Studies on Common Bean (*Phaseolus vulgaris* L.) Rust in Kashmir Valley

Irshad-ul-Islam Khandi
(2012-A-893-M)

Division of Plant Pathology

Faculty of Post-graduate Studies

Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

2014

Studies on Common Bean (*Phaseolus vulgaris* L.) Rust in Kashmir Valley

Irshad-ul-Islam Khandi
(2012-A-893-M)

Thesis

Submitted to

The Faculty of Postgraduate Studies
Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir
in partial fulfilment of requirements for the award of the degree of

Master of Science in Agriculture
(Plant Pathology)

2014

"Parents"

Two lives merge to create a life
One that grows in their tender loving care
A father who looks on, with concern and pride
A mother who nurtures, the child she bears.

They want you to learn life the hard way
Yet, they don't want you to go through the trouble
they are always by your side when you falter
they lift your spirit up when you feel it's bound to crumble.

No one else can ever give such a wonderful gift,
A gift that can be treasured since my childhood began to drift.

DEDICATED MY THESIS

"I've searched the wide world over,
In my search for teachers true.
And from the throngs that crowd life's lanes,
I have selected you"

MY BELOVED PARENTS

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Plant Pathology, Shalimar Campus, Srinagar-190 025

Certificate – I

This is to certify that the thesis entitled, **"Studies on Common Bean (*Phaseolus vulgaris* L.) Rust in Kashmir Valley"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Plant Pathology)**, to the **Faculty of Post-graduate Studies, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Irshad-ul-Islam Khandi (Regd. No. 2012-A-893-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation has duly been acknowledged.

(Dr. T.A. Shah)
Chairman
Advisory Committee

Endorsed

Prof. & Head,
Division of Plant Pathology

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Plant Pathology, Shalimar Campus, Srinagar-190 025

Certificate – II

We, the members of the Advisory Committee of **Mr. Irshad-ul-Islam Khandi (Regd. No. 2012-A-893-M)**, a candidate for the degree of **Master of Science in Agriculture (Plant Pathology)** have gone through the manuscript of the thesis entitled, **"Studies on Common Bean (*Phaseolus vulgaris* L.) Rust in Kashmir Valley"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

Advisory Committee

Chairman

Dr. T.A. Shah,
Programme Coordinator, K.V.K., Kupwara

Members

Dr. V.K. Ambardar,
Associate Professor, Division of Plant Pathology, SKUAST-Kashmir, Shalimar

Dr. M.A. Chattoo,
Associate Professor, RRS/FOA, Wadura
SKUAST-Kashmir

Dr. S.A. Mir
Head, Division of Agri-Statistics
SKUAST-Kashmir

Dean PG Nominee

Dr. Kounser Parveen Wani,
Associate Professor, Division of Vegetable Science, SKUAST-Kashmir, Shalimar

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Shalimar Campus, Srinagar – 190 025

Certificate – III

This is to certify that the thesis entitled, **"Studies on Common Bean (*Phaseolus vulgaris* L.) Rust in Kashmir Valley"** submitted by **Mr. Irshad-ul-Islam Khandi (Regd. No. 2012-A-893-M)** to the **Faculty of Post-graduate Studies, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Plant Pathology)** was examined and approved by the Advisory Committee and External Examiner on …….

Chairman
Advisory Committee

External Examiner

Prof. & Head,
Division of Plant Pathology

Director Education
SKUAST-Kashmir, Shalimar

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Plant Pathology, Shalimar Campus, Srinagar-190 025

Name of the student	:	**Irshad-ul-Islam Khandi**
Registration No.	:	2012-A-893-M
Major Subject	:	Plant Pathology
Minor Subject	:	Vegetable Science
Major Advisor	:	**Dr. T.A. Shah,** Programme Coordinator, K.V.K., Kupwara
Title of the Thesis	:	**"Studies on Common Bean (*Phaseolus vulgaris* L.) Rust in Kashmir Valley"**

ABSTRACT

During the current studies extensive survey of commercially bean growing areas of Kashmir valley was carried out during the *Kharief* cropping season for the year 2013. The disease was found in all the bean growing areas of the Kashmir Valley in varying proportions. The disease incidence and intensity varied from 14.39-30.28 per cent and 6.40-11.86 per cent, respectively. Highest 25.21 per cent disease incidence and 9.92 per cent intensity was recorded in district Srinagar and lowest 16.90 per cent disease incidence and 6.53 per cent intensity was recorded in district Pulwama. The studies on perpetuation of pathogen revealed that the pathogen overwinters on plant debris left on surface while the overwintering capacity decreases with depth. Further out of 31 germplasm lines screened for their reaction against the bean rust pathogen none of the line(s) was found completely immune or resistant to the pathogen. However most of lines were moderately resistant (intermediate in reaction) against pathogen with disease intensity ranging from 2.99-5.00 per cent while germplasm line SKU-R-506 (28.42%) and DARS-R-88 (27.24%) intensity were found highly susceptible to the disease.

Keywords: Incidence, Intensity, Overwintering, Perpetuation, Rust

Signature of Student

Dated_____

Signature of Major Advisor

Dated _____

ACKNOWLEDGEMENT

All praises are to Allah, the Creator and Sustainer of the World and endless blessings of Allah be upon Mohammad^{SAW} the great benefactor of mankind

I strive for words to express my deep sense of gratitude to my honourable guide Dr. T.A. Shah, Programme Coordinator, KVK, Kupwara, SKUAST-Kashmir who has been instrumental in the successful completion of my research work.

With highest degree of veneration, I express my profound gratitude to worthy members of my Advisory Committee, Dr. V.K. Ambardar, Associate Professor, Division of Plant Pathology; Dr. M.A. Chattoo, Associate Professor, RRS/FoA, Wadura; Dr. S.A. Mir, Head, Division of Agri-Statistics and Dr. Kounser Parveen Wani, Associate Professor, Division of Vegetable Science (Dean P.G. Nominee), for their cooperation, guidance, whole hearted support, timely help and useful suggestions.

With great pleasure, I express my deep sense of gratitude and respect for Dr. Qazi Nisar, Professor and Head, Division of Plant Pathology, SKUAST-Kashmir and Dr. G.N. Bhat, Ex-Head, whom I shall ever remain indebted for their painstaking guidance and valuable suggestions during the entire course of these investigations.

My sincere gratitude and thanks are due to all members of teaching/research and supporting staff of Division of Plant Pathology, especially to Prof G.H. Dar, Dr. Ali Anwar, Dr. Khursheed Ahmad, Dr. N.A. Khan, Dr. Ashraf Alam, Dr. B.A. Padder, Dr. Mushtaq Ahmad Bhat, Dr. Najeeb Mughal, Dr. Zahoor Ahmad Bhat, Dr. Mehraj-ud-Din, Dr. Efat Shanaz and Dr. Nageena Nazir for their help rendered during the course of studies.

I also avail this opportunity to pay my hearty thanks to non-teaching staff of Division of Plant Pathology for their help and cooperation during the research work. Heartfelt thanks to the Library staff of SKUAST-K especially Head Librarian.

I owe my thanks to my colleagues and friends Mr. Junaid, Mr. Mudasir, Mr. Rayees, Mr. Nisar, Mr. Mumtaz, Mr. Javid, Mr. Shahid, Mr. Abid, Mr. Arif, Mr. Hilal, Ms. Aisha, Ms. Misba, Ms. Shazia Paswal, Mr. Mudasir Hasssan, Mr. Aijaz, Mr. Salim, and Mr. Imran Mushtaq.

I unfeignedly owe my family, a tremendous filial respect and gratitude for their unending love and affection. They have been instrumental in every success that I have achieved hitherto. They have really endured every sort of hardship and privation for my sake only to reassure that I am not put to the trials and tribulations of life. I cannot afford to forget the times when my parents used to share my worries during my quarterly life crisis and never let me lose hope. The essence of their pristine love is inexplicably unforgettable.

I am colossally grateful to the unconditional love and support of my loving kids, Mr. Haad, Ms. Huda, Ms. Huaida and my Spouse who have been the bliss of my life. Their presence in my life have been a solace of my eyes bestowed on me by Allah(swt). My love increases for them with every passing day.

Finally I extend my sincere thanks to Mr. Younus Ahmad Bhat and Mr. M. Rafiq of M/s Universal Computers, Shalimar for taking lot of care in formatting of this manuscript beautifully.

Irshad-ul-Islam Khandi

Place : Shalimar, Srinagar

Dated :

CONTENTS

LIST OF TABLES

LIST OF PLATES

Chapter – 1

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) belongs to family *Leguminosae* and occupies a premier place among legumes in the world including India, where it is locally called as *Rajmash* (Sharma *et al*., 1994). The crop is distributed worldwide and can grow under diverse agro-ecosystems ranging from tropical, sub-tropical to temperate region (Popelka *et al*., 2004). It is also known as Common bean, Black bean, Navy bean, Pinto bean, Kidney bean, Dry bean, Snap bean and Field bean (Sardana *et al*., 2000). It is a native crop of Central and South America where it is being cultivated extensively and is morphologically highly variable. In India French beans rank second to pea in production and is extensively grown in Himachal Pradesh, Uttar Pradesh, Uttrakhand, Karnataka, Maharashtra and Jammu & Kashmir.

It is an excellent vegetable crop valued both as green vegetable as well as pulse. It is of paramount significance for direct human consumption and a dietary supplement rich in proteins, vitamins and minerals such as calcium, phosphorus, iron and zinc (Broughton *et al*., 2003). Beans are considered as the "meat of the poor" as they are second most important source of protein after maize and the third most important source of calories after maize and cassava (Pachico, 1993). The importance of beans in the human diet can be attributed to the fact that about half the grain legumes consumed worldwide is common beans (Broughton *et al*., 2003). As vegetable it is highly nutritious being rich in vitamin C and pro-vitamin A. Quantitatively each 100g edible portion of common bean green pod contains moisture (91.4%), carbohydrates (4.5%), proteins (1.7%), fat (0.1%), fibre (0.5%), calories (25), vitamin A (321 IU), thymine (0.08 mg), riboflavin (0.06 mg), vitamin C (16 mg), calcium (50 mg), iron (1.7 mg) and phosphorus (28 mg). Moreover, it also contains sodium (4.30 mg), potassium (12 mg), copper (0.21 mg), sulphur (37 mg) and nicotinic acid (0.30 mg) (Hazra and Som, 2005). As a vegetable crop, common bean is cultivated globally over an area of 1.47 million

hectares with an annual production of 17.65 million tons, while in India it is cultivated over an area of about 0.20 million hectares with an annual production of 0.58 million tons (Anonymous, 2010). In Jammu and Kashmir it is cultivated over an area of 2000 ha with an annual production of 400 tons (Masoodi and Masoodi, 2003).

The agro-climatic conditions of Kashmir valley offer an advantage for cultivation of beans. However, the cool and moist climatic conditions prevalent during the growing season of beans predispose beans to a number of biotic stresses like damage by insect pests, diseases and nematodes that adversely affect its production and productivity. The attack by phytopathogenic fungi is the single significant factor that results in yield loses either directly or indirectly.

Beans succumb to a number of diseases such as bacterial blight [*Xanthomonas campestris* pv. *phaseoli* (Smith) Dye], white mould [*Sclerotinia sclerotiorum* (Lib.) de Bary], brown spot [*Pseudomonas syringae* pv. *syringae* (Van Hall)], angular leaf spot (*Phaeoisorio psisgriseola* (Sacc.) Ferraris], rust [*Uromyces appendiculatus* (Pers.) Unger], anthracnose (*Colletotrichum lindemuthianum*) (Sacc. and Magn.) Scrib. and mosaic. Among these rust is the most devastating disease that warrants a serious attention as it inflicts heavy economic losses to the crop, which may reach up to 100 per cent, under conducive conditions (De Jesus Junior *et al*., 2001). The disease has been observed to be predominant and destructive particularly on pencil type of beans and often appear in epidemic proportions in major bean growing areas resulting in extensive damage to the crop causing huge losses ranging from 4.7 to 69.0 per cent in green pod yield depending upon cultivar and age of the crop at the time of infection (Sharma,1989).

Beans in Kashmir valley are grown mainly as intercrop with maize and no chemicals are used on maize. Under such circumstances it looks better to screen the available germplasm to identify the resistant line(s), if any, to reduce the dependence on chemicals.

Although a lot of work has been done on different aspects of bean rust both at national and international levels, no work has been done to investigate the disease under the Kashmir agro-climatic conditions. Keeping in view the huge losses caused by the pathogen and the meager information available on different aspects like identification of the pathogen, physiological studies, germplasm screening and management through cultural and chemical methods, the present investigations were undertaken with the following objectives :

1) Study the status of the disease in bean growing areas of Kashmir valley.
2) Study perpetuation of the pathogen.
3) Screen the available germplasm.

Chapter – 2

REVIEW OF LITERATURE

The pertinent literature available on French bean rust is being reviewed under the following aspects:

2.1 Geographical distribution

2.2 Losses

2.3 Symptomatology

2.4 Pathogenicity

2.5 Perpetuation

2.6 Disease Resistance

2.1 Geographical distribution

Bean rust caused by *Uromyces appendiculatus* (Pers.) Unger has been observed to be predominant and destructive disease of French bean in various parts of the world. It is a major disease affecting dry bean production worldwide (Yoshi, 1980). The disease was first reported from Germany in 1795 (Persoon, 1795). Since then the occurrence of the disease has been reported from various parts of the world like France (Malencon, 1936). USA (Echandi, 1976). Central Andes (Chardon and Toro, 1927) and Bulgaria (Christoff, 1939).

In India, the disease was first reported as early as in 1918 (Butler, 1918). Now the occurrence of this disease has been mainly reported from Karnataka (Sharma, 1989) and Tamil Nadu (Prakasham and Thamburaj, 1991).

2.2 Losses

Bean rust fungus, *U. appendiculatus*, is of worldwide importance as a yield reducing pathogen of *Phaseolus vulgaris* L., causing yield loss of about 50 per cent (De Jesus Junior *et al.*, 2001). Bean rust mainly infects leaves and cause yield losses close to 100 per cent depending on the severity and earliness of infection (Bassanezi *et al.*, 2001). Heavy epidemics occur especially in the tropics

and subtropics as the condition in these areas are conducive for the disease development (Burmeister and Hau, 2009). Yield reduction due to the disease has been documented to vary from 18 to 100 per cent (Lindgren *et al.,* 1995). Severe rust infection results in defoliation, stunted growth and subsequent reduced yields while infected pods may be rejected in the market due to the development of disfiguring lesions (Partridge, 1997; Jacques, 2002). Various workers have reported varying degree of losses due to this disease from year to year in different parts of the world. Rust being a polycyclic disease can cause serious economic losses under favourable environmental conditions by premature defoliation, decrease in the number of pods per plant and their reduced weight (Zaumeyer and Thomas, 1957). In Kenya 36.7 per cent yield losses were observed in plants having 79 per cent infection (Singh and Musyimi, 1981). In United States, up to 78 per cent yield lasses in pinto beans were recorded (Kelly, 1982).

In India losses in green pod yield due to this disease ranged between 4.7 to 69.0 per cent depending upon cultivars, age of the crop at the time of infection and per cent disease intensity (Sharma, 1989). In Almora, Uttrakhand, yield losses up to 60.8 per cent due to this disease has been reported (Sharma, 1998). Severity of the disease varied from 15 to 80 per cent in different areas of Solan district like Nauni, Kandaghat, Chail and Kanuri during 2006 crop season (Gupta *et al.*, 2008)

2.3 Symptomatology

Walker (1952) observed that the disease appear on the leaves as minute almost white, slightly raised spots, which enlarge on susceptible varieties to form brownish, powdery lesions up to 2 mm in diameter, often surrounded by a ring of secondary sori. The sori gradually become very dark brown to black as the teliospore developed. Similar symptoms appeared on the pods and rarely on the stems and petioles.

As many as 2,000 rust pustules may be found on one leaf, and since each is made up of powdery mass of spores, they give rise to rusty colour to anything that touches them, even covering the ground with faintly brownish dust. When the

leaf becomes thoroughly infected it shrivels and falls from the plant (Chupp and Sherf, 1960).

Common symptoms of rust develop on leaves and pods. Initially the pustules develop on the under surface of the leaves as small, white, slightly raised spots. These spots enlarge and form reddish-brown or rust-coloured pustules that are about 1/8 inch in diameter and contain thousands of microscopic summer spores (urediniospores). Spores are readily released from the pustules and give a rusty appearance to anything they contact. Rust can be distinguished from other leaf spots as these spores rub off onto fingers, while blights and bronzing do not. Pustules may be surrounded by a yellow border. Severe infection may cause leaves to curl upwards, dry up, turn brown and drop prematurely. A severely damaged bean field often looks as if scorched. Pod set, pod fill and seed size can be reduced if early infection is severe. Green pods, and occasionally stems and branches, also may become infected and develop typical rust pustules. However, bean rust is not seed-borne (Schwartz *et al.,* 2011). As the host ages, the uredosorus may be replaced by teliospores which are black brown in colour. Telial stage is dark brown to brown coloured and linear. Leaves may turn yellow and dry or they may fall off (Sharma, 2007). With the formation of teliospores, the lesion turns dark brown or black. Infected leaves may turn yellow and dry or fall off prematurely.

2.4 Pathogenicity

Yarwood (1960) found that urediniospores matured 7-8 days after inoculation of greenhouse grown pinto beans. Symptoms appeared first on 5th and 6th day after inoculation, uredia being produced on 8^{th} and 9^{th} day reaching maximum on 14 day. Maximum infection was obtained when inoculated plants were exposed for 11 h or more to 100 per cent RH and number of pustules increased if exposure was for more than 12 h but the time needed for lesions and pustules to become visible was confirmed after 10 days of inoculation on to 25 days old French bean plants (Rey and Lozano, 1961). Gupta *et al*. (2008)

confirmed the pathogenicity of the fungus after 10 days of inoculation on to 25 day old bean plants.

2.5 Perpetuation

Bean rust can survive in cold climate conditions as teliospores and urediospores in crop debris as well as in seed left in the field after harvesting (Singh, 2009). In other areas it survives through grown bean and other species of *Phaseolus* like broad beans, snap beans, lima beans (Batra and Stavely, 1994). Intensive cultivation of beans in areas with atmospheric humidity is one of the conditions favourable for the disease development. In these areas if the crop is attacked early, there may be a total loss. The repeating spores (urediospores) germinate best at 15 to 24^{o}C. About 93 per cent germination of urediospores has been observed at 17.5-22.5^{o}C. The teliospores in crop debris germinate best at 10-15^{o}C. Spores produced at temperature above 24^{o}C show reduced germination (Terhune and Hoch, 1993). The information *vis-a-vis* over-wintering of *U. appendiculatus* indicate that occurrence of sexual stage is very rare further, high incidence of pycnia and aecia on lower surface of stem of infected bean plants both in the field and green house conditions have also been reported (Schwartz *et al*., 2011).

2.6 Host Resistance

Host resistance is the most effective bean rust management strategy. Resistance to bean rust is controlled by a series of several genes that are single and dominant (Kelly *et al.*, 1996). However, the usefulness of host resistance under field conditions may be limited by high virulence diversity of the bean rust pathogen. The large number of races of this pathogen is a major factor contributing to rendering dry or snap bean varieties that are rust resistant in one location or year, susceptible in another, particularly when bean cultivars have single genes for rust resistance. Thiago *et al.* (2007) identified about 12 single pustule isolates of *U. appendiculatus*, the etiological agent of common bean rust.

These isolates have been used to select rust resistant genotypes in a bean growing programme and it was revealed that differential cultivars Mexico 309, Mexico 235 and PI 181996 showed resistance. It was suggested that these cultivars should be used as a sources of resistance in breeding of rust resistant beans. Nine of the rust resistance genes have been named and mapped on various linkage groups (LG) of the consensus linkage map of *Phaseolus vulgaris.* These rust resistance genes are: *Ur-3* (Pv11), *Ur-4* (Pv 01), *Ur-5* (Pv 04), *Ur-6* (Pv 11), *Ur-7* (Pv 11), *Ur-9* (Pv 01), *Ur-11* (Pv 11), *Ur-12* (Pv 07), and *Ur-13* (Pv 08) (Kelly *et al.*, 2003; Miklas *et al.*, 2006).

Severity of rust varies among host species and cultivars. Cultivars having moderate or low susceptibility show only minute pustules. Resistance to rust in common bean is related to leaf pubescence. On leaf surface having large number of trichomes (leaf hair) the infection is prevented by not allowing the germ tubes from urediospores contact the leaf surface (Mumbaga and Steadman, 1992). Difference in resistance level are more pronounced in adult donors than in seedlings. Resistance is mainly due to retriction of haustorium formation, reduced colonization of the host and reduced number of haustoria. These reduce the size of uredinia (Silliro and Rubiales, 2002).

Santana *et al.* (1993) evaluated pod reactions of 18 *P. vulgaris* germplasm lines (three temperate and 15 tropical) to four *Xanthomonas campestris* pv. *phaseoli* (XCP) (Smith) Dye strains and seven *U. appendiculatus* (UA) (Pers.) Unger races. Line × XCP interaction was significant for leaf and pod reactions. The common bean lines XAN-159, BAC-6, and XAN-112 had the best combined leaf and pod resistance to XCP. Line × UA race interactions were significant. Lines IAPAR-14 and BAC-6 had the best combined resistance to XCP and UA. Sixteen Alubia lines (15 with long, straight hairs and one with short, hooked hairs on trifoliolate leaves) derived from single plant selections made in an Alubia landrace (Argentine) were used to evaluate the relation of abaxial leaf pubescence to reaction to rust in a greenhouse experiment. The pinto cultivar UI-114 (short,

hooked hairs) was used as a susceptible check. One plant per pot, replicated six times, in a randomized complete-block design was used. The primary leaves and the sixth trifoliolates of all plants from 12- and 50-day-old plants, respectively, were inoculated with a water suspension of urediniospores (105 cells/ml) of rust isolate US-NP85-10-1. Pustule size and rust intensity were assessed 14 days later. No rust pustules were observed on the sixth trifoliate leaves of the pubescent (long, straight hairs) Alubia lines, but large pustules were observed on the primary leaves (short, hooked hairs) of all Alubia lines and pinto 'UI-114'. As well as on the sixth trifoliolate leaf of A-07-2 and pinto 'UI-144' the latter two with short, hooked hair (Zaiter *et al.,* 1990).

Combination of factors was found responsible for resistance to various races of *U. appendiculatus* in varieties like Golden Gate, Wax and Brown Kentucky Wonder (Dundas, 1942). Varieties like Florida Belle and Florida White Wax were found to combine resistance to some forms of rust with tolerance of heat and drought (Townsend and Wade, 1943). Zaumeyer and Harter (1946) found two new Pinto beans No. 5 and No. 14 combining resistant to rust (*U appendiculatus*). Zaumeyer (1947) also found Florida Belle, a snap bean variety resistant to rust.

Frazier *et al.* (1948) observed that the promising high yielding line of pole green bean which was resistant to rust was the selection of a progeny of cross in between Bountiful × Walualei developed at Hawaii. They further reported a new pole green bean namely Hawaiian Wonder was also resistant to rust and was developed again by crossing between Bountiful × Lnalualei. This variety was adapted to high elevation where rust was a limiting factor (Frazier and Hendrixn, 1949).

Baggett and Frazier (1959) made some tests on smaller scales which indicated resistance in some varieties of bean to rust. Most bean varieties grown in East Africa were found reasonably resistant to rust but White Haricot was liable to severe damage or total loss (Anonymous, 1961). Out of 49 varieties inoculated

with rust race 33, only California Small White No. 643, Kentucky Wonder Wax No. 765, Florigreen and Extender were found to be resistant (Hikida, 1962).

Kiraly *et al.* (1972) suggested that pathogen in the host was killed as a result of host resistance and the necrosis was the consequence and not the cause of hypersensitive type of resistance. Field reaction of 158 lines of bean to natural infection by rust indicated that many of the bush green and red kidney beans were only slightly infected and some of them had race non specific resistance to rust, while pole and most dry beans showed either a high level of specific resistance or were severely rusted and there was no evidence for non specific resistance in these groups (Ballantyne, 1974). Rodriguez (1976) evaluated 105 cultivars at 36 and 50 days after planting to rust and 25 cultivars were found resistant while some showed intermediate resistance. Garcia *et al*. (1980) tested 30 Soviet cultivars in the field and found only 2 cultivars Fana and Asta as relatively resistant to the rust. Ohlander (1980) reported that cvs. like Black Dessie and Negro Mecentral were resistant to rust while Mexican 142, Tengeru 16 and Ethiopia 16, all white-seeded varieties showed moderate resistance to rust.

Stavely (1981) screened different accessions from the International Bean Rust Nurseries and commercial bean cultivars to eleven pathogenically distinct collections of *U. appendiculatus* from Florida, Maryland, Michigan, New Jersey, North Dakota and Tennessee, none was immune or highly resistant to all *U. appendiculatus* collections while cvs. B190 and Compuesto Negro Chimaltenango were resistant, whereas, 78VEF2327-1, Pinto Serrano, P1313624 and S434 were moderately resistant to all collections.

Kolmer and Groth (1982) reported that crosses made between bean line 814 and Pinto III (showing minute rust uredium and moderately resistant reaction to S 1-5 isolate of *U. appendiculatus*) indicated that the minute uredium reaction was controlled by a single dominant gene. Echavez *et al*. (1982) observed that the resistance of black bean cvs. B190 and 2B5-1 to *U. appendiculatus* was derived from Mexico 309. Cultivars ‘US3’ and Early Gallatin were resistant to rust

pathogen and also concluded that resistance at locus, Up1, in US3 was expressed only when the resistance allele was matched to the avirulence allele at UpA1 or UpV3 locus in P10-1 or S1-5 isolate of *U. appendiculatus* (Christ and Groth, 1982).

Yeh (1983) screened different beans germplasm for resistance to *U appendiculatus* and based on the pustule size on the primary and trifoliolate leaves different germplasms were categorised as resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S). Kolmer and Groth (1984) observed that bean cvs. Early Gallatin and Pinto 111 were moderately susceptible and susceptible to rust pathogen, respectively. Schneiter *et al*. (1984) found that cv. Nodak was resistant to bean rust.

Kardin and Groth (1985) demonstrated that simultaneous inoculations of the El and F2 progenies from *Phaseolus vulgaris* crosses Aurora X Pinto 111. Fleetwood X Pinto 111 and Aurora X Fleetwood with seven *U. appendiculatus* isolates, the resistance of Aurora and Fleetwood to each isolate was controlled by a single dominant gene while Aurora contained at least two resistance genes and the small fleck gene in Aurora was epistatic to that in Fleetwood. Steadman *et al.* (1985) found that local cv. Pompadour exhibited necrotic lesions or small pustules (500 µm) in response to all races of rust pathogen and cultivars Early Gallatin, Mexico 309, 51051 and Compuesto Negro Chimaltenango were moderately to highly resistant. Rivera (1995) reported that out of thirty eight local and introduced cvs./lines of beans screened against rust, the best was Negro San Ramon 5, which was resistant. He further demonstrated that the resistance was controlled by several genes or at least one dominant gene conferring resistance to several races of the pathogen.

Sharma (1998) reported the existence of resistance in cvs. like SVM-l and Hans to this disease, while Sikkim Local-2 was moderately resistant Cvs./lines A-801, A-804, Phantom, Apore, Novo, Jalo, Corrente, EMGOPA, 201-Ouro, USLK-2 Light Red Kidney, USDK-4 Dark Red Kidney and USWK-6 White Kidney,

Merlot and Condor exhibited resistance to this disease from various parts of the world (Kelly *et al*., 2000; Singh *et al*., 2000; Rios *et al*., 2001; Miklas *et al.*, 2002; Silva *et al*., 2003; Hosfield *et al*., 2004 and Kelly *et al*., 2005).

Pastor *et al.* (2005) released bean germplasm lines with two genes from Middle American beans and two genes from Andean beans which were effective against all known virulence phenotypes of the bean rust pathogen under greenhouse and field conditions. Cultivars with the largest rust resistance spectra were Redlands Pioneer, California Small White 643, Brown Beauty, A x S 37 and Compuesto Negro Chimaitenango (Souza *et al*., 2005). Mienie *et al.* (2006) reported that the resistance gene Ur-l3 was present in the South African large seeded cuitivar Kranskop, and was used extensively in the local breeding programme. Hang *et al*. (2006) developed a cultivar Silver Cloud', an F_7- derived F_9 line from the cross 'Lisa/Linden', white kidney dry bean exhibited tolerance to bean rust. Cultivars lines like IPR 96-4 (Khati and Hooda, 2006) and Arka Anoop (Aghora *et al*., 2007) have also been found as resistant to this disease in Almora and IIHR, Bangalore, respectively.

Chapter – 3

MATERIALS AND MATHODS

The current studies were undertaken in the Division of Plant Pathology Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. The materials used and methods adopted in achieving the study is described as under:

3.1 Prevalance of disease

Periodic survey of the commercially important bean growing areas of the valley were carried out in four districts viz., Srinagar, Pulwama, Budgam and Baramulla, from July to September during 2013 crop season, to asscess the status of the disease. The plant parts showing characteristic symptoms were collected in paper bags and brought to the laboratory for further studies.

3.1.1 Disease incidence

Per cent disease incidence was calculated as follow:

$$\text{Per cent disease incidence} = \frac{\text{No. of leaves/ pods infected}}{\text{Total no of leaves/pods observed}} \times 100$$

3.1.2 Disease intensity

Per cent disease intensity (PDI) was calculated using the formula

$$PDI = \frac{\sum(n \times v)}{N \times G} \times 100$$

Where, $\sum$ = Summation

n = Number of diseased leaves/pods in each category

v = Category value

N = Total number of leaves examined

G = Highest category value

The data for calculating the disease severity was recorded as per the scale proposed by Mayee and Dattar (1986) with slight modifications:

Score/grade	Description
0	No symptoms on leaf/pod
1	Rust pustules small, scattered, covering 1 per cent or less leaf/pod area
3	Rust pustules more in number, covering 2-10 per cent of leaf/pod area
5	Typical rust pustules covering 11-25 per cent of leaf/pod area
7	Typical rust pustules covering 26-50 per cent of leaf/pod area
9	Typical rust pustules covering 51 per cent or more leaf/pod area

3.2 Characterization of pathogen

Infected plants showing characteristic symptoms of the disease were collected from different locations surveyed and brought to the laboratory for identification of the associated fungus on the basis of morphological characters as suggested by Cummins (1959) under binocular microscope. The morphological characteristics of urediniospores in respect of size shape, colour and echinulations if any were studied

3.3 Pathogenicity

3.3.1 Raising of plant material

In order to raise the plants for the conduct of pathogenicity tests, plastic pots (10 cm dia) were washed in running tap water and were filled with sterilized formalin 5%) soil consisting of soil + sand + FYM in 2:1:1 ratio (w/w/w). In each pot, 3 seeds of french bean cv. Falguni were sown and after seedling emergence, two plants pot^{-1} were maintained.

3.3.2 Preparation of inoculum

3.3.2.1 For inoculation of medium

Fresh urediniospores were brought from field and were collected in watch glass by tapping the freshly appeared rust pustules. Then this inoculum was used for inoculation of the plants with the help of sterilized camel hair brush and flat needle.

3.3.2.2 For inoculation of plant parts

Urediniospore suspension was prepared by brushing freshly formed urediniospores in a Petri-plate containing sterilized distilled water. Few drops (1-2) of Tween-20 were added to separate the spore masses to obtain urediniospore concentration generally in the range of 50-60 urediniospores per microscopic field (magnifying power).

3.3.3.1 Leaf coating method

In order to inoculate the plants by this method, plants were first sprayed with water and then gentle rubbing between the moistened thumb and fore finger was done to remove the waxy coating from the leaves as suggested by Melchers (1915). The wet finger was rubbed on the urediniospore mass collected in watch glass and the same was applied to leaves by gently rubbing the fore-finger to leaf surface. The inoculated plants were then maintained in polythene chamber under high humidity to provide leaf wetness for 24 h and then removed to Glasshouse benches at ambient temperature (20±2°C) and observed regularly for the appearance of the symptoms.

3.3.3.2 Inoculation of detached stem

In order to conduct pathogenicity test on detached stem, tender stems (5-6 cm long) were surface sterilized with ethanol (70%) and placed in Petri plates (150 mm diameter) containing moist sterilized blotting papers on both the sides. The stems were inoculated by leaf coating method and placed in laboratory under ambient temperature (20±2°C) conditions. Simultaneously, control was also

maintained by spraying drops of sterilized distilled water on stems. Each treatment was replicated thrice and the experiment was repeated once.

3.3.3.3 Inoculantion of detached pods

In order to conduct pathogenicity test on detached pods, tender pods were surface sterilized with ethanol (70%) and placed in Petri plates (150 mm dia) containing moist sterilized blotting papers on both the sides. The uninjured pods were inoculated by coating method (3.3.3.1) and placed in laboratory under ambient temperature (20±2°C) conditions. Simultaneously, control was also maintained by spraying drops of sterilized distilled water on uninjured pods. Each treatment was replicated thrice and the experiment was repeated once.

3.4 Perpetuation of pathogen

3.4.1 Role of plant debris in survival of the pathogen

To unveil the role of plant debris in the perpetuation of the pathogen, naturally infected plant parts including pod and leaves were collected from the commercially grown bean fields in the last week of October 2013 and placed in nylon pouches that permit free exchange of water, gases and microorganism. The pouches were placed in soil at 0.0, 7.5 and 15.0 cm depths. The pouches left on the surface of soil were held in position with the help of rocks while the position of the pouches kept inside soil was marked with the help of flags. A set of pouches from each depth was retrieved at regular intervals to check the viability of the fungus.

3.5 Resistance spectrum

Seeds of thirty varieties/lines obtained from the Karwa Damudar Farm, Old Airfield, Srinagar, Kashmir for their susceptibility/tolerance against the pathogen under natural epiphytotic conditions. The lines were sown in 2m long rows in a replicated field trial. Disease reaction of the varieties/lines was evaluated as in 3.1, using the scale given by Van Schoonhoven and Pastor-Corrales (1987):-

Grade	Category	Description
1	Immune	No visible rust pustules
3	Resistant	Presence of only a few and small or intermediate pustules covering less than 2 per cent of foliar area
5	Intermediate	Presence of small and intermediate pustules covering approximately 5 per cent of foliar area
7	Susceptible	Presence of mostly large pustules often surrounded by chlorotic halos covering approximately 10 per cent of foliar area causing some premature defoliation
9	Highly susceptible	Presence of large and very large pustules with chlorotic halos covering more than 25 per cent of foliar area and causing premature defoliation

Chapter – 4

EXPERIMENTAL FINDINGS

The current studies on bean rust were conducted in the Division of Plant Pathology, SKUAST-Kashmir, Shalimar and Department of Plant Pathology, Faculty of Agriculture, Wadura, Sopore, with the objectives of working out the status of disease, to screen the available germplasm and to determine the mode of perpetuation of pathogen.

4.1 Occurrence and severity of disease

In order to determine the occurrence and severity of disease extensive survey of the major bean growing pockets of valley viz., Baramullah, Budgam, Srinagar and Pulwama of Kashmir valley were carried out during 2013. The disease was found on all aerial plant parts (Plate-1). The data regarding incidence and intensity of bean rust is presented in Table-1 and Table-2, respectively.

4.1.1 Disease incidence

4.1.1.1 Disease incidence on leaves

The data presented in Table-1 revealed that the disease was prevalent in all the bean growing areas of Kashmir valley in varying proportions. Highest incidence on leaves was found in district Srinagar followed by Baramullah, Budgam and Pulwama. During the crop season disease incidence ranged from 22.36-30.28 per cent in Srinagar, 14.39-23.46 per cent in Baramulla, 16.98-19.08 per cent in Budgam and 15.50-18.50 per cent in Pulwama.

The data further revealed that among different locations surveyed, disease incidence (30.28 %) on leaves was highest in Maloora region of district Srinagar while lowest (14.39 %) disease incidence was recorded at Gulmarg region of district Baramullah. Significant variation in disease incidence on leaves was observed both among and within districts surveyed.

Table-1 : Incidence and intensity of bean rust on leaves at various locations of Kashmir valley during the year 2013

District	Location	Per cent disease incidence	Per cent disease intensity
Baramulla	Wadoora	23.46	9.10
	Pattan	22.41	8.10
	Gulmarg	14.39	6.13
	Mean	**20.09^{b}**	**7.78^{b}**
Budgam	Kujura	19.08	7.30
	Razwan	16.98	6.97
	Beeru	18.50	7.53
	Mean	**18.18^{c}**	**7.26^{bc}**
Srinagar	Maloora	30.28	11.86
	Herwan	22.36	8.50
	Shalimar	23.00	9.40
	Mean	**25.21^{a}**	**9.92^{a}**
Pulwama	Litter	15.50	6.43
	Newa	16.70	6.40
	Babar	18.50	6.76
	Mean	**16.90^{d}**	**6.53^{d}**
Overall mean		**20.09**	**7.87**
$CD_{(P\leq 0.05)}$			
District		0.26	0.46
Location		0.22	0.40

Plate-1 : Rust on different parts of French bean

4.1.1.2 Disease intensity on leaves

Perusal of data in Table-1 revealed that disease was prevalent in all the bean growing areas with varying intensities depending upon the climatic conditions and cultural practices adopted in combination with the variety of beans under cultivation. Highest (11.86 %) disease intensity on leaves was recorded at Maloora followed by Shalimar (9.40 %) of district Srinagar and Wadura (9.10 %) of district Baramullah. The overall disease intensity on leaves was highest in district Srinagar (9.92 %) followed by district Baramullah (7.78 %), Budgam (7.26 %) and Pulwama (6.53 %). Non-significant variations in disease intensity on leaves was recorded for Litter (6.43 %), Newa (6.40 %) and Babar (6.76 %).

4.1.1.3 Disease incidence and intensity on pods

Perusal of Table-2 data revealed that disease incidence on pods varied from 2.86 per cent at Gulmarg, Baramulla to 6.03 per cent at Maloora in district Srinagar which correspond to the lowest and highest disease incidence, respectively. Among the districts highest disease incidence was recorded at Srinagar (5.02 %) followed by Baramulla (4.00 %), Budgam (3.62 %) and Pulwama (3.35 %).

Highest disease intensity on pods was recorded at Maloora (2.36 %) followed by Wadura (1.88 %) and Shalimar (1.87 %). Among the districts highest disease intensity was recorded at Srinagar (1.97 %) followed by Baramullah (1.56%), Budgam (1.44 %) and Pulwama (1.29 %).

Table-2 : Incidence and intensity of bean rust on pods at various locations of Kashmir valley during 2013

District	Location	Per cent disease incidence	Per cent disease intensity
Baramulla	Wadoora	4.68	1.88
	Pattan	4.47	1.61
	Gulmarg	2.86	1.20
	Mean	**4.00**	**1.56**
Budgam	Kujura	3.83	1.48
	Razwan	3.38	1.35
	Beeru	3.39	1.49
	Mean	**3.62**	**1.44**
Srinagar	Maloora	6.03	2.36
	Herwan	4.46	1.69
	Shalimar	4.59	1.87
	Mean	**5.02**	**1.97**
Pulwama	Litter	3.03	1.28
	Newa	3.33	1.27
	Babar	3.69	1.35
	Mean	**3.35**	**1.29**
Overall mean		**3.97**	**1.55**
$CD_{(P\leq 0.05)}$			
District		**0.010**	**0.007**
Location		**0.140**	**0.006**

4.2 Symptomatology

During the course of surveys, the characteristic symptoms of the disease were found to appear on all aerial parts of plants.

4.2.1 On leaves

The symptoms on leaves appeared as small yellow or white slightly raised lesions on either surface of the leaves (Plate-2 and Plate-2a). These lesions enlarged in size and covered most of the area on the leaf blade. Later these pustules developed into reddish brown or rust coloured pustules. A yellow border surrounded the pustules. These pustules contained rusty coloured mass of spores. Severely infected leaves curled upwards, dried up, turned brown and dropped prematurely.

4.2.2 On stems

Symptoms on stems appeared only when the severity of the disease was very high on the leaves. The symptoms on stems appeared as small elongated and raised lesion (Plate-1). These lesions enlarged in size and merged together. Later these lesions were covered with brown rusty mass of spores.

4.3 Identification of the pathogen

The rust samples collected from various locations contained rusty coloured masses of spores which were identified as urediniospores (Plate-3). The urediniospores were light brown. echinulated, catenulate, one called and thin walled. The associated fungus on the basis of urediniospores characteristics when compared with standard keys (Cummins, 1959) was identified as *Uromyces appendiculatus* (Pers.) Unger.

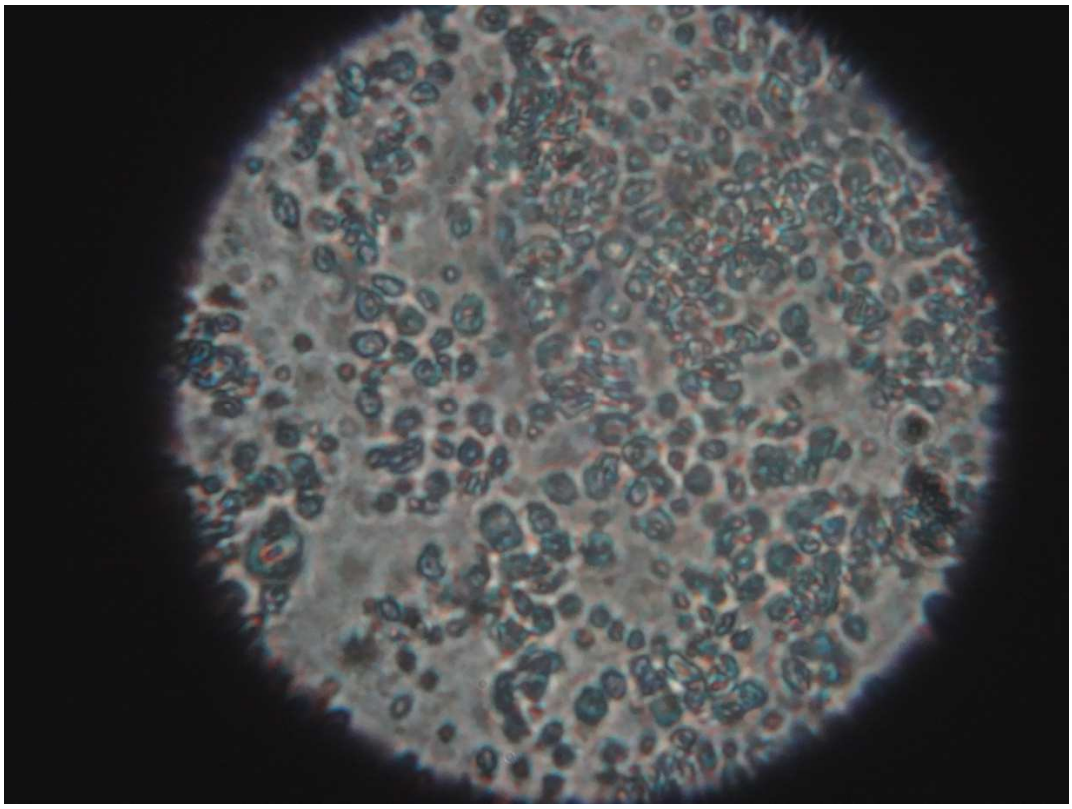
4.4 Pathogenicity

4.4.1 On leaves

Inoculations were made with leaf coating method on cotyledónary and primary trifoliate leaves of French bean cv. French yellow. It was observed that symptoms appeared after an incubation of 6-7 days and 7-8 days on cotyledonary and primary trifoliate leaves, respectively.

Aecia on under surface of leaves

Magnified view of Aecia



Aecial Spores

Plate-2: Aecia and Aecio spores on host

Plate-2a: Pycnia on upper surface of leaves

4.4.2 On stems

The pathogenicity test on stem revealed that the characteristic symptoms of the disease appeared after an incubation period of 9-10 days.

4.4.3 On pods

The pathogenicity test on pods revealed that the characteristic symptoms of the disease did not appear on the pods.

4.5 Morphological characteristics

Perusal of data revealed that *U. appendiculatus* being an obligate parasite could not be cultured on artificial media, so the morphology of casual pathogen was studied on host tissue and is presented in Table-3. The urediniospores were aseptate redish brown in colour measuring about 20.2-30.8 x 20.4-26.5 µm in size with an average of 23 x 21 µm while the teliospores were ellipsoidal, umbonate at apex, brown to dark brown in colour measuring about 27.1-35.5 x 21.6-26.8 (31 x 24) (Plate-3 and 4).

4.6 Germplasm screening

Thirty one germplasm lines/cvs./local sets were evaluated for their reaction to *U. appendiculatus* under natural epiphytotic conditions during 2013 croping season. The data on per cent disease incidence and per cent disease severity was recorded 15 days after inoculation and is presented in Table-4. The data revealed that disease intensity varied from 2.99 to 28.42 per cent and revealed that among the 31 genotypes screened SKU-R-615 exhibited lowest (2.99 %) disease intensity while as SKU R 506 exhibited the highest (28.42 %) disease intensity. The disease incidence ranged from 7.47 to 56.05 per cent with SKU-R-615 exhibited the lowest disease incidence of 7.47 per cent and SKU-R-506 exhibited the highest disease incidence of 56.05 per cent. The test genotypes were allotted to different reaction groups on the basis of disease intensity recorded in each genotype (Table-4).

Table-3 : Morphological characters of *U. appendiculatus*

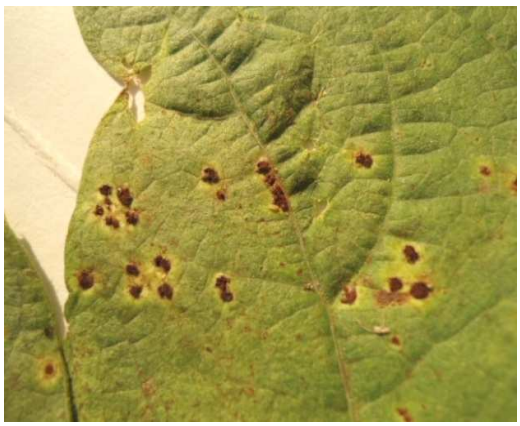
Propagule Type	Colour	Size (µm) On Host	Shape/Structure	Septations
Urediniospores	Redish brown	20.20-30.80 x 20.40-26.50 (23 x 21)*****	Ellipsoidal to ovoidal with spines at surface	Aseptate
Teliospores	Brown to dark brown	27.1-35.5 x 21.6-26.8 (31 x 24)*****	Ellipsoidal, umbonate at apex	-

*Figures in parenthesis are average values

Table-4 : Studies on screening of gemrmplasm against *U. appendiculatus*

S. No.	Germplasm	Per cent Disease Incidence	Per cent Disease Intensity	Reaction
1.	SKU-R-925	10.8	4.32	I
2.	Masterpiece	11.92	4.44	I
3.	SKU-R-916	7.84	3.42	I
4.	SKU-R-71	11.24	4.91	I
5.	SKU-R-204	23.25	9.62	S
6.	SKU-R-924	9.42	3.80	I
7.	Kanchan	7.90	3.16	I
8.	SKU-R-616	9.42	3.96	I
9.	DARS-R-26	9.85	3.94	I
10.	SKU-R-506	56.05	28.42	HS
11.	SKU-R-927	18.25	7.64	S
12.	SSGB-729	24.92	9.97	S
13.	Contender	17.57	7.43	S
14.	SKU-R-23	20.85	8.34	S
15.	SKU-R-91	10.54	4.62	I
16.	SKU-R-114	12.47	4.99	I
17.	DARS-R-42	10.73	4.31	I
18.	SKU-R-76	9.72	3.89	I
19.	SKU-R-9	10.10	4.44	I
20.	SKU-R-914	8.40	3.56	I
21.	SKU-R-615	7.47	2.99	I
22.	SKU-R-104	8.70	3.56	I
23.	SKU-R-107	12.4	5.00	I
24.	DARS-R-60	18.35	7.34	S
25.	SKU-R-908	18.33	7.21	S
26.	DARS-R-65	21.64	8.26	S
27.	SKU-R-928	23.24	9.29	S
28.	DARS-R-4	8.45	3.42	I
29.	DARS-R-88	47.2	27.24	HS
30.	SKU-R-105	21.6	8.64	S
31.	SKU-R -606	14.06	5.24	S

I = Intermediate; HS = Highly susceptible; S = Susceptible

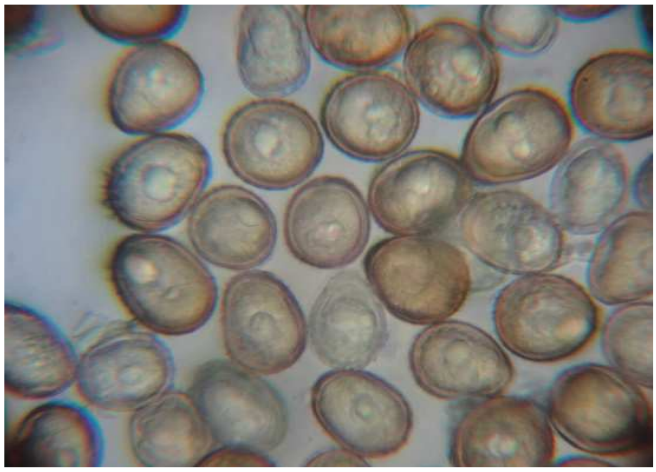


Uredial pustules on leaf surface

Uredial pustules on twig

Uredial pustules on pod

Magnified uredial pustules on leaf



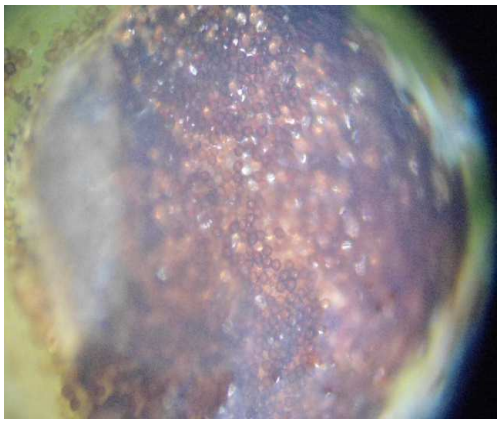
Uredio spores (40X)

Plate-3 : Uredial pustules and spores on different parts of french bean

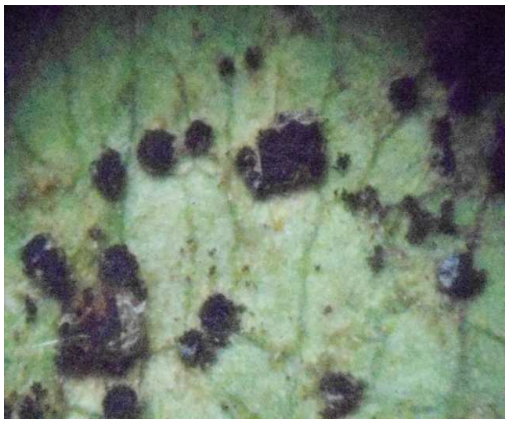
Telial pustules on leaf surface

Telial pustules on petiole

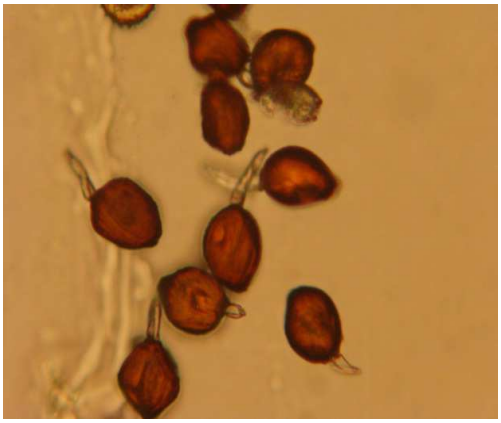
Telial pustules on pod



Mass of teliospores



Magnified view of telia on leaf surface



Teliospores

Plate-4 : Telial pustules and spores on different parts of french bean

Perusal of the data revealed that most of the genotypes (58.06 %) were moderately resistant or intermediate in reaction, 35.48 per cent were susceptible while as remaining 6.45 per cent were highly susceptible to the disease. Among the germplasm screened against the disease , SKU-R-925, Masterpiece, SKU-R-916, SKU-R-71, DARS-R-4, SKU-R-924, KANCHAN, SKU-R-616, DARS-R-26, SKU-R-91, SKU-R-114, DARS-R-42, SKU-R-76, SKU-R-9, SKU-R-914, SKU-R-615, SKU-R-104 AND SKU-R-107 were moderately resistant/ intermediate in reaction to disease with disease intensity ranging from 2.99 to 5.00 per cent. Further, the genotypes DARS-R-88 (27.24 %) and SKU-R-506 (28.42 %) were categorised as highly susceptible lines.

4.7 Overwintering/ Perpetuation

Perusal of data in Table-5 revealed that pathogen overwinters as teliospore on crop debris. The average number of teliosopore/cm^2 leaf area (million per ml) decreased as the bean debris gets incorporated in the soil. The data further revealed that teliospores were recovered from bean debris placed on the surface of soil throughout the overwintering period, however, the average number of teliospores/cm^2 leaf area recovered decreased from 46.6 to 8.1 with viability decreasing from 88.4 at the start of experiment to 12.40 per cent at the end of experiment. It is also evident from the data that no spores were recovered beyond 21^{st} and 14^{th} of March from 7.5 and 15 cm depths, respectively.

Table-5 : Studies on overwintering of *U. appendiculatus* for the year 2013

Date of observation	Average no of teliosopore/cm^2 leaf area (million per ml)			Viability (%)		
	Surface	7.5 cm	15 cm	Surface	7.5 cm	15 cm
01-03-2014	46.6*	15.8	12.2	88.4**	35.2	19.5
07-03-2014	43.4	14.5	10.4	85.6	27.2	15.1
14-03-2014	43.4	12.2	-	84.0	19.3	-
21-03-2014	40.3	-	-	76.8	-	-
28-03-2014	38.4	-	-	67.2	-	-
04-04-2014	36.5	-	-	65.3	-	-
10-04-2014	28.6	-	-	55.9	-	-
17-04-2014	24.7	-	-	47.5	-	-
24-04-2014	24.2	-	-	36.4	-	-
01-5-2014	19.9	-	-	35.4	-	-
08-5-2014	18.4	-	-	30.2	-	-
15-5-2014	16.2	-	-	24.9	-	-
22-5-2014	11.1	-	-	18.6	-	-
28-5-2014	8.9	-	-	17.4	-	-
04-06-2014	8.1	-	-	12.4	-	-

Chapter – 5

DISCUSSION

Common bean (*Phaseolus vulgaris* L.) is one of the most important leguminous crops cultivated round the globe (Broughton *et al*., 2003). The cultivation of crop has increased manifolds owing to its high palatability and economic value. However, it succumbs to a number of biotic and abiotic stresses, most destructive being the rust disease which is one of the main constraints to its production especially in regions with cool and moist agro climatic conditions. The disease often assumes epiphytotic proportions during the months of August and September and reduces potential yields by causing damage to foliage and stems resulting in premature defoliation of the plants (Sharma, 1989; Gupta *et al*., 2008). Keeping in view the economic importance of the disease, research gaps and meagre information available in literature from the Kashmir valley on different aspects, it was worthwhile to investigate the disease with objectives as outlined in the introductory chapter and the results obtained are discussed in the light of available literature as follows:

In the present studies disease incidence and intensity on leaves ranged from 16.90 to 25.21 and 6.53 to 9.92 per cent, respectively, while on pods it ranged from 3.35 to 5.02 and 1.29 to 1.97 per cent, respectively. Highest disease incidence and intensity on leaves and pods were recorded in the district Srinagar while as lowest disease incidence on leaves and pods was recorded in the district Pulwama. Further among different locations surveyed highest disease incidence and intensity on leaves (30.28 and 11.86 %) and pods (6.03 and 2.36 %) was recorded at Maloora while it was lowest (14.39 and 6.13, 2.86 and 1.20 %) at Gulmarg of district Baramullah.

The disease has been recorded from various parts of world including India. In India occurrence of the disease has been reported from Karnataka, Tamil Nadu, Uttarakhand, Orissa, Meghalaya and Sikkim (Sharma, l989; Prakasham and

Thamburaj, 1991; Sharma, 1998; Mishra *et al.*, 1998; Bhat *et al*., 1999; Bhat 2002). Gupta *et al.* (2008) have already reported about 15 to 80 per cent severity of rust in different areas of Solan district during the season of congenial weather (cool and humid) in the locations surveyed during 2006 crop season. The characteristic symptoms of the disease observed on leaves and stems in the present investigations are in accordance with those described by earlier workers (Walker, 1952; Chupp and Sherf, 1960, Dixon, 1981; Singh, 1985; Gupta *et al*., 2008).

The morphological characters of the urediniospores of the fungus such as, colour, size and shape of spores were studied on the host tissue and it was observed that urediospores were light brown to redish brown spores in colour, ellipsoidal to ovoidal with spines at surface, one celled, 13.32-23.84 x 19.98-27.89 µm with an average size of 18.58 X 23.98 µm, while the teliospores were brown to dark brown in colour, ellipsoidal, umbonate at apex in shape measuring about 27.1-35.5 X 21.6-26.8 µm with an average size of 31 X 24 µm which is in accordance with the earlier findings (Walker, 1952; Zaumeyer and Thomas, 1957 and Gupta *et al*., 2008).

The pathogenicity tests revealed that different plant parts namely leaves (cotyledonary and primary trifoliate) and stems were readily infected by the pathogen. On cotyledonary and primary trifoliate leaves, the symptoms appeared after 6-7 days and 7-8 days of incubation, and the symptoms on stems appeared after 9-10 days of incubation. The longest incubation period of the disease on stems (9-10 days) may be due to the presence of mature tissues as compared to the shorter incubation periods (6-8 days) observed in case of leaves supporting tender and juvenile tissues. These observations are in accordance with Rey and Lozano (1961) and Gupta *et al.* (2008). In present investigations these observations are in consonance with Singh (1985) who reported that the pods are rarely infected by this disease.

Thirty one different germplasm/lines were screened against *U. appendiculatus* under natural epiphytotic conditions. Among the germplasm screened against the disease, SKU-R-925, Masterpiece, SKU-R-916, SKU-R-71, DARS-R-4, SKU-R-924, Kanchan, SKU-R-616, DARS-R-26, SKU-R-91, SKU-R-114, DARS-R-42, SKU-R-76, SKU-R-9, SKU-R-914, SKU-R-615, SKU-R-104 and SKU-R-107 were immune to disease with disease intesity ranging from 2.99 to 5.00 per cent. Further, the genotypes DARS-R-88 (27.24 %) and SKU-R-506 (28.42 %) were categorised as highly susceptible.

No information is available regarding the resistance spectrum of germplasm lines screened, so data cannot be compared, however, high levels of resistance have been identified in both Andean and Middle American cultivars (Liebenberg *et al*., 2006). Our findings are also in collaboration with those of Rodriguez (1976), who evaluated 105 cultivars at 36 and 50 days after planting, to rust and found 25 cultivars resistant while some showed intermediate resistance. Bhat *et al.* (1999) also evaluated twenty nine bean accessions against this disease under natural epiphytotic conditions and found three accessions like IC 47643, PI 201489 and P1 247761 to be highly resistant to the disease.

From the current studies it is evident that infected plant debris left on the surface of soil acts as source of inoculums for the next year where as the plant debris that gets incorporated in the soil has no role in the disease recurrence the next year. From the current studies it is clear that the pathogen overwinters as teliospore on the infected plant debris, however, their viability gets decreased with advance in crop season. The current studies are in agreement with those of Gross and Venette (2001) who have reported that deep incorporation of bean debris of rust infected residues from previous growing season will reduce or eliminate the potential for overwintering and initiation of sexual and asexual stages of bean rust pathogen the following season or crop cycle and therefore reduce initial inoculums and delay infection of new crop plants.

Chapter – 6

SUMMARY ANDCONCLUSION

The present investigations on bean rust *U. appendiculatus* (Pers.) Unger were undertaken in relation to occurrence, identification, pathogenicity, screening of the germplasm against the pathogen and to unveil the mode of perpetuation of the pathogen. The results obtained are summarized as under:

The rust disease of beans was prevalent in all bean growing areas of valley with varying degrees of incidence and intensity. The disease incidence and intensity on leaves varied from 16.90 to 25.21 per cent and 6.53 to 9.92 per cent respectively. However the disease incidence and intensity on pods varied from 3.35 to 5.02 per cent and 1.29 to 1.97 per cent, respectively. Highest disease incidence and intensity both on leaves and pods was recorded in district Srinagar while it was lowest in district Pulwama.

Characteristic symptoms appeared as small white, slightly raised spots on either surface of the leaves. These spots enlarged in size and covered most of the area on the leaf blade which later on developed into reddish brown rust coloured pustules surrounded by a yellow border. On stems symptoms appeared as small elongated and raised spots. These spots enlarged in size and coalesed together. Later these spots were covered with brown rusty mass of spores. When the severity of the disease was high, severely infected leaves curled upwards and dropped down prematurely.

The various samples collected from different locations of Kashmir were infected with brown rusty coloured masses of urediniospores. These urediniospores were light brown, echinulated, catenulate, one celled, thin walled, globose to ellipsoidal, measuring 20.2-30.8 x 20.4-26.50 µm in size.

Pathogenicity of the fungus was proved on leaves (cotyledonary and trifoliate) and stems of French bean cv. French Yellow. Incubation period was less on leaves i.e. 6-7 and 7-8 days on cotyledonary and trifoliate leaves,

respectively, while it was 9-10 days on stem. Thirty one different germplasm/lines were screened against *U. appendiculatus* under natural epiphytotic conditions. Among germplasm lines screened against the disease, SKU-R-925, Masterpiece, SKU-R-916, SKU-R-71, DARS-R-4, SKU-R-924, Kanchan, SKU-R-616, DARS-R-26, SKU-R-91, SKU-R-114, DARS-R-42, SKU-R-76, SKU-R-9, SKU-R-914, SKU-R-615, SKU-R-104 and SKU-R-107 were moderately resistant to disease with disease intensity ranging from 2.99 to 5 per cent. Further, the genotypes DARS-R-88 (27.24 %) and SKU-R-506 (28.42%) were categorised as highly susceptible germplasm lines.

The studies on overwintering/survival of pathogen revealed that the pathogen overwinters as teliospores on plant debris left on the soil surface while infected plant debris incorporated deep (7.5 or 15 cm) in the soil has no role in the recurrence of disease next year. It is pertinent to mention here that in Kashmir valley beans are harvested in late October which falls close to winter season and most of the plant debris remain on the surface and has the potential to act as inoculums for the next season. Keeping in view the finding of current studies it is concluded that:

- The disease is present in all the bean growing areas of the valley but in varying proportion depending upon the agro climatic conditions of locality and the cultural practices adopted by the farmers.
- The disease is more severe on leaves and stems of the plant and very mild on the pods owing to the hard nature of pod tissue.
- The germplasm available with the Dryland (*Karewa*) Agriculture Research Station, Budgam, does not exhibit a great degree of resistance which is a challenge to the plant breeders to curb the disease in the present day scenario were people prefer organic food and vegetables. However, the lines showing some resistance may be incorporated in future breeding programmes.

LITERATURE CITED

Aghora, T.S., Mohan, N., Somkumar, R.G. and Ganashan, G. 2007. Breeding French bean *(Phaseolus vulgaris)* for resistance to rust *(Uromyces phasseoli* Reben Wint.). *Journal of Horticultural Sciences* **2**(2): 104-107.

Anonymous, 1961. Record of research for the period 1st January to 31st December, 1960. *Annual Report of East African Agriculture and Forestry Research Organization* 1960: 107.

Anonymous, 2010. *Food and Agriculture Organisation of the United Nations.* Rome (Italy).

Baggett, J.R. and Frazier, W.A. 1959. Disease resistance in the runner Bean, *Phaseolus coccineas* L. *Plant Disease Reporter* **43**(2): 137-143.

Ballantyne, B. 1974. Resistance to rust *(Uromyces appendiculatus*) in beans *(Phaseolus vulgaris*). *Proceedings of the Linnean Society of the New South Wales* **98**(3): 1070-1121.

Bassanezi, R., Amorin, L., Bergamin, A., Hau, B. and Berger, R.D. 2001. Accounting for photosynthetic efficiency of bean leaves with rust, angular leaf spot and anthracnose to assess the crop damage. *Plant Pathology* **50**: 443-452.

Batra, L.R. and Stavely, J.R. 1994. Attraction of two spotted spider mite to bean rust uridinia. *Plant Disease* ***78***: 282-284 .

Bhat, M.N. 2002. Chemical control of rust and angular leaf spot of French bean. *Sikkim Plant Diseases Research* **17**(1): 90-92.

Bhat, M.N., Singh, A.K. and Medhi, R.P. 1999. Reaction of French bean *(Phaseolus vulgaris*) cultivar accessions to rust pathogen *Uromyces appendiculatus. Indian Journal of Agricultural Sciences* **69**(12): 849-850.

Broughton, W.J., Hemandez, G., Blair, M. and Beebe, S. 2003. Bean (*Phaseolus vulgaris*) - model food legume. *Plant and Soil* **252**: 55-128.

Burmeister, L. and Hau, B. 2009. Control of the bean rust fungus *Uromyces appendiculatus* by means of *Trichoderma harzianum*: leaf disc assays on the antibiotic effect of spore suspension and culture filtrates. *BioControl* **54**: 575-585.

Butler, E.J. 1918. *Fungi and Diseases in Plants*. Thacker Sprink and Co. Calcutta, pp. 547.

Chardon, C.E. and Toro, R.A. 1927. Plant disease notes from central Andes. *Phytopathology* **17**: 147-153.

Christ, B.J. and Groth, J.V. 1982. Inheritance of resistance in three cultivars of beans to the bean rust pathogen and the interaction of virulence and resistance genes. *Phytopathology* **72**(7) : 771-773.

Christoff, A. 1939. Revision and notes on the parasitic flora of Bulgaria. *Journal of Agriculture Experimental Station Bulgaria* **9** : 77-85.

Chupp, C. and Sherf, A.F. 1960. *Vegetable Diseases and their Control*. The Ronald Press Company, New York, pp. 693.

Cummins, G.B. 1959. *Illustrated Genera of Rust Fungi*, p. 129.

De Jesus Junior, W.C., do Vale, F.X.R., Coelho, R.R., Hau, B., Zambolim, L., Costa, L.C. and Bergamin, F.A. 2001. Effects of angular leaf spot and rust on yield loss of *Phaseolus vulgaris*. *Phytopathology* **91**: 1045-1053.

Dixon, G.R. 1981. Vegetable Crop Diseases. *AVI Publishing Company, INC Westport, Connecticut*, pp. 404.

Dundas, B. 1942. Breeding beans for resistance to powdery mildew and rust. Abstract in *Phytopathology* **32**(9): 828.

Echandi, E. 1976. Principal fungal diseases of bean (*Phaseolus vulgaris*) in the American tropics in different ecological zones. *Fitopathologia Brasileria* **1** : 171-177.

Echavez, R., Freytag, G.F. and Zapata, M. 1982. Mexico 309 as a source of resistance to bean rust. *Phytopathology* **72**(1) : 169.

Frazier, W.A. and Hendrixn, J.W. 1949. Hawaiian Wonder: new rust resistant pole green *Epoular of Hawii. Agricultural Expermental Station* **28** : 1.

Frazier, W.A., Hendrixn, J.W. and Kikuta, K. 1948. Breeding rust resistant pole green beans. *Hawaii Proceedings of American Society of Horticulture Science* **51** : 468-470.

Garcia, R.M., Diaz Carrasco, H., Piedra, S. and Velazquez, O. 1980. Performance of *Phaseolus vulgaris* L. cultivars in Cuban conditions. *Green Beans Hiforme Cientifico Tecnio* **108** : 23-24.

Gross, P.L. and Venette, J.R. 2001. Overwinter survival of bean rust uridiniospores in North Dakota. *Plant Disease* **85** : 226-227.

Gupta, S.K., Jarial, K. and Kumar, M. 2008. Occurrence of French bean rust in Himachal Pradesh. *Journal of Mycology and Plant Pathology* **38** : 352-353.

Hang, A.N., Miklas, P.N., Silbernagel, M.J. and Hosfield, G.L. 2006. Registration of “Silver Cloud” white kidney dry bean. *Crop Science* **46**(2) : 991-992.

Hazra, P. and Som, M.G. 2005. *Vegetable Science*. Kalyani Publishers, Ludhiana, India, pp. 491.

Hikida, H.R. 1962. Races of bean rust *(Uromyces phaseoli (*pers). Wint var. *phaseoli*, in the *Williamette Valley. Disease Abstract* **22**(10) : 3341-3342.

Hosfield, G.L., Varner, G.V., Uebersak M.A. and Kelly, J.D. 2004. Registration of 'Merlot' small red bean. *Crop Science* **44**(1) : 351-352.

Jacques, D. 2002. Bean diseases and their control. *Agriculture and Agri-food Canada.*

Kardin, M.K. and Groth, J.V. 1985. The inheritance of resistance in two white seeded dry bean cultivars to seven bean rust isolates. *Phytopathology* **75**(11): 1310.

Kelly, J.D. 1982. Varietal and class diversity and accentuation of disease problem in major production area **In**: *Report on Bean Improvement Cooperative and Natural Dry Bean Research Conference. 5-7 January*. University of Florida Gainesvilla.

Kelly, J.D., Gepts, P., Miklas, P.N. and Coyne, P. 2003. Tagging and mapping of genes and QTL and molecular marker-assisted selection for traits of economic importance in bean and cowpea. *Field Crops Research* **82** : 135-154.

Kelly, J.D., Hosfield, G.L., Varner, G.V., Uebersax, M.A. and Taylor, J. 2000. Registration of 'Phantom' black bean. *Crop Science* **40**(2): 572.

Kelly, J.D., Hosfield, G.L., Varner, G.V., Uebersax, M.A. and Taylor, J. 2005. Registration of 'Condor' black bean. *Crop Science* **45**(2): 795-796.

Kelly, J.D., Stavely, J.R. and Miklas, P.N. 1996. Proposed symbols for rust resistance genes. *Annual Report Bean Improvement Cooperation* **39** : 25-31.

Khati, P. and Hooda, K.S. 2006. Multiple disease resistance in rajmash genotypes. *Indian Phytopathology* **59**(4) : 521-522.

Kiraly, Z., Barna, B. and Ersek, T. 1972. Hypersensitivity as a consequence, not the cause, of plant resistance to infection. *Nature London* **239**(5373) : 456-458.

Kolmer, J.A. and Groth, J.V. 1982. Genetics of a minute uredium reaction to bean rust in bean lines 814. *Phytopathology* **72**(7) : 983.

Kolmer, J.A. and Groth, J.V. 1984. Inheritance of a minute uredinium infection type of bean rust in bean breeding line 814. *Phytopathology* **74**(2) : 205-207.

Liebenberg, M.M., Mienie, C.M.S. and Pretorius, Z.A. 2006. The occurrence of rust resistance gene Ur-13 in common bean cultivars and lines. *Euphytica* **150** : 365-386.

Lindgren, D.T., Eskridge, K.M., Steadman, J.R. and Schaaf, D.M. 1995. A model for dry bean yield loss due to rust. *HortTechnology* **5 :** 35-37.

Malencon, G. 1936. Maroccon mycological notes. *Review Mycologie* **1** : 257-275.

Masooodi, M.A. and Massoodi, S.D. 2003. *Agriculture in J&K-A Perspective in Production of Vegetables.* Mohisarw Book Series, Srinagar, pp. 111-126.

Mayee, C.D. and Dattar, V.V. 1986. *Phytopathometry*. Technical bulletin. Marathwada Agriculture University, Parbhani, Maharashtra, pp. 85.

Melchers, L.E. 1915. A way of obtaining an abundance of large uredinia from artificial culture. *Phytopathology* **5** : 236-237.

Mienie, C.M.S., Liebenberg, M., Pretorius, Z.A. and Miklas, P.N. 2006. Scar markers linked to the common bean rust resistance gene Ur.13. *Theoretical and Applied Genetics* **111**(5): 972-979.

Miklas, P.N., Hang, A.N., Kelly, J.D., Strausbaugh, C.A. and Forster, R.L. 2002. Registration of three kidney bean germplasm lines resistantto bean common mosaic and necrosis poty viruses. USLK-2 light red kidney, USDK-4 dark red kidney and USWK-6 White kidney. *Crop Science* **42**(2): 674-675.

Miklas, P.N., Kelly, J.D., Beebe, S.E. and Blair, M.W. 2006. Common bean breeding for resistance against biotic and abiotic stresses: from classical to MAS breeding. *Euphytica* **147** : 105-131.

Mishra, H.N., Mohapatra, A.K., Sahu, Mohapatra, A.K.B. 1998. Performance of French bean under different dates of sowing in Eastern ghat high land zone of Orissa. *Annals of Agricultural Research* **19**(1): 83-88.

Mumbaga, M.T. and Steadman, J.R. 1992. Adult plant rust resistance with leaf pubescence in common beans. *Plant Disease* **76 :** 1230.

Ohlander, L.J.R. 1980. Research on haricot bean *Phaseolus vulgaris* L. production in Ethiopia 1972-1976. *Repportinstitutionen for Vaxiodling* **82**: 294.

Pachico, D. 1993. The demand for bean technology. **In:** *Trends in CIAT Commodities* (Ed. G. Henry). Working document No. 128. CIAT California, Colombia, pp. 60-73.

Partridge, J.E. 1997. Rust of dry beans. *University Nebraska-Lincoln, Department of Plant Pathology.*

Pastor Corrales, M.A., Aime, A.C. and Steadman, J.R. 2005. Guiding the development of common bean cultivars with durable rust resistance based on the genetic diversities of the pathogen and its host. *Proceedings of the 1st International Edible Legume Conference in Conjuction with the IVth World Cowpea Congress, Durban, South Africa*. 17-21 April 2005: 1-10.

Persoon, C.H. 1795. Observations Mycologicae. **In**: [Ed. P. Usteri]. *Annalen der Botanic* **3**: 1-43.

Popelka, J., Carlos, N.T. and Higgins, T.J.V. 2004. Gene technology for grain leg umes can it contribute to the food challenge in developing countries. *Plant Science* **167**: 195-206.

Prakasham, V. and Thamburaj, S. 1991. Efficacy of fungicides in control of rust disease of french beans caused by *Uromyces phaseoli* (Reben) Wimb. *Indian Journal of Mycology and Plant Pathology* **21** : 158-159.

Rey, G. and Lozano, J.C. 1961. Physiological studies on rust of beans caused by *Uromyces phaseoli*. *Acta Agronomy Palmira* **11**: 147-186.

Rios, G.P., Andrade, E.M. and Costa, J.L.S. 2001. Evaluation of resistance of cultivars and lines of common bean to different populations of *Uromyces appendiculatus*. *Fitopatologia Brasileira* **26**(2): 128-133.

Rivera, C.G. 1995. Incorporation of resistance to race 29 of French bean rust (*Uromyces appendiculatus* (Pers.) Unger) in the cultivars Pacuaral Vaina Morada 55.

Rodriguez, M.C.A. 1976. Resistance of French bean (*Phaseolus vulgaris* L.) to rust *(Uromyces appendiculatus* (Pers) Unger and comparison of two methods of evaluation by visual scales. *Pesquisa Agropecuaria Brasileira* **51** : 1373-1378.

Santana, E.A., Mumbaga, M.T., Coyne, D.P. and Steadman, J.R. 1993. Sources of resistance to common bacterial blight and rust in elite *Phaseolus vulgaris* L. germplasm. *HortScience* **28** : 644-646.

Sardana, V., Dhingre, K.K., Gill, M.S. and Singh, I.J. 2000. Production technology of French beans (*Phaseolus vulgaris* L.). *Agriculture Review* **21** : 141-154.

Schneiter, A.A., Grafton, K.F., Burke, D.W. and Weiser, G.C. 1984. Nodak an early maturing pinto bean cultivar. *North Dakota Farm Research* **42**(2): 26.

Schwartz, H.F., Steadman, J.R. and Harveson, R.M. 2011. *Rust of Dry Beans*. University of Nebraska-Lincoln Regional Extension Publication, pp. 2936-2937.

Sharma, A.K. 1998. Epidemiology and management of rust disease of French bean. *Vegetable Science* **25** : 85-88.

Sharma, P. 2007. *Vegetable Disease Diagnosis and Biomanagement*: Symptomatic Diagnosis. Aavishkar Publishers, Jaipur, pp. 47.

Sharma, P.N., Sharma, O.P. and Tyagi, P.D. 1994. Status and distribution of bean anthracnose in Himachal Pradesh. *Himachal Pradesh Journal of Agriculture Research* **20** : 91-96.

Sharma, S.R. 1989. Yield losses caused by rust in French beans. *Plant Disease Research* **4** : 92-94.

Silliro, J.C. and Rubiales, D. 2002. Histochemical characterization of resistance to *Uromyces vicia faba* bean. *Phytopathology* **92** : 294.

Silva, L.O., Moraes, E.A., Aidar, H., Thung, M., Gutierrez, J.A., Teran, H., Morlase, F.J., Pastor Corrales, M.A., Schwartz, H.F. and Singh, S.P. 2003. Registration of 'EMGOPA 201-Ouro' common bean. *Crop Science* **43**(5) : 1881-1882.

Singh, J.P. and Musyimi, A.B.R. 1981. Effect of rust on bean yield. *Indian Phytopathology* **34** : 378-379.

Singh, R.S. 1985. Diseases of vegetable crops *3rd ed. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi,* pp. 268-271.

Singh, R.S. 2009. *Diseases of Vegetable crops,* Oxford and IBH, New Delhi, pp. 50-88.

Singh, S.P., Teran, H.P., Munoz, C.G. and Takegani, J.C. 2000. Registration of multiple disease resistant carioca dry bean A-801 and A-804 germplasm. *Crop Science* **40**(6) : 1836-1837.

Souza, T.L.P.O. de Ragagnin, V.A., Sanglard, D.A., Moreira, M.A. and Barros, E.G.de. 2005. Resistance test to *Uromyces appendiculatus* through pathogen inoculation in commom bean detached leaves. *Acta Scientiarum Agronomy* **31**(2) : 197-201.

Stavely, J.R. 1981. Resistance to United States collections of *Uromycesphaseoli in Phaseolus vulgaris. Phytopathology* **71**(8): 905-906.

Steadman, J.R., Ramirez, W., Hindman, D.W. and Andcoyne, D.P. 1985. Patogenic variation sin bean rust fungus *Uromyces phaseoli* and sources of resistance in the Dominican Republic. *Phytopathology* **75**(10): 1179.

Terhune, B.T. and Hoch, H.C. 1993. Substrate hydrophobicity and adhesion of *Uromyces* urediospores and germlings. *Experimental Mycology* **17** : 241.

Thiago, L., Souza, P.O., Vilmar, A., Demerson, A., Maurilio, A. and Everaldo, G. 2007. Identification of races of selected isolates of *Uromyces appendiculatus* from Minas Gerais (Brazil) based on the new International Classification System. *Fitopathology Brassiliana* **32** : 104-109.

Townsend, G.R. and Wade, B.L. 1943. Close up of something new in snap beans Two varieties developed for Florida resist rust, mildew, common mosaic and are heat and drought tolerant. *Plant Breeding Abstract* **13**(3) : 268.

Van Schoonhoven, A. and Pastor-Corrales, M.A. 1987. Standard system for the evaluation of bean germplasm. *Cento International de Agriculrura Tropical (CIAT). Cali, Colombia*, pp. 29-30.

Walker, J.C. 1952. *Diseases of Vegetable Crops*. Mc grew-Hill Company Inc., pp. 529.

Yarwood, C.B. 1960. Uredospore production by *Uromyces phaseoli*. Abstract in *Phytopathology* **50**: 59.

Yeh, C.C. 1983. Screenig of beans for rust resistance and physiological races of bean- rust leaves. *Journal of Agricultural Research of China* **32**(3) : 259-269.

Yoshi, K. 1980. Common Blight of beans, pp. 157-172. **In :** *Bean Production Problems in Tropics.* [Eds. H.F. Schwertz and M.A. Pastor Corrales]. Centro International de Agricultural Tropical, California**.**

Zaiter, H.Z., Coyne, D.P. and Steadman, J.R. 1990. Rust reaction and pubescence in Alubia Beans. *HortScience* **25** : 664-665.

Zaumeyer, W.J. 1947. Control of plant diseases. Year book of Agriculture United States. *Department of Agriculture,* pp. 333-337.

Zaumeyer, W.J. and Harter, L.L. 1946. Pinto 5 and 14 new rust resistant beans for dry land area of the West. *5th Seedsnt* **9**(8) : 15, 50, 54.

Zaumeyer, W.J. and Thomas, H.R. 1957. A monographic study of bean diseases and methods for their control. *United States Department of Agriculture Technical Bulletin* **868** : 225.

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Shalimar Campus Srinagar – 190 025
-::o::-

CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. V.K. Razdhan, Professor & Head, Division of Plant Pathology, SKUAST-Jammu during viva voce examination held on 12th of November, 2014 have been incorporated in the manuscript entitled **"Studies on Common Bean (*Phaseolus vulgaris* L.) Rust in Kashmir Valley"** submitted by **Mr. Irshad-ul-Islam Khandi (Regd. No. 2012-A-893-M).**

(Dr. T.A. Shah)
Chairman
Advisory Committee