU treated seeds followed by *Trichoderma harzianum* Anand treated seeds. The post- emergence mortality ranged between 4.25 - 5.80% in treated seeds, whereas, it was 18.95% in untreated plots (Table 29). The maximum yield was obtained with *Trichoderma harzianum* Anand treatment followed by *T. viride* PAU.

Table 29. Effect of seed priming and soil application of *Trichoderma* spp. on *wilt & dry root rot* of chickpea

Treatment	Germination (%)	Pre emergence mortality (%)	Post emergence mortality (%)	Root rot/wilt Complex (%)	Crop Stand (%)	Yield (kg/plot)
Trichoderma harzianum (Anand)	94.05 (75.89)	5.95 (14.07)	5.0 (12.86)	10.95 (19.30)	89.05 (70.66)	1367.00
T.viride (PAU)	94.50 (76.50)	5.50 (13.46)	4.25 (11.85)	9.75 (18.13)	89.75 (71.35)	1354.17
T.harzianum (Palampur)	92.20 (73.78)	7.80 (16.18)	4.75 (12.53)	12.55 (20.72)	87.70 (69.45)	1341.67
T.viride (Palampur)	90.90 (72.49)	9.10 (17.47)	5.80 (13.90)	14.90 (22.66)	84.85 (67.11)	1237.50
T.harzianum (PAU)	92.50 (74.13)	7.65 (15.99)	4.25 (11.85)	11.90 (20.15)	88.10 (69.81)	1145.83
Carbendazim	91.45 (73.00)	8.55 (16.96)	5.00 (12.89)	13.50 (21.58)	86.45 (68.39)	983.33
Control	79.60 (63.15)	20.40 (26.81)	18.95 (25.79)	39.35 (38.83)	60.65 (51.13)	783.33
CD	1.76	1.73	1.55	1.54	1.67	-

Figures within brackets are transformed values

Common bean (Rajmash)

Resistance sources

Bean common mosaic virus (BCMV): In an attempt to identify durable sources of resistance, 209 common bean accessions comprising indigenous and exotic accessions were evaluated under glasshouse/ greenhouse conditions against BCMV strain NL-7n. The comparative account of resistance spectrum of the test genotypes against NL-7n strain is given in Table 30. The indexing of resistant accessions done through DAS- ELISA test and RT-PCR using BCMV specific antiserum and CP gene specific primers, respectively, confirmed the resistant nature of the test germplasm. Out of 209 accessions, forty-nine accessions showed resistance whereas all other genotypes were susceptible to BCMV NL-7n. The resistant accessions comprised of only exotic germplasm whereas none of the indigenous accession was resistant to the test strain.

Table 30. Sources of resistance found against NL- 7n strain of BCMV in common bean

Bean accessions	**Resistant genotype**
Indigenous collections	NIL
Exotic collections	EC-24944, EC-127372, EC-271475, EC-271477, EC-271481, EC-285565, EC-400396, EC-500643, EC-500807, EC-530823, EC-530886, EC-530906, EC-530915, EC-530917, EC-530926, EC-530929, EC-530944, EC-530998, EC-537973, EC-537975, EC-537994, EC-537995, EC-537996, EC-24948, EC-131808, EC-241421, EC- 241422, EC-241425, EC-253820, EC- 271476, EC-271480, EC-271488, EC- 271497, EC- 271498, EC-271500, EC- 271530, EC-271533, EC-271537, EC-271545, EC- 271552, EC-271556, EC- 271562, Great Northern UI-123, Sanilac, Monroe, Jubila, Improved Tendergreen 40031, Black Turtle Soup, Amanda.

Assessment of yield loss due to BCMV

The viral infection caused a significant reduction in all the yield contributing factors of the plant *viz.,* plant height, number of branches per plant, number of pods per plant, average number of seeds per pod, average pod length, and weight of 100 seeds, when compared with the healthy plants. The plants raised from infected seeds were severly affected compared to those which were artificially inoculated. The plants response to viral infection reduced with the increase in plant age, i.e., the effect of virus infection on the growth parameters decreased with delay in inoculations at each growth stage (Table 31).

Table 31. Effect of virus infection on various growth parameters on cv. Jawala

Treatments	Plant height (cms)		No. of branches / plant		No. of pods/ plant		Average no. of seeds/ pod		Pod length (cms)		Seed yield (g)		100 seed weight (g)	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Seed borne	30.98	30.33	2.00	2.00	2.00	2.00	2.00	2.00	7.20	6.43	2.27	2.50	32.23	31.07
Inoculation at primary leaf stage	41.69	47.10	2.00	2.33	3.00	3.00	2.33	3.00	8.06	7.65	3.14	3.02	41.23	36.18
Inoculation at third trifoliate leaf stage	51.83	51.77	2.33	2.33	3.00	3.67	3.00	3.00	8.84	9.55	3.82	3.65	45.83	45.80
Inoculation at flower initiation stage	59.18	60.72	2.33	2.00	3.33	4.33	3.33	3.33	10.11	10.42	4.29	4.25	47.53	48.96
Inoculatiojn at pod formation stage	61.62	63.17	3.00	2.33	3.00	5.00	3.67	4.00	10.93	11.05	5.07	4.69	51.53	55.37
Control	64.57	66.90	3.00	2.67	3.33	6.33	4.00	4.67	12.03	12.24	6.73	6.86	59.50	60.87
Critical Difference (CD=0.05)	1.29	0.85	0.28	0.84	0.44	0.59	0.56	0.58	0.52	0.65	0.24	0.58	1.36	1.34
Coefficient of variance (CV) (%)	1.49	1.0	6.52	19.90	8.47	8.07	10.87	9.96	3.06	3.76	3.35	2.4	1.64	1.63

In the infected plants the yield, was reduced by 44.71 and 47.13 per cent during 2015 and 2016, respectively, inclusive of plants bearing no pods. The determinant of BCMV induced yield reduction was decrease in the average number of seeds per pod (28.35 %) and number of pods per plant (43.16 %) in 2015 and 2016, respectively. The height was another parameter, which showed 24.01 and 39.28 per cent reduction, respectively. In the year 2016, number of branches was the least affected parameter with 17.54 per cent reduction, whereas all other parameters were statistically at par (Table 31). Actual mean yield of BCMV infected plants in 2015 and 2016, were: Y1= (100-44.71) =55.29%; Y2= (100- 47.13) = 52.87% respectively (Table 32).

Table 32. Influence of BCMV infection on the yield of cv. Jawala under protected conditions

component	Healthy plants		Infected plants		% Decrease	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**
Plant height (cms)	64.570 (0.47)	66.90 (0.19)	49.06 (2.2)	40.62 (0.29)	24.01	39.28
No. of branches per plant	3.00 (0.00)	2.67 (0.33)	2.34 (0.13)	2.19 (0.19)	22.2	17.54
No. of pods per plant	3.333 (0.33)	6.33 (0.33)	2.87 (0.133)	3.60 (0.13)	13.98	43.16
Average no. of seeds per pod	4.000 (0.00)	4.67 (0.33)	2.87 (0.199)	3.07 (0.07)	28.35	34.28
Pod length (cms)	12.027 (0.17)	12.24 (0.02)	9.03 (0.147)	9.02 (0.23)	24.95	26.33
Wt (g)/100 seed	59.50 (0.40)	60.44 (0.44)	43.67 (0.43)	43.48 (0.39)	26.6	28.57
Wt (g)/plant	6.730 (0.07)	6.86 (0.08)	3.72 (0.11)	3.63 (0.05)	44.71	47.13

Figures in parenthesis is the standard error

Yield loss assessment under field conditions

Under field conditions, three hundred infected and two- hundred healthy seeds were sown and fifty plants showing prominent bean mosaic disease symptoms like mosaic, blistering, vein banding, leaf rolling were tagged and used for recording data. Similarly fifty healthy plants were tagged. The virus had significant effect on the yield contributing characters with an exception that, the virus induced increased number of branches and number of pods in severely stunted plants. The average yield reduction over the span of two years was 37.14 per cent. Plant height was severely affected with 44.94 per cent reduction whereas pod length was little affected by viral infection with 1.64 per cent reduction only. Though an increase in number of pods were observed, they bore very few seeds and thereby, per cent reduction of 29.75 was observed in average number of seeds per pod. The actual mean yield of BCMV affected plants was 62.86 per cent (Table 33).

Table 33. Influence of BCMV infection on the yield of cv. Jawala at field conditions

Component	Critical difference (CD=0.05)	Healthy plants	Infected plants	% Decrease
Plant height(cms)	3.26	51.64 (2.89)	28.43 (1.02)	44.94
No. of branches per plant	0.86	2.44 (0.12)	3.08 (0.13)	-25.00
No. of pods per plant	0.36	2.94 (0.13)	3.68 (0.21)	-24.88
Average no. of seeds per pod	0.31	4.06 (0.19)	2.85 (0.14)	29.75
Pod length(cms)	1.58	9.53 (0.41)	9.37 (0.17)	1.64
Wt(g)/plant	0.72	4.22 (0.35)	2.87 (0.16)	37.14

Figures in parenthesis is the standard error

D. Oilseeds
Soybean

Resistance sources

Frogeye leaf spot (FLS): In IVT, entries viz. KDS 1045, RVS 2009-9 & RSC 10-52 and PS 1589, MACS 1543, DSb 32, KDS 921, AMS-MB 5-19, NRC 127 & AMS-MB 5-18 were absolutely and highly resistant, respectively against FLS *(Cercospora sojina)*. Whereas, in AVT-I, line JS 20-116 was free from FLS while PS 1572 was highly resistant and in AVT-II, line KDS 869 was highly resistant against FLS.

Pod blight (PB): Entries viz. PS 1589, PS 1587, KDS 921, AMS-MB 5-19, TS 70, NRC 124 & AMS-MB 5-18 and MACS 1520, RVS 2009-9, NRC 126, Himso 1687, SL 1113 & MACS 1505 were absolutely and highly resistant, respectively against PB (*Colletotrichum truncatum*) in IVT. Whereas, in AVT-I, PS 1572 remained disease free while NRC 117, PS 1556, PS 1569, RVS 2010-1 and SL 1074 were highly resistant. In AVT-II, JS 20-96 and SL 1028 were found free from pod blight (Ct) while JS 20-87, JS 20-98, PS 1556 and RVS 2007-06 were found highly resistant.
Brown spot (BS): Entries viz. DS 3105 in IVT, PS 1569 in AVT-I and VLS 63 © in IVT, AVT-I & II were highly resistant against BS (*Septoria glycines*).
Multiple disease resistance: Entries viz. KDS 921, PS 1589, RVS 2009-9, AMS-MB 5-19 and AMS-MB 5-18 in IVT were found highly resistant against FLS and PB and were also having multiple disease resistance against three major diseases i.e. FLS, PB and Brown Spot. PS 1572 in AVT-I was observed highly resistant against FLS and PB.

Management

Pod blight: An experiment comprising eight treatments i.e. seed treatment alone with chemicals/ bio-agent and in combination with foliar sprays with chemical/ bio-agent along with check, was conducted with 3 replications in RBD. Seed treatment with fungicide and two foliar sprays with thiophanate methyl effectively managed the pod blight and resulted in higher seed yield (Table 34).

Table 34. Effect of seed treatment and foliar application of chemicals and bio-agent on pod blight

Treatment	Germination (%)	Plant stand (%)	Pod blight Index (%)	% pod infected (Ct)	100 seed weight (g)	Seed yield (kg/ha)	B:C
T1: Seed Treatment (ST) with Carboxin + Thiram @ 2g/kg seed (Vitavax Power)	73.3	59.2	40.7(39.6)	28.5(32.3)	11.75	1229.6	0.70
T2: ST with carbendazim + mancozeb (Saaf) @ 2g/kg seed	67.8	61.4	34.8(36.1)	28.8(32.4)	12.20	1285.2	0.78
T3: ST with *Trichoderma viride* @ 5 g/kg seed	65.0	56.5	34.1(35.7)	30.5(33.5)	11.90	1285.2	0.79
T4: T1 + spray with thiophanate methyl @ 0.1% at 55 and 75 DAS	74.5	61.4	6.7(14.8)	7.7(15.7)	13.11	1577.8	1.02
T5: T2 + spray with thiophanate methyl @ 0.1% at 55 and 75 DAS	67.9	61.9	10.4(18.5)	11.9(20.0)	12.67	1518.5	0.95

T6: T3 + spray with thiophanate methyl @ 0.1% at 55 and 75 DAS	64.7	56.3	14.1(21.9)	10.5(18.6)	12.58	1385.2	0.78
T7: spray with thiophanate methyl @ 0.1% at 55 and 75 DAS	58.4	53.5	14.1(21.9)	8.4(16.7)	12.68	1570.5	1.04
T8: Spray with *Trichoderma viride* @ 5g/L at 55 and 75 DAS	58.9	52.9	30.4(33.4)	13.6(21.5)	12.630	1296.3	0.68
T9: Control	61.0	55.1	49.7(44.8)	36.4(37.1)	11.85	1085.2	0.68
CD (P=5%)	5.290	6.065	4.831	5.529	0.682	173.3	-

Rapeseed & Mustard

Resistance sources

Alternaria blight: A total of 43 entries of rapeseed-mustard germplasm were screened against *Alternaria* blight under natural conditions. The disease severity on leaves at the time of maximum disease appearance (100 DAS) ranged from 46.7 (EC-339000) to 77.7 % (TS-46) whereas, on pods it varied from 24.4% (RGN-330) to 75.5% (PT-2010-5) at the time of crop maturity. In **Uniform Disease Nursery,** the severity on leaves at100 DAS varied from 33.9% in DRMR-316 to 78.8% in RMT-1-10-1 and on pods ranged from 21.1 % (PRD-2014-1) to 68.8% (RTM-314) at the time of crop maturity under natural infection. Entries viz. PRD-2014-21, ABS (3) -16, DRMR-316, EC-399299 and DLSC-1 showed low (< 25%) disease severity on pods. In **National Disease Nursery,** the severity on leaves ranged from 52.2% (in DRMRIJ-12-51) to 76.6% (in DRMRIJ-12-21) at 100 DAS whereas, on pods it varied from 20% (DRMRAB-7-13) to 55.5% (DRMRIJ-12-21).

White rust: Out of 43 entries of rapeseed-mustard germplasm evaluated under natural infection, three entries viz. PYS-2010-3, DLSC-1 and EC-339000 remained free from disease while, entries viz. JT-90-1, PDZ-4, PDZ-6, PDZ-1, PDZ-5, PT-2010-5 and TS-46 recorded low (< 10%) disease severity. There was negligible formation of stagheads. In **Uniform Disease Nursery,** entries viz. DRMR-100, DRMR-316, DRMR-312, GSL-1, DLSC-1, YSB-9, RTM-314 and DRMR-2-11 remained free from disease whereas, entries viz. PDZ-1, PDZ-3, PDZ-2, DRMR-2035, RMT-10-9-1, RMT-1-10-1, RMWR-09-5-1 and DRMR-1-5 recorded low (< 10%) disease severity on leaves. There was no staghead formation in any of the entry. In **National Disease Nursery,** three entries viz. DRMRIJ-12-48, DRMRIJ-12-40 and DRMRMJA-35 remained free from disease while, entries like DRMRIJ-12-39, DRMRIJ-12-21, DRMRIJ-12-26, DRMRIJ-12-37, RMWR-09-5 and BIO-YSR showed less than 10% disease severity on leaves under artificial conditions. Staghead formation was not observed.

Linseed

Resistance sources

Rust: A total of 221 entries of linseed were screened against rust and wilt under natural conditions at SAREC, Kangra. Entries viz. CC-11, CC-25, CC-31, CC-32, CC-65, CC-68, CC-74, CC-99, CC-102, CC-106, CC-122, CC-129, CC-136, CC-142, CC-149, CC-188 and CC-212 scored 0 while, entries viz. CC-1, CC-5, CC-16, CC-58, CC-72, CC-84, CC-145 and CC-151 scored 1 on 0-5 scale against rust. In **Uniform Disease Nursery,** out of 68 entries 29 viz., UDN-1, 2, 3, 6, 7, 8, 9, 10, 13, 14, 22, 23, 24, 31, 32, 33, 34, 35, 38, 39, 42, 43, 44, 45, 55, 61, 62, 64 and 66 scored 0 whereas, two entries viz. UDN-36 and UDN-49 scored 1 on 0-5 rating scale

under natural infection. In **UDNA (Uniform Disease Nursery under Artificial conditions)** entries coded UDNA-2, 4, 9, 10, 11, 12, 19 and 23 were observed highly resistant (disease score 0) to rust. Evaluation of 32 **promising entries/ elite material** under high inoculum pressure of rust revealed entries viz. LC-2279-4, NL-260, PKDl-72, Sheela, Padmini, Binwa, BPL-19, LC-2023, PKDL-65, LCk-9320, Surbhi, RLC-49, BAU-08-07, LC-2002, and KL-221 to be highly resistant(score 0) while, entries viz. LC-147, Nagarkot and KL-190 resistant(score 1) to rust.

Wilt: None of the 221 entries was found free or highly resistant to wilt. However, entries viz. CC-5, CC-31, CC-32, CC-72, CC-74 and CC-188 showing highly resistant to resistant reaction to rust were found moderately resistant to wilt disease. In **Uniform Disease Nursery,** entries coded UDN-2, 3, 9, 10, 22, 31, 32, 33, 34, 36, 39, 42, 43, 44, 45, 49, 61, 62 and 64 showing highly resistant to resistant reaction to rust were also found resistant to wilt disease under natural infection. Seven entries viz. Nagarkot, Binwa, PKDL-65, Surbhi, LC-2002, KL-221 and RLC-49 from **elite material** had <10% wilt incidence.

Management

Rust and Alternaria blight: A field experiment was conducted during *rabi* 2016-17 at SAREC, Kangra to evaluate eight different treatment combinations of fungicides and bio-agents against linseed rust using susceptible variety T-397. The lowest disease severity (12.0%) of rust was observed in case of seed treatment with Vitavax Power (2g/kg seed) + two foliar sprays of hexaconazole (0.1%), first at the disease initiation and second after 15days interval. Whereas, the lowest disease severity of Alternaria bud blight was recorded in case of seed treatment with Vitavax Power (2g/kg seed) + two foliar sprays of mancozeb (0.25%), first at the disease initiation and second after 15days interval (Table 35). Highest seed yield was given by seed treatment with Vitavax Power (2g/kg seed) + two foliar sprays of hexaconazole (0.1%). The highest test weight (1000 seed wt) was found in case of seed treatment with Vitavax Power (2g/kg seed) + two foliar sprays of mancozeb (0.25%).

Table 35. Management of rust and *Alternaria* blight in linseed

Treatments	**Disease severity (%)**		**Yield (kg/ha)**	**1000 seed wt (g)**
	Rust	**Alt Bud blight**		
T1: Seed treatment (ST) with *Trichoderma viride* (4g/kg seed) + two foliar sprays of mancozeb (0.25%)	58.0(49.7)	9.5	815	5.83
T2: Seed treatment (ST) with *T. viride* (4g/kg seed) + two foliar sprays of propiconazole (0.1%)	26.0(30.6)	8.6	730	5.92
T3: Seed treatment (ST) with *T. viride* (4g/kg seed) + two foliar sprays of hexaconazole (0.1%)	20.0(26.5)	8.1	789	5.85
T4: Seed treatment (ST) with Vitavax Power (2g/kg seed) + two foliar sprays of mancozeb (0.25%)	46.0(42.7)	6.3	908	6.0
T5: Seed treatment (ST) with Vitavax Power (2g/kg seed) + two foliar sprays of propiconazole (0.1%)	20.0(26.5)	7.2	950	5.94
T6: Seed treatment (ST) with Vitavax Power (2g/kg seed) + two foliar sprays of hexaconazole (0.1%)	12.0(20.2)	7.0	1002	5.9
T7: Three foliar sprays of mancozeb (0.25%)	56.0(48.4)	10.4	835	5.88
T8: Untreated check	77.3(61.6)	20.6	451	5.23
CD (5%)	5.7	2.4	117	0.36

Variability in liseed rust pathogen: Two new isolates of *Melampsora lini* causing rust in linseed collected during the crop season under report along with six earlier studied isolates (2015-16) were tested for variability on the basis of disease reaction on a set of internationally recognized differential hosts (Table 36).

Table 36. Reaction of differential varieties against different isolates of *Melampsora lini*

Name of Isolate		Reaction on host differentials										
	Burke (L^1)	Stewart (L^2)	Wilden (L^5)	Barnes (L^7)	Bison (L^9)	Golden selection (L^{10})	Williston Brown(M^1)	Ward (M^2)	Bombay (N)	Koto (P)	Akmolinsk (P^1)	CI 2008(M^6)
2016-17												
Kangra 3 (Yol)	S	S	R	R	R	R	S	R	S	R	R	S
Kangra 4 (Rajiana)	R	S	R	R	S	R	S	R	S	R	R	R
2015-16												
Kangra 1	R	R	R	R	R	R	R	R	S	R	R	R
Kangra 2	R	S	R	R	S	R	S	R	S	R	R	R
Malan	R	R	R	R	R	R	R	R	S	R	R	R
Palampur	R	R	R	R	R	R	R	R	S	R	R	R
Jogindernagar	R	R	R	R	R	R	R	R	S	R	R	R
Gurdaspur	R	R	R	R	R	R	S	R	S	R	R	R

The disease reaction of these isolates on internationally used differential hosts revealed the presence of probably four races in the region. The isolates Kangra 1, Malan, Palampur and Jogindernagar constituted same race probably race 43 reported to prevail in the region by earlier workers as all these isolates were only virulent on the variety Bombay attacking resistant gene N. The isolates Kangra 2 and Kangra 4 represented another race virulent on four differentiating lines Stewart (L2), Bison (L9), Williston Brown (M1) and Bombay (N). Kangra 3 isolate represented different race virulent on five hosts namely Burke (L1), Stewart (L2), Williston Brown (M1), Bombay (N) and CI 2008 (M6). Whereas, Gurdaspur isolate represented different race attacking resistant genes Bombay (N) and Williston Brown (M1).

E. Vegetables

Capsicum

Resistance sources to PMMoV: Out of tested germplasm only one line i.e. P1-260429 was found to be resistant and all other lines were susceptible to the virus (Table 37).

Table 37. Reaction of capsicum germplasm against PMMoV under greenhouse conditions

S. No.	Accession Number/ Name	Reaction
1.	Local Landraces- Him Chili-9, Him Chili-43, Him Chili-11, Him Chili-3, Him Chili- Him Chili-41, Him Chili-8, Him Chili-35, Him Chili-15, Him Chili-1, Him Chili- Him Chili-39, Him Chili-18, Him Chili-13, Him Chili-16, Him Chili-4, Him Chili- Him Chili-24, Him Chili-30, Him Chili-21	**Susceptible**
2.	Indigenous Collections- IC-545656, IC-545671, IC-545730, IC-545648, IC-545681, I 545674, IC-545653, IC-545727, IC-545679, IC-545680, IC-545731, IC-545649, I 545728, IC-545729	**Susceptible**
4.	Recommended cultivars- Indira, Nandi, Ujala, Nandita, PhuleJyothi, Natasha, Ind Bharath, Orobelle, IndamSupergold, California Wonder, Indian F1 hybrid, Spin Bomby, IndamLaxmi, Inspiration, Arka Gaurav, Grauda, Vaishali, Tiwari, Surajmuk Paladin, MacKang, Indresh, Mahabharata, Toronto, US, Swarna	**Susceptible**
5.	PI-260429	**Resistant**

Tomato

Management

Target leaf spot: During 2016 an experiment for the management of target spot of tomato using seven fungicides was conducted and minimum disease severity was observed in plants sprayed with tebuconazole (11.1%) followed by copper oxychloride (12.5%), hexaconazole (13.3), carbendazim (13.5%), difenoconazole (14.4%) and mancozeb (17.6%) as compared to control having 76.5 % disease severity. Maximum per cent increase in yield was found in plants sprayed with tebuconazole (61.8 %) followed by copper oxychloride (60.0%) and hexaconazole (58.6%) over control (Table 38).

Table 38. Fungicidal management of target spot of tomato under protected cultivation

Fungicide	Conc (%)	% disease severity	% disease control	Yield kg/plant	% yield increase
*Copper oxychloride	0.3	12.5 (20.7)	83.7	1.50	60.0
*Mancozeb	0.25	17.6(24.8)	76.9	1.30	53.8
Carbendazim	0.1	13.5(21.5)	82.4	1.35	55.6
*Azoxystrobin	0.5	21.6(27.7)	71.7	1.15	47.8
Tebuconazole	0.5	11.1(19.4)	85.5	1.57	61.8
Difenoconazole	0.5	14.4(22.2)	80.6	1.20	50.0
Hexaconazole	0.5	13.3(21.4)	82.6	1.45	58.6

Control	-	76.5(60.9)	-	0.60	-
C.D	-	3.10	-	0.19	

Figures in parenthesis are arc sine transformation values
***** Chemical has CIB crop label claim

Cucumber

Management

Gummy stem blight: Minimum disease severity was found in plants sprayed with Cymoxanil 8%+ mancozeb 64% WP (1.0%) followed by Zineb 75% WP (2.3%) and Azoxystrobin 25 SC (4.3%) as compared to control having 16.7 % disease severity. Similarly maximum per cent disease control was observed in plants sprayed with Cymoxanil 8%+ mancozeb 64% WP(Moximate) (94.0 %) followed by Zineb 75% WP (Indifil Z 78) (86.2%) and Azoxystrobin 25 SC(Amistar) (74.3%) over control (Table 39).

Table 39. Evaluation of fungicides for the management of gummy stem blight of cucumber

Fungicide	Conc (%)	% disease severity	% disease control	Yield kg/ plant
*Zineb 75% WP (Indifil Z 78)	0.25	2.3	86.2	3.58
*Azoxystrobin 25 SC(Amistar)	0.1	4.3	74.3	2.90
*Cymoxanil 8%+ mancozeb 64% WP(Moximate)	0.25	1.0	94.0	4.00
*Benomyl 50% WP(Benlate)	0.05	5.0	70.1	2.63
Carbendazim 75% WP(Bavistin)	0.05	6.7	59.9	2.68
Control	-	16.7	-	2.06
C.D	-	3.75	-	

***** Chemical has CIB crop label claim

Bottlegourd

Management

Gummy stem blight: Soil application of boron followed by three foliar sprays of carbendazim 12% + mancozeb 63% WP resulted in effective disease control of 85.8 per cent, followed by 82.2 per cent disease control by six foliar sprays of carbendazim 12% + mancozeb 63% WP alone. The per cent disease control achieved by foliar sprays alone and in combination with soil application of boron was at par but spraying of bottlegourd crop thrice in combination with soil application of boron was more effective and highly economical in providing protection to crop by delaying the expression of the disease by one month and reducing the number of sprays to half (Table 40).

Table 40. Field evaluation of fungicides against wilt disease of bottlegourd

Treatments	Dose (gm/lt)	Wilt incidence (%)	Disease control (%)

Carbendazim 12% + Mancozeb 63% WP (FS)	2.5	13.3 (21.4)	82.2 (65.2)
Carbendazim 12% + Mancozeb 63% WP (FS) + Boron (SA)	2.5 + 5.0	10.7 (19.1)	85.8 (67.9)
Mancozeb (FS)	2.5	32.6 (34.8)	56.8 (48.9)
Mancozeb (FS) + Boron (SA)	2.5 + 5.0	31.5 (34.1)	58.3 (49.8)
Difenoconazole (FS)	1.0	21.8 (27.8)	71.2 (57.5)
Difenoconazole (FS) + Boron (SA)	1.0 + 5.0	19.2 (25.9)	74.6 (59.8)
Carbendazim (FS)	1.0	28.0 (31.9)	63.0 (52.5)
Carbendazim (FS) + Boron (SA)	1.0 + 5.0	25.0 (30.0)	67.0 (55.0)
Propiconazole (FS)	1.0	26.2 (30.8)	65.3 (54.0)
Propiconazole (FS) + Boron (SA)	1.0 + 5.0	23.9 (29.2)	68.5 (55.8)
Benomyl (FS)	0.5	18.2 (25.3)	75.9 (60.6)
Benomyl (FS) + Boron (SA)	0.5 + 5.0	16.5 (24.0)	78.1 (62.1)
Control	-	75.7 (60.4)	
CD (p=0.05)		1.79	1.95

*Average of three replications, figures in parenthesis are arc sine transformed values; FS=Foliar spray; SA=Soil application (5g/pit)

Palampur

Una

Plate 1: Field trial on evaluation of fungicides against wilt disease of bottlegourd

Bean

Management

Bean anthracnose: Chemical treatment with bavistin was found to be more effective as it resulted in 96.67 per cent germination without any seed borne infection. Among bioagents, bioagents in

combination i.e., Panchgavya + *Trichoderma viride*, *Trichoderma viride* + *Pseudomonas* fluorescence were noticed to be best as they gave 96.67 and 97.33 per cent germination along with 2.75 and 4.79 seed borne infection (Table 41). Individually Panchgavya, *Trichoderma harzianum* & *T. viride* were also effective resulting in 96.67, 97.33 and 96.67 per cent germination and 3.45, 9.25 and 5.17 per cent seed borne infection.

Table 41. Effect of various bioagents and organic inputs on seed germination and seed borne infection of *C. lindemuthianum* causing bean anthracnose under *in vitro* conditions

Sr. No.	Treatments	Germination %	Seed borne infection	Disease score
T1	*Trichoderma harzianum*	97.33 (80.72)	9.25 (3.16)	4.11 (2.24)
T2	*Trichoderma viride*	96.67 (79.82)	5.17 (2.39)	3.45 (2.08)
T3	*Pseudomonas fluorescence*	94.67 (77.27)	5.28 (2.43)	3.52 (2.09)
T4	*Trichoderma harzianum* + *Trichoderma viride*	91.33 (72.87)	6.2 (2.56)	2.19 (1.73)
T5	*Trichoderma harzianum*+ *Pseudomonas fluorescence*	95.33 (77.75)	2.45 (1.82)	3.15 (2.00)
T6	*Trichoderma viride* + *Pseudomonc fluorescence*	97.33 (80.72)	4.79 (2.32)	3.42 (2.08)
T7	Panchgavya only	96.67 (79.57)	3.45 (2.07)	3.1 (2.00)
T8	Panchgavya+ *Trichoderma harzianum*	95.00 (77.09)	5.61 (2.49)	3.33 (2.04)
T9	Panchgavya+ *Trichoderma viride*	96.67 (79.57)	2.75 (1.79)	2.07 (1.73)
T10	Panchgavya+ *Pseudomonas fluorescence*	92.67 (74.29)	1.44 (1.48)	2.88 (1.91)
T11	Bavistin	96.67 (79.57)	0.00 (1.00)	0.00 (1.00)
T12	Healthy seed	97.33 (80.72)	0.00 (1.00)	0.00 (1.00)
T13	Infected seed	66.67 (54.74)	25.00 (4.18)	6.5 (2.31)
T14	Jeevamrit	70.67 (57.46)	3.77 (1.82)	2.83 (1.73)
CD		5.05	0.78	0.13

Pea

Evaluation of germplasm

Powdery mildew: Three hundred and ten germplasm lines were evaluated under net house and *in vitro* conditions against *Erysiphe pisi* and 31 lines *viz.*, HFPU, P-1797, P-1783, P-1052, HFP-7, HFP-8, P-1808, P-1820, P-1813, P-1377, P-1422-1, P-1811, IPF-99-25, KMNR-400, LFP-566, LFP-569, LFP-552, LFP-573, JP-501-A/2, PMR-21, KMNR-894, P-1280-4, P-1436-9, P-200-11, IPFD-99-13, HVDP-15, DPP-43-2, LFP-517, LFP-570, JP Ajjila & JP-15 were found to be resistant.

Refinement of differential set to study pathogenic variability: The pathogenic variability was studied *in vitro* by screening 54 lines against 6 powdery mildew isolates individually. Depending upon their differential reaction, 13 lines were selected in order to refine the existing differential set. These 13 lines were further screened with 10 isolates and finally 4 lines were selected and added into existing differential set. Finally the refined differential set of 11 lines *viz.*, JI-2302, EC-329561, NIC-11181, EC- 292164, PB-29B, JI- 2480 and EC-334160, Palam Priya, PMR-10, VN-53 and EC-381866 with Lincoln as check was selected to study the pathogenic variability of pea powdery mildew.

Pathogenic variability: The virulence pattern of the 24 isolates of *E. pisi* was studied on refined differential set comprising of 11 lines *viz.*, JI-2302, EC- 329561, NIC-11181, EC- 292164, PB-29B, JI- 2480, EC-334160, Palam Priya, PMR-10, VN-53, EC-381866 and Lincoln as check using detached leaf method under *in vitro* conditions. Twenty four pea powdery mildew isolates were grouped into 17 pathotypes (PMP-1 to PMP-17) on the basis of their reaction on the set of 11 differential lines (Table 42).

Table 42. Grouping of 24 isolates of pea powdery mildew into pathotypes

Designation of Pathotypes	Isolates	
	No.	Location/Place of Collection
PMP-1	2	Palampur and Dalang Maidan
PMP-2	3	Trilokinath, Gondhla and Fuktal
PMP-3	2	Baga Chunogi and Janjehali
PMP-4	2	Chailchowk and Samtana
PMP-5	2	Keylong and Sisoo
PMP-6	2	Sangla and Kawang
PMP-7	1	Kutheda
PMP-8	1	Berthin
PMP-9	1	Akrot
PMP-10	1	Kukumseri
PMP-11	1	Koksar
PMP-12	1	Karpet
PMP-13	1	Jalma
PMP-14	1	Gompa Thang
PMP-15	1	Khangsar
PMP-16	1	Udgos
PMP-17	1	Tingrit

Inheritance of resistance: To study the inheritance of resistance F_2 population of eleven crosses (resistant x susceptible) were evaluated with 4 pathotypes of *E. pisi*. Approximately 100 F_2 seeds of each cross were sown under polyhouse conditions for evaluation of resistance to powdery mildew. *In vitro* evaluation of F_2 was carried out under greenhouse conditions on detached leaves. The data were classified into discrete class frequencies and tested for goodness of fitness with chi-square test. The observed and expected frequencies of resistant and susceptible reaction of parent and F_2s are given in Table 43.

Table 43. Inheritance of resistance in F_2 population of pea against powdery mildew

Cross	Pathotypes	Total plants	Resistant plants	Susceptible plants	Chi-sq. value	Expected Ratio (R:S)	Table value
DPP-362 x Lincoln	PMP-5	95	25	70	0.0877*	1:3	3.841
	PMP-6	93	24	69	0.0322*	1:3	3.841
	PMP-14	95	31	64	2.9508*	1:3	3.841
	PMP-16	93	29	64	1.8960*	1:3	3.841
	Average	**94**	**27**	**66**	**0.8085***	**1:3**	**3.841**
JP-501-A/2 x Lincoln	PMP-5	89	24	65	0.1835*	1:3	3.841
	PMP-6	86	22	64	0.0155*	1:3	3.841
	PMP-14	84	24	60	0.5714*	1:3	3.841
	PMP-16	85	23	62	0.1921*	1:3	3.841
	Average	**86**	**23**	**62**	**0.2015***	**1:3**	**3.841**
PMR -21 x Lincoln	PMP-5	97	27	70	0.4158*	1:3	3.841
	PMP-6	95	28	67	1.0140*	1:3	3.841
	PMP-14	92	28	64	1.4492*	1:3	3.841

	PMP-16	91	28	63	1.6153*	1:3	3.841
	Average	**93**	**27**	**66**	**0.8064***	**1:3**	**3.841**
KMNR – 894 x Lincoln	PMP-5	75	20	55	0.1111*	1:3	3.841
	PMP-6	78	21	57	0.1538*	1:3	3.841
	PMP-14	75	20	55	0.1111*	1:3	3.841
	PMP-16	75	22	53	0.7511*	1:3	3.841
	Average	**75**	**20**	**55**	**0.1111***	**1:3**	**3.841**
JI - 2480 x Lincoln	PMP-5	92	25	67	0.2318*	1:3	3.841
	PMP-6	87	25	62	0.6475*	1:3	3.841
	PMP-14	89	27	62	1.3520*	1:3	3.841
	PMP-16	85	24	61	0.4745*	1:3	3.841
	Average	**88**	**25**	**63**	**0.5454**	**1:3**	**3.841**
Acacia x Lincoln	PMP-5	82	24	58	0.7967*	1:3	3.841
	PMP-6	84	22	62	0.0634*	1:3	3.841
	PMP-14	84	22	62	0.0634*	1:3	3.841
	PMP-16	81	24	57	0.9259*	1:3	3.841
	Average	**82**	**23**	**59**	**0.4065***	**1:3**	**3.841**
EC-381866-1 x Lincoln	PMP-5	87	25	62	0.6475*	1:3	3.841
	PMP-6	91	28	63	1.6153*	1:3	3.841
	PMP-14	89	24	65	0.1835*	1:3	3.841
	PMP-16	89	28	61	1.9812*	1:3	3.841
	Average	**89**	**26**	**62**	**0.9700***	**1:3**	**3.841**
Mr. Big x Lincoln	PMP-5	75	19	56	0.0044*	1:3	3.841
	PMP-6	75	22	53	0.7511*	1:3	3.841
	PMP-14	78	22	56	0.4273*	1:3	3.841
	PMP-16	77	23	54	0.9740*	1:3	3.841
	Average	**76**	**21**	**54**	**0.3684***	**1:3**	**3.841**
PMR – 10 x Lincoln	PMP-5	81	22	59	0.2016*	1:3	3.841
	PMP-6	83	23	60	0.3253*	1:3	3.841
	PMP-14	85	26	59	1.4156*	1:3	3.841
	PMP-16	81	24	57	0.9259*	1:3	3.841
	Average	**82**	**23**	**58**	**0.5040***	**1:3**	**3.841**
JI – 2302 x Lincoln	PMP-5	80	24	56	1.0666*	1:3	3.841
	PMP-6	86	24	62	0.3875*	1:3	3.841
	PMP-14	83	25	58	1.1606*	1:3	3.841
	PMP-16	80	24	56	1.0666*	1:3	3.841
	Average	**82**	**24**	**58**	**0.7967***	**1:3**	**3.841**
JI – 1766 x Lincoln	PMP-5	83	27	56	2.5100*	1:3	3.841
	PMP-6	88	26	62	0.9696*	1:3	3.841
	PMP-14	87	23	64	0.9578*	1:3	3.841
	PMP-16	85	22	63	0.0352*	1:3	3.841
	Average	**85**	**24**	**61**	**0.4745***	**1:3**	**3.841**

*= Accepted

Thus, studies on inheritance of resistance in 11 lines *viz.*, DPP-362, JP-501-A/2, PMR-21, KMNR-894, JI-2480, Acacia, EC-381866-1, Mr. Big, PMR-10, JI-2302 and JI-1766 showed that resistance is governed by a single recessive gene against pea powdery mildew caused by *E. pisi*.

Allelic Relationship: To reveal the allelic relationship of the identified sources of resistance with known *er* gene carrier pea lines having *er1* (JI-2302), *er2* (JI-2480) and 3 resistant accession *viz.*, Acacia, PMR-10, and EC-381866-1 along with susceptible check Lincoln were used and their infection type and reaction types have been presented in Table 44. The selected 3 resistant lines were crossed with JI-2302 (*er1*) and JI-2480 (*er2*) in 8 cross combinations *viz.*, JI-

2480 x Acacia, JI-2480 x PMR-10, JI-2480 x EC-381866-1, JI-2480 x Lincoln, JI-2302 x Acacia, JI-2302 x PMR-10, JI-2302 x EC-381866-1 and JI-2302 x Lincoln during 2014 and 2015 under net house and green house. The data revealed that cross JI-2480 x Acacia produced infection type '2' thus, giving resistant reaction against powdery mildew isolate, revealing that resistance in line Acacia is controlled by *er2* gene. Crosses JI-2480 x PMR-10 and JI-22480 x EC-381866-1 were found to be susceptible against powdery mildew giving infection type '3' (susceptible) revealing that resistance in lines PMR-10 and EC-381866-1 is not conferred by gene *er2*. While cross JI-2480 x Lincoln gave highly susceptible reaction. In case of cross JI-2302 x Acacia infection type '3' (susceptible) was produced revealing that in line Acacia resistance is not controlled by gene *er1*. Crosses JI-2302 x PMR-10 and JI-2302 x EC-381866-1 produced infection type '2' (resistant) which showed that in lines PMR-10 and EC-381866-1 resistance is conferred by gene *er1*. While cross JI-2302 x Lincoln gave highly susceptible reaction.

Table 44. Evaluation of F_1 population for allelic relationship with known *er* genes against pea powdery mildew caused by *Erysiphe pisi*

S.No.	Cross	Infection Type against PM-1	Reaction Type
1.	JI-2480 x Acacia	2	R
2.	JI-2480 x PMR-10	3	S
3.	JI-2480 x EC-381866-1	3	S
4.	JI-2480 x Lincoln	4	S
5.	JI-2302 x Acacia	3	S
6.	JI-2302 x PMR-10	2	R
7.	JI-2302 x EC-381866-1	2	R
8.	JI-2302 x Lincoln	4	S
Parents			
1.	JI-2480 (*er2*)	1	R
2.	JI-2302 *(er1)*	1	R
3.	Lincoln	4	S

The resistant reaction obtained in cross JI-2480 x Acacia indicated that line Acacia might be having *er2* gene as in line JI-2480. Similarly, in case of JI-2302 x PMR-10 and JI-2302 x EC-381866-1 the resistant reaction showed that resistance in lines PMR-10 and EC-381866-1 is controlled by *er1* gene as in line JI-2302.

F. Forages

Resistance sources

Maize: Out of 23 entries of maize evaluated against leaf blight 5 were found resistant.

Cowpea: Out of 19 entries of cowpea evaluated against blight 16 entries were found moderately resistant. However, none of the cowpea entries was found resistant to root rot, whereas, 6 entries were found moderately resistant.

Oats: During *Rabi* 70 lines of oats were evaluated and 5 entries were found moderate resistant against powdery mildew.

Berseem: In berseem, 14 entries were evaluated and all were found either resistant or moderately resistant to root rot

The over view of resistant stocks in different nurseries is given in Table 45.

Table 45. Field screening of *Kharif* & *Rabi* breeding material of fodder crops

Crop	Name of Trial	Entries	No of Resistant	Moderate Resistant
Maize (Leaf blights)	IVTM	12	2 (IVTM- 9 & 12)	9 (IVTM-1 to 7, 9 & 11)
	AVTM (1 &2)	6	2 (AVTM-3 & 6)	3 (AVTM-2,4 &5)
	AVTM (Seed)	5	1 (AVTM-2)	4 (AVTM-1,3,4 &5)
Cowpea (Root rots)	IVTC	10	-	3 (IVTC-2, 5 &13)
	AVTC	9	-	3 (AVTC- 1, 8 & 10)
Oats (Powdery mildew)	IVTO SC	12	-	
	IVTO(MC)	10		
	IVTO (Dual)	11		
	AVTO(SC)-2	11		4 (AVTO(SC)-2-2, 6, 7 & 9)
	AVTO(SC)-2 (Seed)	11		1 (AVTO(SC)-2 (S)-11)
	AVTO-1(MC)	8		
	AVTO(SC)-1	10		
Beseem(root rot)	IVT B	7	3 (IVTB- 4,5 &6)	4 (IVTB-1,2,3 and 7)
	AVTB	4	All	-

Maize

Management

Banded leaf & sheath blight: Seed treatment with carbendazim followed by two sprays of carbendazim was found highly effective giving 92% disease control of BLSB and 20% increase in yield over check in fodder maize. This treatment was followed by seed treatment with carbendazim and one spray each of carbendazim and *P. fluorescens* which provided 79.5% disease control and 15.2% increase in yield over check. Seed treatment with *T. viride* alone and in combination with two sprays of *P. fluorescens* were also effective as compared to control and gave 30.6 and 45.4% disease control and 3.9 & 6.3% increase in the GFY over check, respectively (Table 46).

Table 46. Integrated disease management of BLSB of fodder maize

Treatment	BLSB		GFY	
	Incidence (%)	Control (%)	(q/h)	Increase (%)
Seed treatment with *T. viride*@ 5g/kg	12.2	30.6	275.3	3.9
Seed treatment with carbendazim@ 2 g/kg seed	6.5	63.1	285.7	7.8

T_1 + Two spray of carbendazim@ 1g/l	4.5	74.4	295.7	11.5
T_1 + Two foliar sprays with *P. fluorescens*@ 5g (CFU 10^7) /l	9.6	45.4	281.7	6.3
T_2 + Two spray of carbendazim@ 1g/l	1.4	92.0	318.0	20
T_2 + Two foliar sprays with *P. fluorescens*@ 5g (CFU 10^7) /l	5.7	67.6	281.7	6.3
T_1 + One spray each of carbendazim@ 1g/l and *P. fluorescens* @ 5g (CFU 10^7) /l	4.6	73.9	297.7	12.3
T_2 + One spray each of carbendazim@ 1g/l and *P. fluorescens* @ 5g (CFU 10^7) /l	3.6	79.5	305.3	15.2
Control	17.6	0	265.0	0
CD	1.04		8.7	

Cowpea

Management

Root rot & foliar diseases: The most effective treatment i.e. seed treatment with tebuconazole 2DS @ 1g/ kg seed + NSKP (50 g/ kg seed) followed by foliar spray of propiconazole @ 1ml/ l at 15 days interval was validated for the management of diseases *viz.*, root rot, anthracnose and leaf blight of cowpea. It was observed that root rot incidence and leaf blight severity was maximum in late sown crop, whereas anthracnose was maximum in early sown crop. The maximum yield was obtained in the normal sown crop with an increase of 39.11% over control as compare to early and late sown crop. The root rot was controlled by 69.7% in early sown crop followed by 62.5% in normal and 55.4% in late sown crop, however, the disease control was 68.0, 76.2 & 77.4 percent in anthracnose and 77.7, 76.6 and 72.3 percent in case of leaf blight respectively, in three dates of sowing (Table 47) .

Table 47. Integrated management of root rot and foliar diseases of forage cowpea

Treatment		Severity/ incidence						Yield (q/ha)	
Main (DOS)	Sub	Root rot		Anthracnose		Leaf blight		GFY	
		Incidence (%)	% Control	Severity (%)	% Control	Severity (%)	% Control	Yield	% Increase
04.06.16	T_1	3.56 (10.82)	69.7	7.56	68.0	4.83	77.7	91.96	17.7
	T_2	11.73 (20.01)	-	23.60	-	21.67	-	78.10	-
19.06.16	T_1	8.36 (16.79)	62.3	7.83	76.2	6.50	76.6	98.67	39.1
	T_2	22.20 (28.09)	-	32.93	-	27.80	-	70.93	-
04.07.16	T_1	17.90 (25.01)	55.4	2.96	77.4	3.80	72.3	73.50	17.5
	T_2	40.13 (39.29)	-	13.10	-	13.73	-	60.67	-
CD		1.65	-	0.90	-	1.39	-	4.84	-

Treatments:

T_1 =Seed treatment with tebuconazole 2DS @ 1g/kg seed + NSKP (50 g/kg seed) followed by foliar spray of propiconazole @ 1ml/l at 15 days interval.

T_2 =No treatment

Date of Sowing

T_A = 1st Date of sowing i.e. 15 days before Normal Days of Sowing

T_B = 2nd Date of sowing i.e. Normal Days of Sowing

T_C = 3rd Date of sowing i.e. 15 days after Normal Days of Sowing

Sorghum

Management

Foliar diseases: Among the 11 treatments for the management of Zonal leaf spot, the seed treatment with carbendazim followed by two sprays of propiconazole was found highly effective giving 89.9% disease control and 25.8% increase in the yield over check. This treatment was followed by seed treatment with *T. viride* and two spray of propiconazole which gave 87.9% disease control with 23.2% increase in the yield over check (Table 48).

Table 48. Integrated disease management of foliar diseases of forage sorghum

Treatment	Zonate leaf spot		GFY	
	Disease severity (%)	Control (%)	(q/h)	Increase (%)
Seed treatment with *T. viride* @ 5g/kg	51.8 (45.99)	20.7	253.3	4.2
Seed treatment with carbendazim @ 2 g/kg seed	41.9 (40.32)	35.9	254.3	4.6
Two foliar sprays with neem bio-pesticide (Achook) @ 3%	33.8 (35.51)	48.3	260.7	7.2
Two foliar sprays with propiconazole @ 1g/l	10.4 (18.82)	84.1	293.7	20.8
T_1 + Two foliar sprays with neem bio-pesticide (Achook) @ 3%	28.8 (32.46)	55.9	275.3	13.3
T_1 + Two foliar sprays with propiconazole @ 1g/l	7.9 (16.37)	87.9	299.3	23.2
T_2 + Two foliar sprays with neem bio-pesticide (Achook) @ 3%	24.6 (29.64)	62.4	275.7	13.5
T_2 + Two foliar sprays with propiconazole @ 1g/l	6.6 (14.82)	89.9	305.7	25.8
T_1 + One spray each of neem bio-pesticide (Achook) @ 3% and propiconazole @ 1g/l	18.4 (25.41)	71.9	293.0	20.6
T_2 + One spray each of neem bio-pesticide (Achook) @ 3% and propiconazole @ 1g/l	14.6 (22.42)	77.7	288.0	18.5
Control	65.4 (53.96)	0	243.0	0
CD	2.32		7.09	

Red clover

Management

Soil bonre and powdery mildew diseases: Seed treatment with carbendazim @ 2 g/ kg seed followed by three foliar spray of hexaconazole @ 0.1 % gave best management of powdery mildew having 3.8 percent disease severity and 93.9 per cent disease control with 45.7 per cent increase in yield as compared to control. Seed treatment with carbendazim @ 2 g/ kg seed followed by and one spray each of *Trichoderma*, wettable sulphur and hexaconazole provided best management of soil borne diseases (2.2 % severity and 86.7 % disease control) and good control of powdery mildew (6.0 % severity and 90.4 % disease control) with 62.9 per cent increase in yield over check (Table 49).

Table 49. Management of soil bonre and powdery mildew diseases in red clover seed crop

Treatment	% Severity or incidence				Yield	
	Powdery mildew	% control	Soil borne diseases	% control	(q/ha)	% increase
T_1 =Seed treatment with *Trichoderma* @ 5g/kg seed	62.6 (52.3)	-	8.3	50.0	0.80	14.3
T_2 = Seed treatment with carbendazim @ 2 g/kg seed	53.7 (47.1)	14.4	4.4	73.5	0.84	20.0
T_3= T_1 + Three foliar spray of *Trichoderma* @ 0.5%	40.4 (39.7)	35.6	7.1	57.2	0.86	22.9
T_4= T_2 + Three foliar spray of *Trichoderma* @ 0.5%	38.4 (38.3)	38.8	4.2	74.7	0.93	32.9

T_5= T_1 + Three foliar spray of wettable sulphur@ 0.3%	12.7 (20.9)	79.7	6.6	60.2	0.98	40.0
T_6 = T_2 + Three foliar spray of wettable sulphur@ 0.3%	11.6 (19.9)	81.5	3.9	76.5	0.94	34.3
T_7 = T_1 + Three foliar spray of hexaconazole @ 0.1 %	7.0 (15.4)	88.8	6.9	58.4	0.91	30.0
T_8 = T_2 + Three foliar spray of hexaconazole @ 0.1 %	3.8 (11.2)	93.9	3.8	77.1	1.02	45.7
T_9 = T_1 + One spray each of *Trichoderma,* wettable sulphur and hexaconazole	5.3 (13.3)	91.5	6.6	60.2	1.00	42.9
T_{10} = T_2 + One spray each of *Trichoderma,* wettable sulphur and hexaconazole	6.0 (14.2)	90.4	2.2	86.7	1.14	62.9
T_{11} =Control	62.7 (52.3)	-	16.6	-	0.70	-
CD (5%)	1.90		1.27		0.11	

G. Protected Cultivation

Management:

Target leaf spot of Tomato: Experiment on the management of target spot of tomato using seven fungicides revealed that minimum disease severity was observed in plants sprayed with tebuconazole (11.1%) followed by copper oxychloride (12.5%), hexaconazole (13.3), carbendazim (13.5%), difenoconazole (14.4%) and mancozeb (17.6%) as compared to control having 76.5 % disease severity. Maximum per cent increase in yield was found in plants sprayed with tebuconazole (61.8 %) followed by copper oxychloride (60.0%) and hexaconazole (58.6%) over control (Table 50).

Table 50. Fungicidal management of target spot of tomato under protected cultivation

Fungicide	Conc.	% disease severity	% disease control	Yield kg/plant	% yield increase
*Copper oxychloride	0.3	12.5 (20.7)	83.7	1.50	60.0
*Mancozeb	0.25	17.6(24.8)	76.9	1.30	53.8
Carbendazim	0.1	13.5(21.5)	82.4	1.35	55.6
*Azoxystrobin	0.5	21.6(27.7)	71.7	1.15	47.8
Tebuconazole	0.5	11.1(19.4)	85.5	1.57	61.8
Difenoconazole	0.5	14.4(22.2)	80.6	1.20	50.0
Hexaconazole	0.5	13.3(21.4)	82.6	1.45	58.6
Control	-	76.5(60.9)	-	0.60	-
C.D	-	3.10	-	0.19	

Figures in parenthesis are arc sine transformation values
***** Chemical has CIB crop label claim

Management

Gummy stem blight of cucumber: Experiment on the management of gummy stem blight of cucumber using five fungicides revealed that minimum disease severity was observed on plants sprayed with cymoxanil 8% + mancozeb 64% WP (1.0%) followed by Zineb 75% WP (2.3%), and azoxystrobin 25 SC (4.3%) as compared to control having 16.7 % disease severity. Maximum per cent disease control was observed in plants sprayed with Cymoxanil 8% + mancozeb 64% WP(Moximate) (94.0 %) followed by Zineb 75% WP (Indifil Z 78) (86.2%) and Azoxystrobin 25 SC(Amistar) (74.3%) over control (Table 51).

Table 51. Evaluation of fungicides for the management of gummy stem blight of cucumber

Fungicide	Conc.	% disease severity	%disease control	Yield kg/ plant
*Zineb 75% WP (Indifil Z 78)	0.25	2.3	86.2	3.58
*Azoxystrobin 25 SC (Amistar)	0.1	4.3	74.3	2.90
*Cymoxanil 8%+ mancozeb 64% WP (Moximate)	0.25	1.0	94.0	4.00

*Benomyl 50% WP (Benlate)	0.05	5.0	70.1	2.63
Carbendazim 75% WP (Bavistin)	0.05	6.7	59.9	2.68
Control	-	16.7	-	2.06
C.D	-	3.75	-	

***** Chemical has CIB crop label claim

Demonstration on integration of crop production & protection technologies

i) **Management of capsicum diseases:** Root/collar rot incidence appeared at Palampur just after transplanting which was successfully managed with drenching copper oxychloride @ 0.3%. The first incidence of powdery mildew was observed in the fourth week of June and the same has been contained by giving three sprays of fungicides i.e. tebuconazole (0.05%), dinocap and hexaconazole.

ii) **Management of tomato diseases**: Powdery mildew attack the crop and two sprays of azoxytrobin (@ 0.1%) effectively manage the disease while one spray of Equation Pro (Famoxadone 16.6% + Cymoxanil 22.1% SC) @ 0.1% as foliar application effectively managed the late blight and leaf spots rot of tomato.

iii) **Management of cucumber diseases:** Powdery mildew of cucumber appeared at Palampur and was managed with the application of azoxytrobin @ 0.1%. The downy mildew appeared at on cv. Kian and was effectively managed with two sprays of Moximate (Cymoxanil 8% + mancozeb 64% WP) @ 0.25% at 15 days interval.

Collar rot of capsicum

Target spot of cucumber

Plate 2. New emerging fungal diseases of capsicum and cucumber in polyhouse

H. Seed Pathology

Status of seed borne diseases

Rice: Out of 171 rice seed samples collected from five districts of Himachal Pradesh 32 samples were found infected with **bunt** incidence ranging between 0.1 to 0.4 percent, maximum being in district Una. This year there was almost 50 percent increase in number of sample showing rice bunt over the previous year. **Grain discolouration** incidence was recorded in almost all the areas with incidence between 5.0 to 45.00 per cent. In different seed samples, nine fungi viz. *Fusarium solani* (0 to 0.7%), *Penicillium* sp. (0 to 4%), *Alternaria alternata* (0 to 3%), *Curvularia lunata* (0 to 0.7%), *Dreschlera oryzae* (0 to 1.1%), *Aspergillus* sp. (0 to 0.2%), *Helminthosporium* sp. (0 to 0.1%), *Magnoporthe oryzae* (0 to 0.5%) and *Phoma* sp. (0 to 0.6%) were recorded.

The observations made on occurrence of diseases on hybrid rice and some improved varieties of rice showed wide distribution of **false smut** in different varieties across the locations surveyed with severity ranging from 3-5 on 0-9 point scale. The hybrid PAC 807 showed high incidence of **neck blast** in some of the locations (Table 52) which used to be almost resistant previously and severity of neck blast on this hybrid ranged from 10 to 50 per cent with a maximum at Massal area of Nagrota Bagwan in district Kangra. **BLB** was not observed on hybrids this year, whereas **sheath rot** and **sheath blight** was in traces in some of the locations.

Table 52. Status of seed borne diseases in hybrid rice varieties cultivated in Himachal Pradesh

Location District/ region	Variety	False Smut Incidence (%)	False Smut Incidence (Scale 0-9)	BLB Severity (%)	Neck Blast Incidence	Sheath Rot	Sheath Blight Incidence	Brown Spot
Kangra								
Rait	Arize 6129	7.5	3	-	-	-	-	-
Mainjha	D 834	12.5	5	-			T	-
Mainjha	PAC 807	7.5	3	-	32.5	T	T	-
Massal	PAC 807	8.0	3	-	50.0	-	-	-
Rehan	Godrej 4011	-	-	-	-	-	-	5.0
Bhedu Mahadev	PAC 807	5.0	3	-	35.0	-	-	-
Sirmour								
Kotri Beas	Arize 6444	20.0	5	-	20.0	-	5	3.5
Akalgarh	Arize 6444	2.0	3	-		5	-	-
Akalgarh	Hyb. 786	-	-	-	10.0	T	-	25.0
Bukhri	Arize 6444	2.0	3	-	-	5	-	-
Fatehpur	Arize 6444	2.0	3	-		5	-	-
Bohlion	Sudha 999	2.0	3	-	-	-	-	2.0
Solan								
Nalagarh	Arize 6444	10.0	5	-	-	-	-	-
Dharampur	Hyb. 748	7.5	5	-	-	-	-	-

Wheat: The incidence of **loose smut** in farmers own saved seed was assessed in 336 samples, collected from different wheat growing areas of the state. Out of 336 samples, 21 samples were found to possess loose smut infection with overall incidence ranging between 0.0 to 0.4 per cent with a mximum of 0.4 % in Balad area of district Kangra and Rori (Dharmpur area) of district Solan. However, overall incidence was low in the state. Out of 355 samples collected from seven districts of Himachal Pradesh, Karnal bunt was recorded in only 46 seed samples with an incidence ranging from 0.1 to 8.1 percent with a maximum incidence of 8.1% in Lakhroon area of Una district. However 24 samples showed infection above the certification level.

Role of seed infection on seed germination and disease incidence in crops

In three crops viz., chili, common bean (Rajmash) and rice, the correlation of seed infection levels with the seed germination and seed mortality was studied under *in vitro* conditions using rolled paper towel (Rice and Common bean) and blotter method (chili). The seeds showing necrosis and discoloration was marked as infected seed and the different infection levels were fixed as 0-25, 26-50, 50-75 and >75%. The seed germination in all the three crops decreased with the increase in infected seed area along with higher seed mortality (Fig 2).

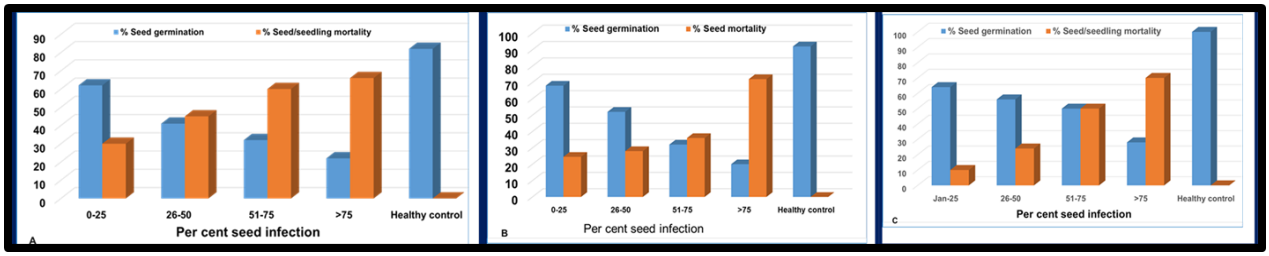

Fig 2. Effect of seed infection levels on disease in nursery and seed health (A; Chili; B: Common bean C: Rice)

Detection technoque for seed borne pathogens (PCR based protocol)

A PCR based ptrotocol for the detection of PMMoV a *Tobamovirus* from chilli seeds through RT-PCR using the viral Coat Protein (CP) specific primers was standardized. Seeds were harvested from the virus infected plants indexed through DAS-ELISA for the presence of the virus. The infected and healthy chili seed samples were crushed to a fine powder in chilled pestle and mortar using 750 µl Trizol reagent to extract the total RNA. The total RNA isolated was checked on agarose gel for its quality and then subjected to cDNA synthesis using MMLV reverse transcriptase. The cDNA was amplified using the viral coat protein specific primers (F5'CCAATGGCTGACAGATTACG-3'and R5'CAACGACAACCCTTCGATTT-3') with initial denaturation of 94°C for 4 min followed by 35 cycles of 94°C for 15 sec, 48°C for 40 sec and 72°C for 1 min and final extension of 7 min at 72°C to confirm the presence of PMMoV. The PCR product was checked on 1.2% agarose gel along with a negative control (water used as template) and positive control (plasmid isolated from clone having CP gene used as template) (Fig. 3). The amplification of ~740 bp product was observed in both the seed sample and positive control while no band was observed in negative control however, further validation of the protocol is needed to use it for routine purpose.

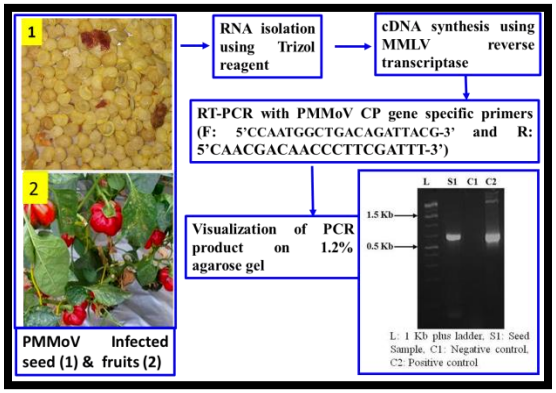

Fig 3. PCR based protocol for the detection of *Pepper mild mottle virus* (PMMoV) from chili seeds

Management

Seed borne infection of bean anthracnose: In order to find a suitable non-chemical method of managing the seed borne infection of bean anthracose pathogen in bean an experiment was conducted to see the effect of bioagents, organic inputs like panchgabya and Jeevamrit using susceptible variety Jawala (Table 53). Chemical treatment with bavistin was found to be more effective as it resulted in the 96.67 per cent germination without any seed borne infection. Among the bioagents , the bioagents in combination i.e., Panchgavya+ *Trichoderma viride, Trichoderma viride +Pseudomonas* fluorescence were noticed to be best as they gave 96.67 and 97.33 per cent germination along with the 2.75 and 4.79 seed borne infection. In alone Panchgavya, *Trichoderma harzianum* & *T. viride* was also effective as they resulted in the 96.67, 97.33 and 96.67 per cent germination with the 3.45, 9.25 and 5.17 per cent seed borne infection.

Table 53. Effect of various bioagents and organic inputs on seed germination and seed borne infection of *C. lindemuthianum*

S. No.	Treatments	Germination %	Seed borne infection	Disease score
T1	*Trichoderma harzianum*	97.33 (80.72)	9.25 (3.16)	4.11 (2.24)
T2	*Trichoderma viride*	96.67 (79.82)	5.17 (2.39)	3.45 (2.08)
T3	*Pseudomonas fluorescence*	94.67 (77.27)	5.28 (2.43)	3.52 (2.09)
T4	*Trichoderma harzianum* + *Trichoderma viride*	91.33 (72.87)	6.2 (2.56)	2.19 (1.73)
T5	*Trichoderma harzianum*+ *Pseudomonas fluorescence*	95.33 (77.75)	2.45 (1.82)	3.15 (2.00)
T6	*Trichoderma viride* + *Pseudomonas fluorescence*	97.33 (80.72)	4.79 (2.32)	3.42 (2.08)
T7	Panchgavya only	96.67 (79.57)	3.45 (2.07)	3.1 (2.00)
T8	Panchgavya+ *Trichoderma harzianum*	95.00 (77.09)	5.61 (2.49)	3.33 (2.04)
T9	Panchgavya+ *Trichoderma viride*	96.67 (79.57)	2.75 (1.79)	2.07 (1.73)
T10	Panchgavya+ *Pseudomonas fluorescence*	92.67 (74.29)	1.44 (1.48)	2.88 (1.91)
T11	Bavistin	96.67 (79.57)	0.00 (1.00)	0.00 (1.00)
T12	Healthy seed	97.33 (80.72)	0.00 (1.00)	0.00 (1.00)
T13	Infected seed	66.67 (54.74)	25.00 (4.18)	6.5 (2.31)
T14	Jeevamrit	70.67 (57.46)	3.77 (1.82)	2.83 (1.73)
CD		5.05	0.78	0.13

I. Molecular Plant Pathology

Detection of *Stagonospora nodorum* with molecular markers

The DNA of twenty five isolates from samples pertaining to different locations, produced 448-bp fragment when amplified with JB433 (5´-ACACTCAGTAGTTTACTACT-3´) and JB434 (5´-TGTGCTGCGCTTCAATA-3´) specific primers (Fig 4).

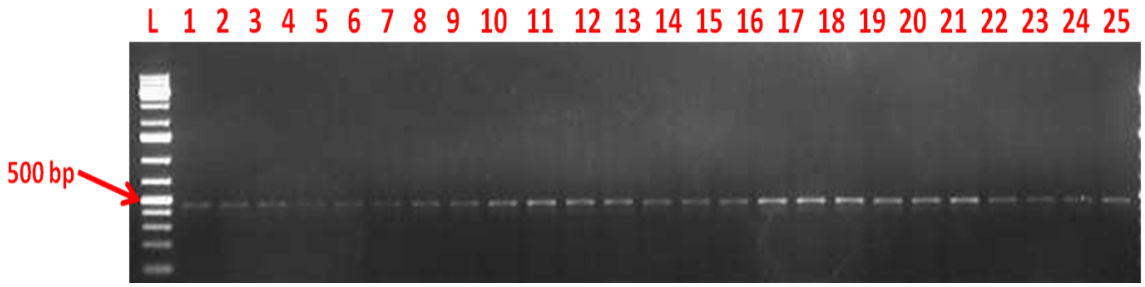

Fig 4. Amplification profile of twenty five isolates of *Stagonospora nodorum*

Evolutionary analysis was done by using MEGA7 (Fig 5). In phylogenetic analysis, the sequences taken from NCBI Genbank along with test isolate clustered in two groups, separating *Zymoseptoria tritici* as out-member and all other species in another group. Further, within this group two sub-groups were formed in which all the *nodorum* species were clustered together along with the test isolate and *P. cumpignensis, P. uniseptata, P. nigrans, P. avenaria* and *P. avenae* were grouped separately. Identification of the test pathogen based on morpho-cultural traits as *S. nodorum* was further confirmed through rDNA analysis which shows the importance of DNA barcode marker(s) for fungal taxonomy.

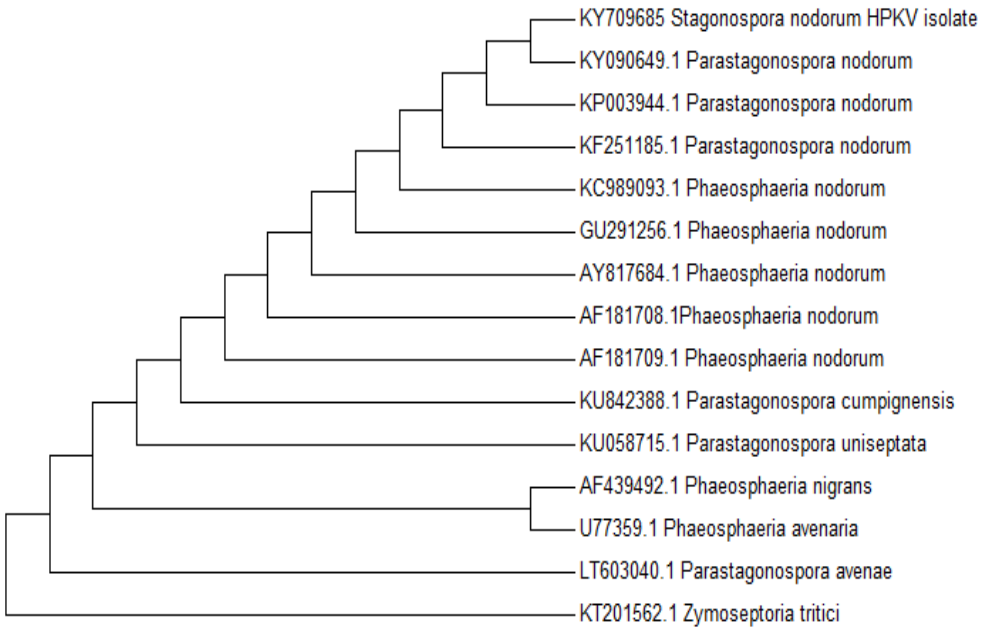

Fig 5. rDNA sequence based phylogenetic analyses revealing evolutionary relationships among different *Stagonospora* species using Neighbour Joining method conducted in MEGA 7

The test pathogen showed 98 per cent homology with other reported *S. nodorum* isolates throughout the world on molecular basis and thus, identity of present isolate(s) was established as *Stagonospora nodorum*. Hence, in the present studies symptomatology, morphological as well as molecular identification conclusively proved that SNB of wheat is caused by *Stagonospora nodorum*.

Fine mapping of *Co-Ind* gene in common bean land race KRC5 possessing resistance to different races of *Colletotrichum lindemuthianum*

1. Fine mapping of the *Co-Ind* gene in KRC-5 using microsatellite markers

i) **Mapping population:** A *mappi*ng population of Jawala (R) X KRC-5 (S) F_2 and RILS (F_8/F_9) was generated at MAREC, Sangla, Kinnaur, HP, during kharif 2016 for use in fine mapping of the resistant gene in land race KRC-5. A total of 700 F_2 seeds were harvested from F_1 seeds. A population of ~ 300 RILS (F_8/ F_9) was generated to fine map the resistance gene.

ii) **Maintenance of *C. lindemuthianum* races:** Fungal cultures of *C. lindemuthianum* races 3, 7, 100, 259, 337, 503, 1395, 513, 529 are being maintained on Mathur media under *in vitro* conditions after confirming their identity on differential bean varieties. Each race culture is transferred to susceptible cv. Jawala after every 3rd subculture to maintain its virulence.

iii) **Phenotyping of mapping population**: The phenotyping of parents Jawala (Resistant) KRC-5 (Susceptible) and the mapping population with *C. lindemuthianum* race 3 using g*erminating seed met*hod (Sharma et al., 2006) and detached leaf/ pod was initiated. The disease reaction was scored after six and twelve days of inoculation following 0-5 point scale (Drijfhout & Davis, 1986), where 0 = no disease symptoms; 1 = pin point lesions; 2 = small lesions, not sunken; 3 = large sunken lesions; 4 = large, deep lesions up to stem centre and 5 = seedlings killed by the pathogen. Plants showing reaction type of 0, 1, 2 were graded as resistant while those showing 3, 4, and 5 were graded as susceptible. The phenotyping of the F2 and RIL population is in progress. A population of 396 F_2 and 96 F_7 individuals was screened against anthracnose using *C. lindemuthianum* race 3. Out of 3*96 F_2 population*, 262 were found resistant and 134 susceptible. Among F_7, 69 individual were found resistant whereas, 27 were found susceptible. Further phenotyping of F_8 population (200) is in progress.

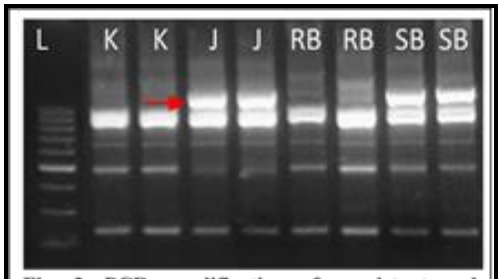

Fig. 3. PCR amplification of resistant and susceptible parents and their DNA bulks of cross Jawala x KRC 5 with RAPD primer OPR15. K: KRC5 (Resistant); J: Jawala (susceptible); RB: Resistant bulk; SB: Susceptible bulk; L: 100bp ladder

Fig 6. PCR amplification of resistant and susceptible parents and their DNA bulks of cross Jawala x KRC 5 with RAPD primer OPR 15

2. Conversion of R-gene linked RAPD marker to SCAR marker and its validation

Two RAPD markers OPF-06 (5'-GGGAATCGG-3') and OPR15 (5'-GGACAACGAG-3') which were found polymorphic in trans phase against (susceptible Jawala and resistant KRC5) were subsequently used for the development of SCAR markers (Fig 6). Both OPF6 and OPR15 markers linked to *Co-Ind* gene in land race KRC5 generated a polymorphic DNA fragment of 0.5kb and 1.2kb size respectively in susceptible parent and F_7 individuals (Fig 7a & b). The polymorphic fragments were gel purified, cloned in pGMET-Easy vector and custom sequenced.

The complete nucleotide (OPF6 522 bp and OPR15 1,134 bp) of polymorphic fragment containing respective RAPD markers was used for designing SCAR marker using Primer 3 programme.

For OPF6 based SCAR, primer pair ScJK5-OF6-F: 5-GGGAATTCGGGGACAAAACT GATAAA-3' and ScJK5-OF6-R: 5-GGGAATTCGGTGGAGATTATTACATGG-3' was the most versatile primer pair, whereas for OPR15, ScJK5-OR15-F: 5-GGACAACG AGTACA ATCTGGGGA-3' & ScJK5-OR15-R: 5-GGACAACGAGGTGGTGGAGGACAT-3' consistently amplified a specific DNA fragment in the parents and bulks. Similar to RAPD marker, a panel of 109 RILS ($F_{2:7}$) was used to validate the segregation of both the SCARs which co-segregated in the similar fashion like that of RAPD primers OPF6 & OPR15, thus confirming their linkage to the resistance gene.

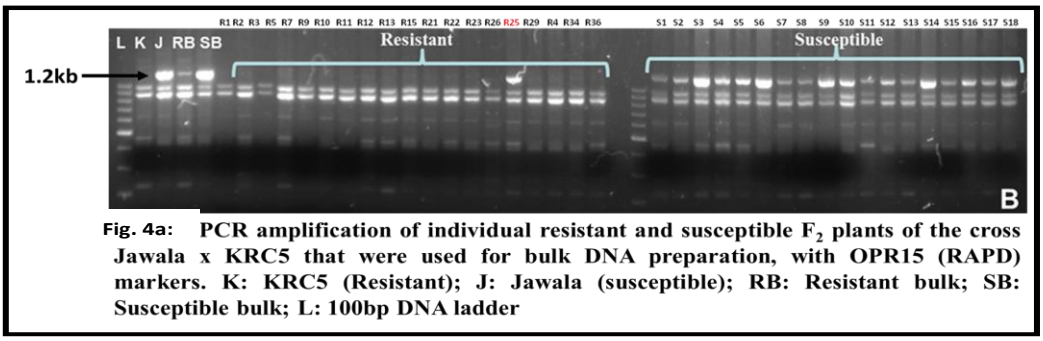

Fig. 4a: PCR amplification of individual resistant and susceptible F_2 plants of the cross Jawala x KRC5 that were used for bulk DNA preparation, with OPR15 (RAPD) markers. K: KRC5 (Resistant); J: Jawala (susceptible); RB: Resistant bulk; SB: Susceptible bulk; L: 100bp DNA ladder

Fig 7a. PCR amplification of individual resistant and susceptible F_2 plants of the cross Jawala x KRC5 that were used for bulk DNA preparation, with OPR15 (RAPD) markers. K: KRC5 (Resistant); J: Jawala (susceptible); RB: Resistant bulk; SB: Susceptible bulk; L: 1000bp DNA ladder

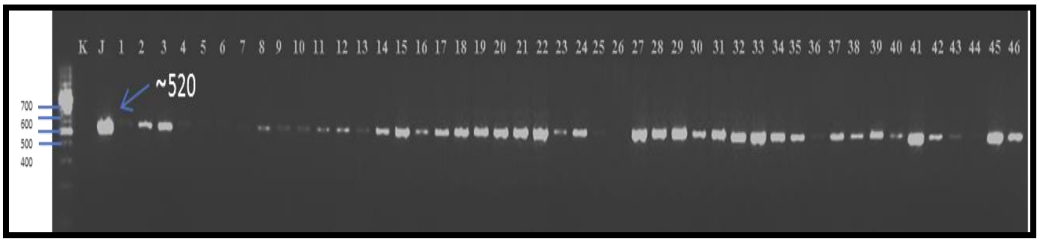

Fig 7b: validation of SCAR marker ScJK5-OF6$_{522}$ F_2 and $F_{2:7}$ RIL population of Jawala x KRC 5 cross.

3. Development of SSR markers for fine mapping using the genomic resources of *Phaseolus vulgaris*

To determine the tentative physical position of resistance loci identified in landrace KRC5, the sequences of *Co-ind* gene linked marker ScJK5-OR15$_{1136}$ and ScJK5- OF6$_{522}$ were BLAST searched against the genome sequence of Andean common bean cultivar G19333. The region between these two markers was retrieved from Phytozome by BLAST search to know the genomic location (Chromosomal *Phaseolus* database (Phytozome 11; https://phytozome.jgi.doe.gov/pz/portal.html) of the marker. SSRs were identified in those regions using the SSRIT tool of gramene database (www.gramene.org). Primers flanking the SSR locus were designed using the primer 3.0 software (http://frodo.wi.mit.edu/primer3/; Rozen and Skaletsky, 2000). A panel of 400 SSR and 53 In-Del markers have been designed from the region using genome sequence of *Phaseolus vulgaris* available in public domain. For

polymorphism survey of parental genotypes, initially a set of 30 SSR primers representing all the three chromosomes have been screened on Jawala and KRC5 parents and three primers are found polymorphic (Fig 8). Further evaluation of these primers on F_2 and F_7 populations is under progress. Among 48 In-Del markers, eight primers were found polymorphic on Jawala and KRC5 parents (Fig 9) and further screening of markers under progress.

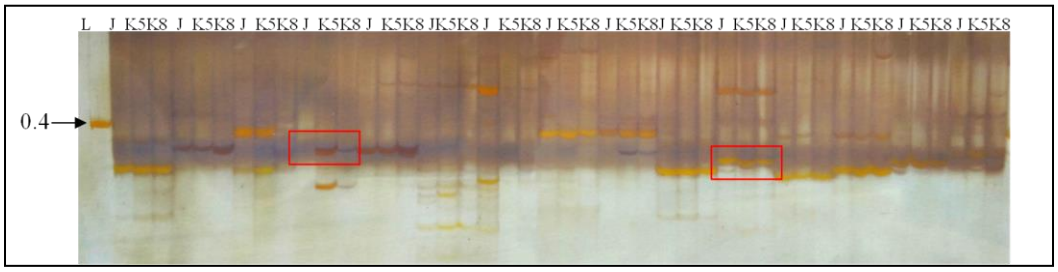

Fig 8: Screening a panel of 15 SSR primers on Jawala, KRC 5 and KRC8 parents on 4% PAGE followed by silver staining of gel. L- Represents low molecular weight marker

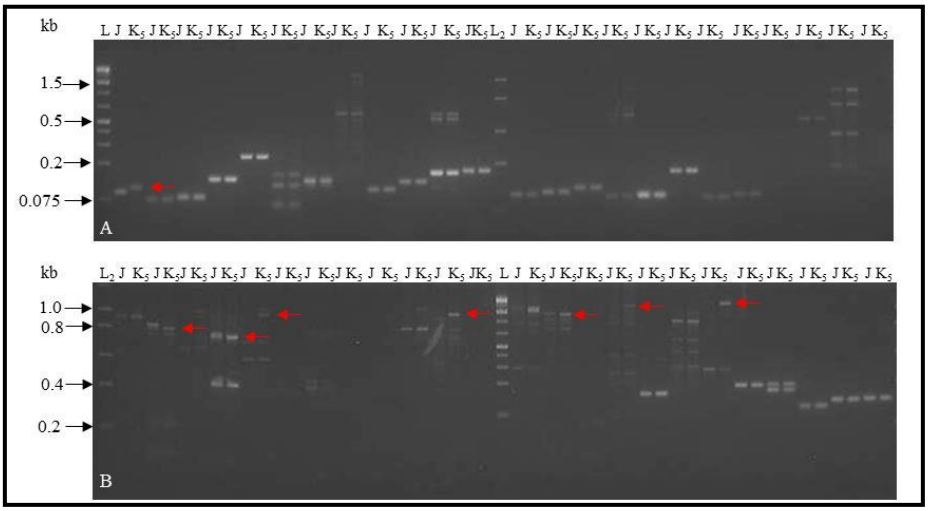

Fig 9. Screening of 48 In-Del primers on susceptible (Jawala-J) and resistant (KRC5-K_5) parents on 2.5% agarose gel. Red arrows indicate polymorphic markers Fig, 6A: Represents 1-24 In-Del marker and Fig. 6B represents; 25-48 In-Del marker L- represents 1kb DNA ladder and L_2 represents low molecular weight marker.

4. Test of allelism to establish the novelty of the R-gene in KRC5

Crosses between KRC5 and the genotypes possessing known anthracnose resistance genes mainly in the Andean genepool (Michigan dark red kidney (MDRK), Perry Marrow, Widusa; Kaboon; G, Mexique-222) possessing different resistant genes were made at CSK HPKV, Mountain Agricultural Research and Extension Center, Sangla, Kinnaur and Palampur. The F1 seed of various cross combinations have been sown at MAREC Sangla and F_2 populations are being generated at Palampur and MAREC, Sangla to deduce the allelic relationship of the genes present in parental genotypes.

Molecular characterization of BCMV NL-7n strain

1. Fill genome sequencing of BCMV NL-7n strain

i) RNA Isolation, RT-PCR and RACE- PCR amplification: The young infected leaves of susceptible cv. Jawala and cv. Redlands Greenleaf C showing prominent symptoms were used for total RNA isolation. The quality and integrity of total RNA was determined on 1 per cent agarose gel. For full genome amplification of the test strain, cDNA was synthesized strands using Oligo $(dT)_{18}$ and Hc-Pro reverse primer for RT- PCR. For RACE- PCR, Oligo $(dT)_{18}$ anchored primer was used. Different fragments of genome were amplified using a 12 primer pairs, which generated amplicons of expected size on 1.2 percent agarose gel (Fig. 10). Likewise for 5' and 3' UTR, ampilcons of 833 and 170 bp (5' RACE-2R and 5' RACE-3R) and 379 and 202bp (3'RACE-2F and 3' RACE-3F) were obtained in RACE- PCR. The gel-purified products were used for cloning.

ii) Cloning and sequencing: The gel-purified amplicons ligated in pGEMT-Easy and RBC T&A cloning vectors at 4 °C overnight were used for transformation into *E. coli* strain *DH5α* competent cells. After transformation, *E. coli* strain *DH5α* competent cells were kept overnight for antibiotics selection at 37◦C on LB ampicillin agar plates supplemented with IPTG and X-gal. At random, ten white colonies representing transformed ones (Fig 11) were selected for (cPCR) and restriction digestion for the confirmation of positive clones. The colony PCR (cPCR) generated desired amplicons with vector specific primers (T7 and SP6 for pGEMT- Easy and M13 universal primer for T&A vector) as well as gene specific primers confirmed the presence of desired inserts **(**Fig. 12**).** The positive clones were used for the isolation of recombinant plasmids, the recombinant plasmids were freeze dried in lyophilizer (Alpha 1-2 LD) and custom sequenced.

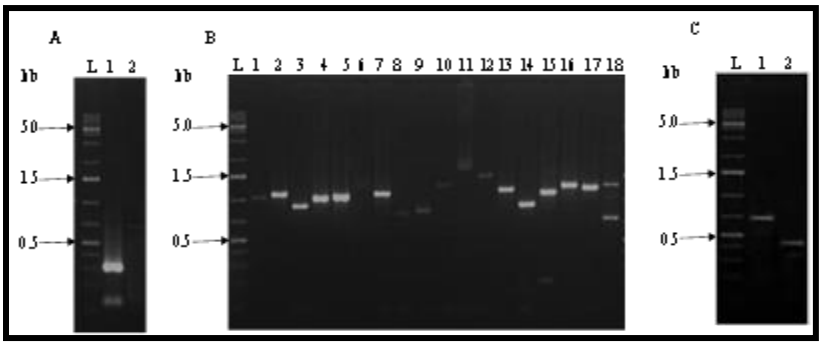

Fig 10. Genome amplification of BCMV NL-7n strain. Lanes L- 1 kb DNA ladder A- 5'UTR region:1- 5'-RACE-3, 2- 5'-RACE-2; B- CDS region of BCMV NL-7n strain were 1- P1-1, 2-P1-2, 3- P1-3, 4- HC-Pro-1 , 5- HC-Pro-2, 6- HC-Pro-3, 7- P3-1, 8- P3-2, 9- 6K1, 10- CI-1 , 11- CI-2, 12- CI&6K2, 13- NIa-VPg, 14- NIa-Pro-1, 15- NIa-Pro-2, 16- NIb-1, 17- NIb-2&NIb-3, 18- CP;C- 3'UTR: 1- 3'-RACE-2, 2- 3'-RACE-3

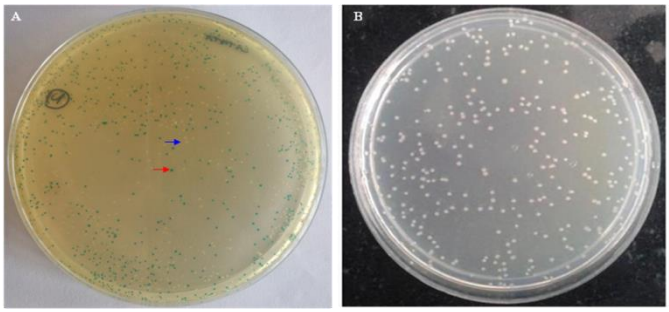

Fig 11. Cloning and screening of RT-PCR amplified products into TA vector. A- Blue and Red arrow indicates transformed colony of *E. coli* with and without inserts respectively. B-Positive control (pGEM-T Easy vector system) containing control insert

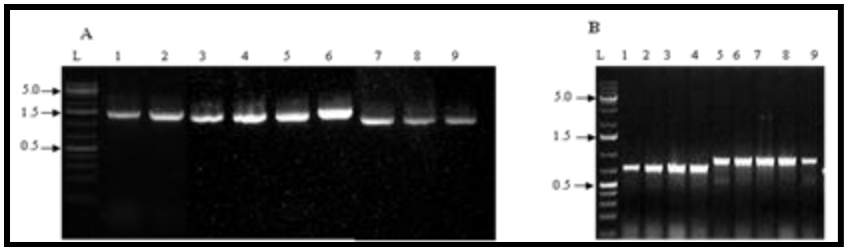

Fig 12. Confirmation of transformed colonies containing different fragments of BCMVNL-7n genome (white) by colony PCR using vector specific primers. L-1 kb plus DNA ladder; A- represents P1-1 region (1-3), P1-3 (4-6) & Hc-Pro1 (7-9). B- represents P3-1 region (1-2), P3-2 (3-4), NIb (6-9**)**

iii) Sequence analysis: Sequences obtained after custom sequencing were subjected to vecscreen software to remove vector sequences and then BLAST analyzed separately, which confirmed the identity of the sequenced regions as a part of the BCMV genome. Different fragments of genome were assembled manually. The NL-7n strain genome consists of 10045 nucleotides (nt) comprising of 5'-UTR (93 nt), P1 (1329 nt), HC-Pro (1371 nt), P3 (1041 nt), 6K1 (156 nt), CI (1902 nt), 6K2 (159 nt), NIa-Vpg (570 nt), NIa-Pro (729 nt), NIb (1548 nt), CP (861 nt), 3'-UTR (256 nt) and Poly(A) tail (30 nt) regions. The complete genome was submitted in the GenBank vide accession number KY057338 (Fig13). The genome length of the strain NL-7n (10045 bp) is within the range of BCMV strains which varied from 9992 bp (BCMV-Cowpea isolate) to 10086 bp (PStV). The size of the virus is also within the range of other potyviruses, where genome size varies between 9465 bp (CABMV) to 10538 bp (OYDV). The base composition of BCMV NL-7n strain calculated using DNA Base Composition Tool, showed the base frequencies of 32.07, 25.53, 24.34 and 18.07 per cent AUGC, respectively. The pair frequency of AU and GC were 57.59 and 42.41 per cent. The base composition of AUGC is almost similar to that of BCMV NL-1(32.2, 25.7, 24.1 and 18.0 %) and BCMV NL-1n (32.3, 25.6, 24.1 and 17.9 %).

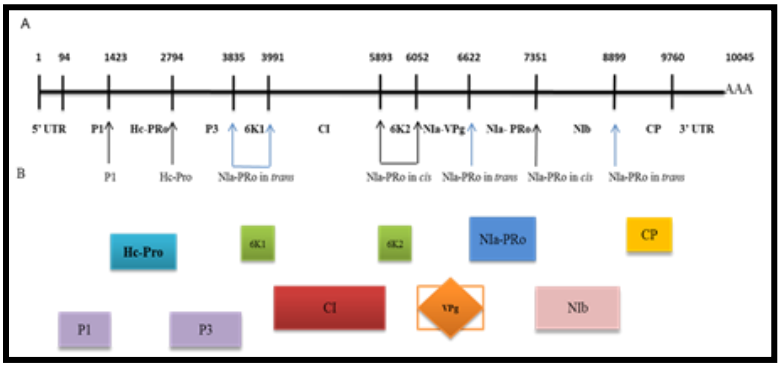

Fig 13. Genomic map of BCMV NL-7n (KY057338). (A) The +ssRNA genome (~10.045kb in size) is represented by a line and the single ORF translates a single polyprotein. (B) The polyprotein contains sequences that possess proteinase which yields ten proteins (represented in coloured boxes). Black arrow indicates *cis* cleavage, while blue arrow indicates cleavage in *trans*

2. Nucleotide and protein sequence analysis of BCMV NL-7n with BCMV strains

a) Nucleotide sequence analysis: Full genome nucleotide sequences of test strain BCMV NL-7n and other related strains/ isolates of BCMV were used for multiple alignment, pairwise comparison and phylogenetic analysis.

i) Phylogenetic analysis, pairwise comparison and relationship of BCMV NL-7n with strains of BCMV and other virus species of family *Potyviridae* at nucleotide level: The

phylogenetic analysis of test strain with BCMV strains of *Potyviridae* family using MEGA6 software based on nucleotide sequences using neighbor joining method with AgMV strain ND 402(AY623626) as the out group member showed that BCMV NL-7n clustered with strains of BCMV *viz.*, BCMV NL-1 (AY112735), AJ312437), *Peanut stripe virus* (U05771) and YBMV(JN 190431). Whereas other cluster contained *Cocksfoot Streak Virus* (AF499738), JMV isolate CNPGL (KT833782), BYMV (D83749), *Tobacco Etch Virus* (M11458), KoMV- F (AB219545), and TMV- isolate Ningbo (AJ851866) (Fig 14). Phylogenetic analysis clearly revealed the identity of the test strain as BCMV species of the genus *Potyvirus*. The per cent similarity ranged between 80-98 per cent with the BCMV strains and 35-66 per cent with other viruses of *Potyviridae* family.

ii) Multiple alignment analysis, phylogenetic analysis, pairwise comparison and relationship of BCMV NL-7n with strains of BCMV and BCMNV at nucleotide level: Multiple sequence alignment of full genome sequences of BCMV NL-7n stain with BCMV strains/isolates taken from NCBI GenBank at nucleotide level showed that test strain exhibited maximum homology with BCMV strains and lowest with strains BCMNV.

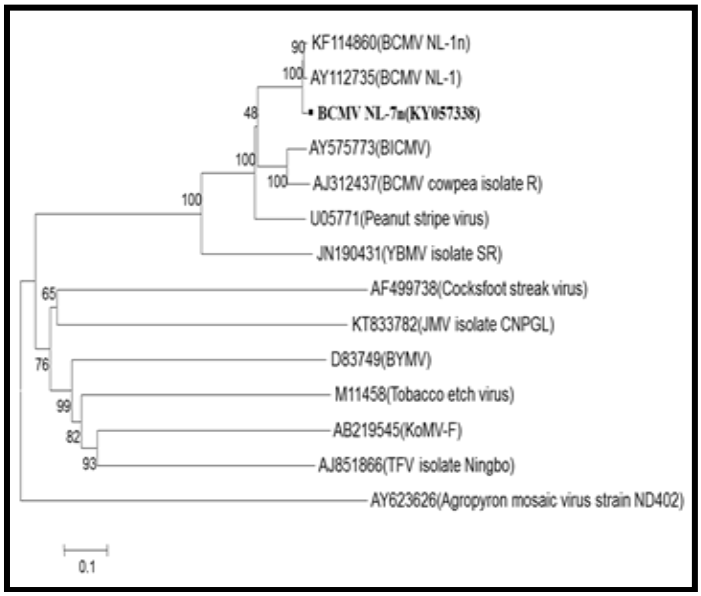

Fig 14. Phylogenetic tree inferred using the Neighbor-Joining method, showing relationship between BCMV NL-7n and other viruses of *Potyviridae* based on complete genome nucleotide sequence using Mega6 software

Phylogenetic analysis based on CP region, could not distinguish BCMV NL-7n from other BCMV strains where the percent similarity ranged between 95-98 per cent (Fig 15). In the phylogenetic analysis based on complete genome, the test strain clustered along with strains of BCMV where as BCMNV clustered in another group (Fig. 4.5b). Percent similarity between NL-7n and other BCMV strains/ isolates ranged between 84 to 98 per cent and with the BCMNV strains from 58 to 59 per cent on nucleotide basis. Further, within BCMV group, strains were clustered in subgroups. BCMV NL-7n strain clustered with BCMV NL-1 and BCMV NL-1n (Figure 4.5). The maximum identity (98%) of BCMV NL-7n was observed with BCMV NL-1 and BCMV NL-1n in pairwise similarity indices while, the lowest per cent similarity of 58-59 per cent was observed against BCMNV strains thus clearly establishing the identity of BCMV NL-7n strain as BCMV species of the genus *Potyvirus.*

b) Amino acid sequence analysis: Full genome nucleotide sequences of test strain BCMV NL-7n, related strains/ isolates and viruses of family *Potyviridae* were translated by Expasy tool available online and used subsequently for multiple alignment and phylogenetic analysis.

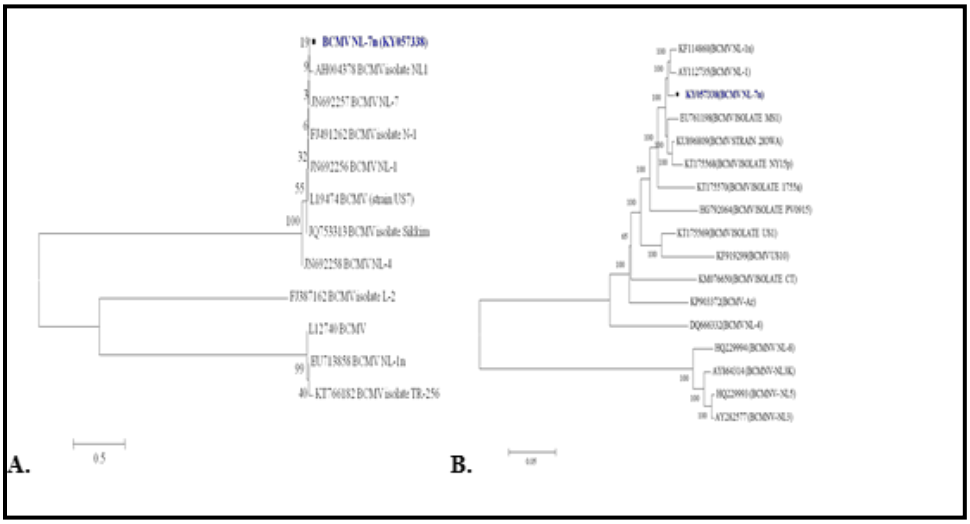

Fig 15. Phylogenetic tree inferred using the Neighbor-Joining method, showing relationship between BCMV NL-7n and other related strains of BCMV based on CP gene and complete genome nucleotide sequence

Multiple sequence alignment of deduced amino acid sequences of BCMV NL-7n strain with other BCMV strains/isolates showed that test strain exhibited maximum similarity with BCMV strains and minimum with strains of BCMNV. Phylogenetic analysis of test strain with BCMV and BCMNV strains presented in Fig 16 revealed that BCMV NL-7n clustered with strains of BCMV and all BCMNV strains clustered in separated group. Similarly, BCMV NL-7n and other BCMV strains/isolates homology ranged between 89 to 99 per cent whereas with BCMNV strains it was between 67 to 68 per cent on amino acid basis which further indicated that BCMV NL-7n belongs to strains of BCMV.

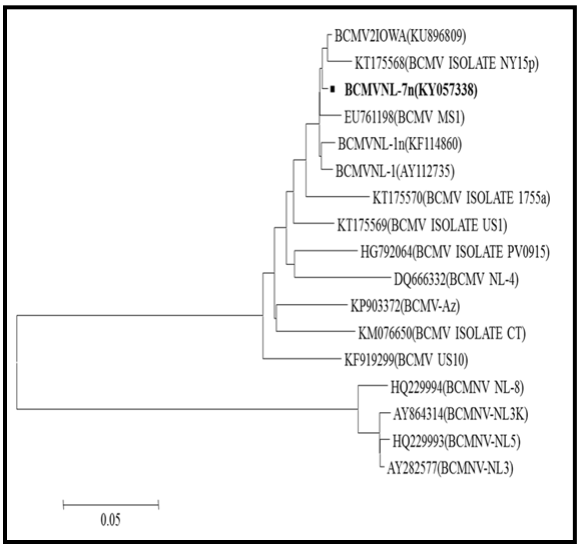

Fig 16. Phylogenetic tree inferred using the Neighbor-Joining method, showing relationship between BCMV NL-7n and other related strains of BCMV based on amino acid sequences using Mega6 software

Molecular characterization of pepper mild mottle virus (PMMoV)

The virus cultures were maintained on susceptible hybrid-"California Wonder" through sap inoculation using celite as an abrasive and leaves from infected samples were stored at -20ºC for further work. The samples collected from different areas of the HP state were screened for the presence of virus through DAS-ELISA using the virus specific antibodies (commercially available, BIOREBA) and RT-PCR using the coat protein (CP) specific primers. The DAS ELISA show the wide prevalence of the virus in some of the areas as reported earlier (Table 54). The PCR product was then analyzed on 1.2% agarose gel stained with ethidium bromide. An amplification product of 730 bp corresponding to the CP gene of the virus was observed in case of positive samples while no such amplification was there in healthy sample (Fig. 17).

Table 54. Serological testing of different samples collected through DAS-ELISA

S No	Location	Total Number of samples	No. of negative samples	OD_{600} of negative samples	No. of positive samples	OD_{600} of positive samples
1.	Baijnath	14	14	0.2265-0.6428	00	-
2.	Kangra	13	13	0.1726-0.3450	00	-
3.	University Polyhouses	04	03	0.2088-0.4236	01	1.0428
4.	Bilarpur, Hamirpur, Kullu, Mandi	38	12	0.4993-0.9371	26	1.0202-2.6585

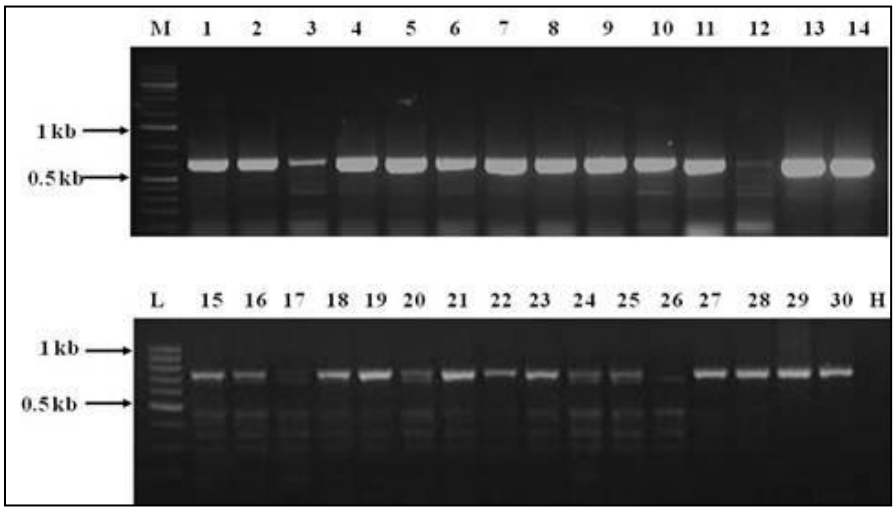

Fig. 17. RT-PCR of different samples using Coat protein specific primers.M: 1 kb plus ladder, L: 100 bp ladder, 1-30: Infected Samples, H: Healthy sample

EXTENSION EDUCATION

The extension activities undertaken by the faculty of this department at head quarter, research stations and KVKs during 2016-17 are described as under:

Advisory service	Advisory and consultancy services to farmers and visitors regarding diagnostic and management of diseases of cereals, pulses, oilseeds, vegetables, spices and other crops was provided to more than 1500 persons in the Department, Research Stations, KVKs, ATIC and during field visits
Liaison/ collaboration	Liaison was established with various national and international agencies like ICARDA, AVRDC, ICRISAT, NBPGR, MYMV, RKVY, ATMA, PAU, Department of Agriculture etc.
Training programmes	Faculty participated in different on campus and off campus training programmes at headquarters and field and delivered 303 numbers of lectures to farmers
Front-line demonstrations	14 numbers of FLDs on cultivation & protection technology were conducted
Radio/ TV talks	18 Radio and TV talks were delivered by faculty on various topics
Field demonstrations	455 numbers of field demonstrations were conducted
Adaptive trials	30 numbers of adaptive trials were conducted
Kisan melas/ divas	20 numbers of kisan melas/ divas were organized
Workshops	Faculty attended/ participated in 22 numbers of workshops including Agricultural Officers Workshops on *rabi* and *kharif* crops
Literature	33 numbers of pamphlets, popular articles and technical bulletins were published
Telephone help line services	697 calls were attended and suitable solutions of problems were suggested to the farmers

Quantity of spawn/ mushroom produced: During the year under report, **40 Q** of mushroom spawn was prepared and sold. Apart from this **30 tonnes** of mushroom compost and **400 kg** fresh mushroom were prepared/ raised and sold.

PUBLICATIONS

Research

Published:

Banyal, D.K., Sood, V.K., Singh, Amar and Mawar, Ritu (2016). Integrated management of oat diseases in north-western Himalaya. *Range Management & Agroforestry* 37 (1): 84-87

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SUMMARY

- The new fungicide viz. tricyclazole 20% + tebuconazole 16% SC @ 2.25 ml per litre was highly effective against leaf and neck blast giving 62.6 and 85.4% reduction in disease respectively.
- Wheat/ triticale entries viz. TL 2942 (C), TL 2969 (C), TL 3011, TL 3012, TL 3013, TL 3014, TL 3015 TL 3007 and TL 3008 remained free from powdery mildew infection while, HPW 251 (C), HS 490 (C), UP 2993, VL 1012 and VL 3013 remained free from hill bunt infection.
- Two sprays of new fungicides BAS 751 04 F EC @ 1.6 ml/l and BAS 750 02 F SC @ 0.8 ml/l were found effective for the control of stripe rust of wheat providing more than 90 per cent rust control.
- Maize hybrids LG.34.05, Kanak-51, DEKALB 9179, SIRI 5455, P 3542, P 3436 and Star-9 were found resistant to Turcicum Leaf Blight and Maydis Leaf Blight and better in yield (> 70 q/ha) and can be suitable for commercial cultivation.
- Two foliar sprays of Azoxystrobin @ 0.05% gave excellent control(66.61%) of banded leaf and sheath blight (BLSB) with an increase of 61.34 in yield as compared to control under artificial epiphytotic conditions.
- Rapeseed-mustard genotypes namely PYS-2010-3, DLSC-1 , EC-339000, DRMR-100, DRMR-316, DRMR-312, GSL-1, YSB-9, RTM-314, DRMR-2-11, DRMRIJ-12-48, DRMRIJ-12-40 and DRMRMJA-35 were found highly resistant to white rust.
- Linseed entries viz. UDNA-2, UDNA-4, UDNA-9, UDNA-10, UDNA-11, UDNA-12, UDNA-19 and UDNA-23 were observed highly resistant (disease score 0) to rust.
- Soybean entry PS 1572 (AVT-I) was highly resistant against both FLS and pod blight (Ct) diseases while lines viz. JS 20-96 and SL 1028 (AVT-II) remained free from pod blight (Ct) and JS 20-87, JS 20-98, PS 1556 and RVS 2007-06 were highly resistant.
- Soybean seed treatment with fungicide carboxin + thiram (Vitavax power) @ 2g/kg seed and two foliar sprays with thiophanate methyl @ 0.1% at 55 and 75 days after sowing effectively managed the pod blight and resulted in higher seed yield (15.8q/ha) as compared to control (10.8 q/ha).
- A PCR based method has been Standardized to *Pepper mild mottle virus* (PMMoV) from chili seeds
- Forty-nine common bean accessions resistant to BCMVNL-7n strain, showed the presence of three resistance genes *viz., I, bc-1*^{2} and *bc-3* in 40, 16 and 08 common bean accessions using tightly linked SCAR markers.
- Target spot of cucumber and collar rot of tomato were new records of diseases under protected cultivation
- Foliar sprays of Folicur (0.05%)/ karathane (0.05%)/ Contaf (0.1%) at 15 days interval were found effective in the management of capsicum powdery mildew
- Moximate (Cymoxanil + mancozeb) sprays at @ 0.25% were found effective in the management of downy mildew of cucumber
- Equation Pro (Famoxadone 16.6% + Cymoxanil 22.1% SC) @ 0.1% as foliar application effectively managed the late blight and buckeye rot of tomato
- During the year under report, **40 Qtls** of mushroom spawn, **30 tonnes of** mushroom compost and **400** kg fresh mushroom were prepared/ produced and sold.