

Influence of Weather and Soil Parameters on Development of Wet Root Rot in Pulse Crops and Virulence Analysis of *Rhizoctonia solani* Isolates

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Received: July 23, 2012 Accepted: August 6, 2012 Online Published: October 12, 2012

doi:10.5539/jas.v4n11p195

URL: <http://dx.doi.org/10.5539/jas.v4n11p195>

Abstract

Wet root rot caused by *Rhizoctonia solani* Kühn in pulse crops was favored by wide range of soil parameters like temperature, humidity, pH, electric conductivity and soil texture. The areas surveyed for the collection of the isolates showing variable atmospheric temperature and relative humidity and low to medium levels of soil organic carbon and high level of available phosphorus influenced the development of the disease incidence from 2-48%. Seventy three cultivars of mungbean, twenty eight cultivars of urdbean and eight cultivars of cowpea were evaluated against virulent isolate of *R. solani* (RASC 30) to design a set of differential cultivars for virulence analysis. Two cultivars of urdbean, namely, NDU3-4 and IPU2-14, one cultivar of mungbean, namely, HUM 1 and three cultivars of cowpea, namely, V240, V585 and DCP7 showed resistant reactions. Four cultivars of urdbean, namely, TU94-2, KU323, KUG216 and B3-8-8, one cultivar of mungbean, namely, PDM54 and two cultivars of cowpea, namely, V578 and DCP13 were moderately resistant against the pathogen. The virulence analysis of 90 isolates of the pathogen representing 7 anastomosis groups (AGs) isolated from pulse crops of 16 agro-ecological regions of India on a set of differential cultivars, namely, HUM 1, PDM 54 and Pusa Vishal of mungbean, NDU 3-4, KU 323, Uttara of urdbean and V 240, V 578 and Pusa Sukomal of cowpea grouped the isolates into five pathotypes. The differential cultivar for each pathotype was identified. The pathotypes were not corresponding to the AG type of the isolates. Except one pathotype (isolate RMPG28 belonging to AG2-3), each pathotype had the isolates from different AGs.

Keywords: virulence, differential cultivars, pathotypes, *Rhizoctonia solani*, soil conditions

1. Introduction

India is recognized globally as a major pulse producing country sharing 25% of the global pulse production. India grows a variety of pulse crops under a wide range of agro-ecological conditions in 23.4 mh with 14.6 mt production and 625 kg ha⁻¹ productivity (Agricultural Statistics at a Glance, 2010). Biotic stresses are the major cause of low productivity of pulse crops in India. Amongst the fungal pathogens, *Rhizoctonia solani* Kühn [teleomorph - *Thanatephorus cucumeris* (Fr.) Donk] is a seed- and soil-borne plant pathogen causing web blight/wet root rot in pulse crops besides other agricultural and horticultural crops. Chickpea (*Cicer arietinum* L.), cowpea [*Vigna unguiculata* (L.) Walp.], mungbean [*Vigna radiata* (L.) Wilczek], urdbean [*Vigna mungo* (L.) Hepper] lentil (*Lens culinaris* Medikus) and french bean (*Phaseolus vulgaris* L.) are the major pulse crops cultivated world wide under different agro-climatic conditions are affected by *R. solani*. The pathogen causes considerable yield loss in mungbean and urdbean in India (Dubey, 2003). Yield loss up to 57% in mungbean was reported from Iran (Kaiser, 1970). The intensive crop cultivation and modified agro-practices have increased the populations of *R. solani* in soil and gradually built up new disease problems. *R. solani* is genetically diverse in respect of pathogenicity as well as cultural/morphological and physiological characters. Initially, *Rhizoctonia* spp. are classified in different species or groups on the basis of morphological and cultural characters (Parmeter & Whiteny, 1970). Isolates of *R. solani* have been traditionally classified into different anastomosis groups (AGs) (Ogoshi, 1987; Carling, 1996).

Very limited studies on the virulence characterization and grouping of the host-specific isolates of *R. solani* have been carried out so far. Attempt has not been made yet to identify the pathotypes/races of *R. solani* associated

with pulse crops based on virulence analysis on host differentials. The host differentials for pulse crops are also not available worldwide. The pathotypes of the pathogen have not been correlated with agro-ecological regions, AGs and soil and weather parameters. Keeping these points in view, the present study was aimed to standardize the host differentials to determine the pathotypes/races among the populations of *R. solani* representing various AGs associated with various pulse crops in different agro-ecological regions of India having diverse cropping sequences and to determine the influence of weather and soil parameters on disease development in different areas.

2. Materials and Methods

2.1 Cultures of *Rhizoctonia Solani* and Cultivars of Mungbean, Urdbean and Cowpea

Ninety (representative of 470 isolates) isolates of *R. solani* isolated from different pulse crops from 16 agro-ecological regions covering 21 states of India and being maintained in Pulse Laboratory, Division of Plant Pathology, Indian Agricultural Research Institute, New Delhi were used in the present study. The cultivars/genotypes of mungbean, urdbean and cowpea included in the present study were collected from Division of Genetics, Indian Agricultural Research Institute, New Delhi.

2.2 Weather and Soil Parameters

The soil samples along with diseased specimens were collected from 9 states, namely, Delhi, Uttar Pradesh, Rajasthan, Jammu and Kashmir, Uttarakhand, Punjab, Gujarat, Maharashtra and Assam. The pooled samples of each location (48 soil samples) were analyzed for nitrogen, carbon, phosphorus, salinity, pH and soil texture. The weather parameters as soil and atmospheric temperature, soil and atmospheric relative humidity were also recorded in these areas by using portable digital humidity and temperature recorder.

2.3 Reaction of Different Cultivars of Mungbean, Urdbean and Cowpea against *R. solani*

In order to find out resistant sources to constitute a set of differential cultivars for analysis of virulence, 28 cultivars of urdbean, 8 cultivars of cowpea and 73 cultivars of mungbean were evaluated against *R. solani* (RASC 30) under sick pot soil condition. Surface sterilized (0.1% formalin) plastic pots (20 cm dia) were filled (2 kg pot⁻¹) with sterilized soil (1% formalin). The soil was inoculated 2-days prior sowing with 10-day-old inoculum (10 g kg⁻¹ soil) of *R. solani* multiplied on sorghum grains (Dubey et al., 2009). Ten seeds of urdbean, mungbean and cowpea in each pot were sown on August 22, 2009 separately in three replications. The incidence of wet root rot was recorded at 15 days interval up to maturity of the crop plants.

2.4 Virulence Analysis

Virulence analysis of 90 representative isolates including international testers of 7 AGs of the pathogen was carried out on a set of 10 differential cultivars, namely, HUM 1, PDM 54 and Pusa Vishal of mungbean, NDU 3-4, KU 323, Uttara and KUG 216 of urdbean, and V 240, V 578 and Pusa Sukomal of cowpea in net house. Twelve seeds of each cultivar were sown on August 3, 2010 and July 13, 2011 in 20 cm diameter surface sterilized plastic pots (0.1 % mercuric chloride) filled with 2 kg sterilized soil (1 % formalin for 15 days) and inoculated with 10-day old culture of *R. solani* multiplied on sorghum grains (10g kg⁻¹ soil) 2 days before sowing. Pots with un-inoculated soils were also maintained as control for comparison. The incidence of wet root rot was recorded at 15 days interval up to maturity of the crop plants.

2.5 Virulence Analysis of AG Groups and Their Combinations

A set of pot experiment was conducted to test the virulence of the isolates representing two AG groups for AG1- isolate RUPM83 and RUPU82 and for AG4- isolate RUPM66 and RUPU69) individually and in combinations along with hybrid culture of the same group in three replications. Surface sterilized (0.1% formalin) plastic pots (10 cm diameter) were filled (500g pot⁻¹) with sterilized soil (1% formalin). The soil was inoculated 2 day prior sowing with 10-day-old inoculum as mentioned earlier. Ten seeds of mungbean (cv Ratna) were sown on August 1, 2009 in each pot. The incidence of wet root rot was recorded at 15 days interval up to maturity of the crop plants.

2.6 Observations Recorded and Data Analysis

The wet root rot incidence was recorded on the basis of number of plants showing wet root rot symptoms out of the total plants and the cultivars/genotypes were categorized into resistant (0-10% root rot incidence), moderate resistant (>10-20% root rot incidence), susceptible (>20-50% wet root rot incidence) and highly susceptible (>50% root rot incidence). Finally, the reactions were presented as resistant (0-20%) and susceptible (>20%) for pathotype grouping (Dubey, 2003).

3. Results

3.1 Influence of Weather and Soil Parameters

The soil and atmospheric temperature and relative humidity recorded in different parts of the country were variable. The results (Table 1) indicated that the disease favoured by wide range of soil (18.1-41.0°C) and atmospheric (8.1-46.3°C) temperature and soil (28-68%) and atmospheric (20-87%) relative humidity. The disease development was also favoured by variable soil parameters. The soil pH range from 5.56-8.71 and electric conductivities from 0.03 - 0.51 ds m⁻¹ favoured the disease development. The majority of areas surveyed showed low to medium level of soil organic carbon and total nitrogen ranging from 62.7-492.8 kg ha⁻¹. Available phosphorus was from 1.2-98.3 kg ha⁻¹ and the soil samples collected from most of the areas showed high phosphorus status. Soil texture was also variable in areas surveyed from loam to sandy loam and silty to clay loam (Table 2).

Table 1. Soil and atmospheric temperature and humidity recorded during survey in different parts of the country

State/District	Soil parameters		Atmospheric parameters		Mean range of disease incidence (%)
	Temperature (°C)	Humidity (%)	Temperature (°C)	Relative humidity (%)	
			Min - Max	Min - Max	
Uttar Pradesh					
Mirzapur	19.4	59	20.3 - 29.3	38 - 72	15-29
Mirzapur	21.6	58	21.8 - 28.9	40 - 74	10-25
Mirzapur	19.2	62	20.3 - 29.3	35 - 72	12-20
Mirzapur	21.6	58	21.8 - 28.9	40 - 74	11-25
Mirzapur	20.2	68	22.1 - 28.5	38 - 74	12-26
Jhansi	36.1	52	34.1 - 40.3	32 - 70	10-36
Jhansi	35.2	52	34.1 - 40.3	35 - 72	8-30
Jhansi	37.5	56	32.1 - 41.3	32 - 68	8-40
Jhansi	36.0	52	31.1 - 40.3	32 - 73	14-34
Gorakhpur	21.2	51	17.8 - 28.0	40 - 78	5-30
Gorakhpur	18.1	50	09.2 - 20.8	36 - 76	7-25
Gorakhpur	18.4	50	08.1 - 25.8	36 - 76	10-32
Kanpur	22.4	58	17.9 - 28.4	38 - 76	7-36
Kanpur	21.8	54	18.1 - 28.2	36 - 72	7-40
Varanasi	21.8	56	20.6 - 25.0	40 - 82	8-23
Varanasi	19.1	65	21.6 - 28.0	36 - 76	10-19
Jaunpur	20.8	51	10.2 - 27.7	38 - 78	5-20
Rajasthan					
Jaipur	34.1	48	32.1 - 36.4	30 - 68	5-26
Jaipur	35.8	46	32.1 - 36.4	30 - 68	9-30
Hanumangarh	32.8	41	31.1 - 38.4	35 - 62	5-20
Sriganganagar	35.8	48	32.1 - 40.4	38 - 72	4-10
Jammu & Kashmir					
Samba	38.2	28	36.2 - 46.3	26 - 50	5-20
Samba	38.6	28	36.2 - 46.3	26 - 50	7-30
Samba	38.8	28	36.2 - 46.3	26 - 50	3-25
Udhampur	35.5	20	34.4 - 42.6	20 - 48	2-20
Kathua	35.7	27	35.3 - 45.6	25 - 49	3-17
Uttarakhand					
U. S. Nagar	32.8	59	30.2 - 36.8	62 - 81	5-40
U. S. Nagar	31.3	62	31.2 - 38.1	62 - 72	10-45
U. S. Nagar	31.1	62	31.2 - 38.1	62 - 72	6-48
Tehri Garhwal	29.8	52	28.9 - 33.8	45 - 68	5-28
Tehri Garhwal	33.8	60	29.5 - 35.2	42 - 62	6-35
Tehri Garhwal	32.3	56	31.2 - 33.7	38 - 65	4-30
Panjab					
Ludhiana	32.3	59	31.2 - 33.8	62 - 87	7-30
Ludhiana	32.3	59	31.2 - 33.8	62 - 87	4-24
Ludhiana	22.3	59	31.2 - 33.8	62 - 87	5-25
Ludhiana	32.8	60	31.2 - 33.8	62 - 87	6-26
Ludhiana	33.8	60	33.1 - 35.2	42 - 62	4-24
Gujarat					
Ahmedabad	41.0	56	30.3 - 41.0	28 - 70	5-14
Ahmedabad	40.4	53	30.3 - 41.0	28 - 70	6-16
Anand	35.4	56	28.4 - 44.7	28 - 70	5-22
Anand	35.4	56	28.4 - 44.7	28 - 70	6-20
Anand	34.2	50	28.0 - 41.0	28 - 70	5-23
Anand	35.5	52	28.4 - 44.7	28 - 70	5-19
Maharashtra					
Pune	26.1	48	28.2 - 43.5	31 - 63	5-10
Pune	26.3	48	28.2 - 43.5	31 - 63	4-8
Pune	33.3	38	28.2 - 43.5	31 - 63	5-10
Assam					
Nalbari	31.9	52	27.2 - 35.8	48 - 74	4-22
Jorhat	33.1	56	31.8 - 37.6	52 - 79	4-37

Table 2 Soil parameters of various soil samples collected from different parts of the India

State /District	Sample No.	pH	EC (ds/m)	Organic Carbon (g/kg)	Total Nitrogen (kg/ha)	Available P (kg/ha)	Texture Class
Uttar Pradesh							
Mirzapur	SPL-1	5.85	0.24	5.3	313.6 (3.8 : 1)*	94.3	Loam
Mirzapur	SPL-2	6.54	0.03	4.1	246.4 (3.7 : 1)	98.3	Loam
Mirzapur	SPL-27	7.42	0.18	6.1	246.4 (5.5 : 1)	82.3	Silty clay
Mirzapur	SPL-28	7.49	0.07	8.6	246.4 (7.8 : 1)	81.6	Sandy loam
Mirzapur	SPL-29	8.23	0.10	5.7	188.1 (7.1 : 1)	20.5	Loam
Jhansi	SPL-12	7.62	0.06	4.7	125.4 (9.4 : 1)	7.3	Sandy clay loam
Jhansi	SPL-13	7.53	0.03	4.6	246.4 (4.2 : 1)	90.2	Sandy clay loam
Jhansi	SPL-14	7.34	0.12	4.3	188.1 (5.4 : 1)	22.5	Sandy loam
Jhansi	SPL-15	7.63	0.10	10.7	246.4 (9.1 : 1)	88.7	Sandy clay loam
Gorakhpur	SPL-42	5.60	0.42	4.3	188.1 (5.4 : 1)	23.5	Loam
Gorakhpur	SPL-43	8.05	0.14	3.9	188.1 (4.9 : 1)	25.6	Sandy loam
Gorakhpur	SPL-44	5.56	0.21	3.6	156.8 (5.1 : 1)	20.4	Loam
Varanasi	SPL-30	8.24	0.21	5.3	188.1 (7.1 : 1)	37.1	Clay loam
Varanasi	SPL-46	7.93	0.20	5.7	246.4 (5.2 : 1)	39.6	Loam
Kanpur	SPL-40	6.69	0.20	4.7	188.1 (5.9 : 1)	20.3	Loam
Kanpur	SPL-41	7.75	0.15	5.0	246.4 (4.5 : 1)	21.0	Loam
Jaunpur	SPL-45	6.62	0.11	3.1	125.4 (6.2 : 1)	1.2	Loam
Rajasthan							
Jaipur	SPL-3	7.61	0.03	1.8	188.1 (2.3 : 1)	29.9	Sandy loam
Jaipur	SPL-4	7.69	0.16	1.5	125.4 (3.0 : 1)	32.0	Sandy loam
Hanumangarh	SPL-5	8.07	0.04	1.7	125.4 (3.4 : 1)	19.2	Loamy sand
Sriganganager	SPL-6	7.99	0.08	2.6	156.8 (3.7 : 1)	34.1	Loamy sand
Jammu & Kashmir							
Samba	SPL-7	7.44	0.51	3.1	188.1 (3.9 : 1)	20.9	Sandy loam
Samba	SPL-8	8.25	0.25	6.2	313.6 (4.4 : 1)	24.4	Sandy loam
Samba	SPL-9	8.09	0.07	2.4	125.4 (4.8 : 1)	19.6	Loam
Udhampur	SPL-10	7.98	0.19	4.3	125.4 (8.6 : 1)	39.2	Clay loam
Kathua	SPL-11	8.21	0.21	2.9	62.7 (14.5 : 1)	20.5	Loam
Uttarakhand							
U. S. Nagar	SPL-16	5.64	0.15	12.7	313.6 (8.6 : 1)	64.0	Sandy clay loam
U. S. Nagar	SPL-17	6.62	0.10	17.2	492.8 (7.7 : 1)	52.3	Sandy clay loam
U. S. Nagar	SPL-18	6.26	0.06	10.2	250.8 (9.1 : 1)	42.6	Sandy clay loam
Tehri Garhwal	SPL-19	6.05	0.10	8.9	282.2 (7.4 : 1)	58.9	Silt loam
Tehri Garhwal	SPL-20	6.07	0.13	24.9	313.6 (17.1 : 1)	40.3	Silt loam
Tehri Garhwal	SPL-21	5.86	0.08	8.9	246.4 (8.1 : 1)	55.7	Silt loam
Panjab							
Ludhiana	SPL-22	7.69	0.07	6.7	188.1 (8.4 : 1)	34.1	Sandy clay loam
Ludhiana	SPL-23	7.82	0.20	5.4	188.1 (6.7 : 1)	32.6	Sandy clay loam
Ludhiana	SPL-24	8.28	0.05	9.4	188.1 (11.7 : 1)	30.2	Sandy clay loam
Ludhiana	SPL-25	7.81	0.09	2.9	125.4 (5.8 : 1)	26.4	Sandy loam
Ludhiana	SPL-26	7.52	0.13	7.3	246.4 (6.6 : 1)	25.0	Sandy loam
Gujarat							
Ahmedabad	SPL-31	8.60	0.07	2.8	62.7 (14.0 : 1)	16.6	Loamy sand
Ahmedabad	SPL-32	8.67	0.03	2.6	94.0 (6.5 : 1)	17.0	Loamy sand
Anand	SPL-33	8.66	0.13	2.9	94.0 (7.2 : 1)	81.0	Clay loam
Anand	SPL-34	8.71	0.09	2.8	125.4 (5.6 : 1)	75.0	Clay loam
Anand	SPL-35	8.55	0.05	1.9	125.4 (3.8 : 1)	64.2	Clay loam
Anand	SPL-36	6.80	0.27	1.9	125.4 (3.8 : 1)	60.3	Clay loam
Maharashtra							
Pune	SPL-37	8.45	0.14	6.0	219.5 (6.6 : 1)	35.4	Clay loam
Pune	SPL-38	8.46	0.08	6.6	282.2 (5.5 : 1)	37.0	Clay loam
Pune	SPL-39	8.19	0.10	6.7	188.1 (8.4 : 1)	24.4	Clay loam
Assam							
Nalbari	SPL-47	5.83	0.11	8.5	313.6 (6.1 : 1)	25.2	Sandy loam
Jorhat	SPL-48	6.34	0.15	5.6	219.5 (6.2 : 1)	22.2	Sandy loam

Low carbon- 5g/kg, medium carbon- > 5-7.5g/kg and high carbon- > 7.5g/kg;

Low phosphorus- 11kg/ha, medium phosphorus- > 11-25kg/ha and high phosphorus- > 25 kg/ha;

*Figures given in parentheses are C:N ratios.

3.2 Reaction of Different Cultivars

The results (Table 3) indicated that out of 28 cultivars of urdbean, only 2 cultivars, namely, NDU 3-4 and IPU 2-14, out of 73 cultivars of mungbean, one cultivar, namely, HUM 1 and out of 8 cultivars of cowpea, 3 cultivars, namely, V 240, V 585 and DCP 7 showed resistant reaction. Four cultivars of urdbean, namely, TU 94-2, KU 323, KUG 216, B 3-8-8, one cultivar of mungbean, namely, PDM 54 and 2 cultivars of cowpea, namely, V 578 and DCP 13 were found moderately resistant against the disease. Rest 96 cultivars of urdbean, mungbean and cowpea showed susceptible to highly susceptible reactions.

Table 3. Screening of different varieties of urdbean, mungbean and cowpea against *Rhizoctonia solani* (RASC 30)

Crop/Varieties	Mortality (%)		Total mortality (%)	Reaction
	Pre emergence (%)	Post emergence (%)		
Urdbean				
Azad urd	26.67	0.00	26.67	S
B 3-8-8	20.00	0.00	20.00	MR
Ballabh urd-1	16.67	6.67	23.34	S
Barabanki local	20.00	6.67	26.67	S
BS 23-5	53.33	0.00	53.33	HS
IPU 2-14	0.00	0.00	0.00	R
IPU 2-33	63.00	3.33	66.33	HS
IPU 5-13	33.33	0.00	33.33	S
KU 323	13.33	3.33	16.66	MR
KU 99-4	33.33	3.33	36.66	S
KU 99-5	36.67	0.00	36.67	S
KU 99-20	40.00	0.00	40.00	S
KU 99- 21	40.00	10.00	50.00	S
KUG 6-3	63.33	3.33	66.66	HS
KUG 216	13.33	0.00	13.33	MR
Mash 1-1	26.67	3.33	30.00	S
MBU 108	26.67	3.33	30.00	S
NDU 3-4	10.00	0.00	10.00	R
NDU 3-5	26.67	13.33	40.00	S
NDU 5-3	93.33	0.00	93.33	HS
MDU 5-7	26.67	0.00	26.67	S
OBG 31	73.33	3.33	76.66	HS
Pant U-31	46.67	0.00	46.67	S
Sarla	46.67	0.00	46.67	S
TU 94-2	20.00	0.00	20.00	MR
Uttara	33.33	0.00	33.33	S
UH 4-6	50.00	3.33	53.33	HS
VallabhUrd1	40.00	3.33	43.33	S
Mungbean				
AKM 99-10	23.33	6.67	30.00	S
AKM 99-14	50.00	0.00	50.00	S
Barabanki	20.00	30.00	50.00	S
BDU 1	35.00	5.00	40.00	S
C 5	70.00	10.00	80.00	HS
C 6	50.00	5.00	55.00	HS
CGG 973	35.00	40.00	75.00	HS
COGG 912	43.33	16.67	60.00	HS
Ganga 8	55.00	15.00	70.00	HS
GM 4-2	35.00	30.00	65.00	HS
GM 5-8	50.00	20.00	70.00	HS
HUM-1	10.00	0.00	10.00	R
IPM 2-9-1	45.00	35.00	80.00	HS
IPM 2-9-3	30.00	5.00	35.00	S
IPU 2-33	30.00	15.00	45.00	S
IPU 7-19	20.00	40.00	60.00	HS
IPU 7-3	25.00	40.00	65.00	HS
K 851	36.67	10.00	46.67	S
KM 2268	30.00	40.00	70.00	HS
KM 2272	30.00	15.00	45.00	S

Kopargaon	45.00	5.00	50.00	S
KU 99-19	60.00	10.00	70.00	HS
KUG 531	40.00	0.00	40.00	S
LGG 946	35.00	20.00	55.00	HS
Meha	33.33	0.00	33.33	S
MGG 359	40.00	0.00	40.00	S
MGG 360	35.00	30.00	65.00	HS
MH 2-15	50.00	0.00	50.00	S
MH 709	75.00	5.00	80.00	HS
MH 721	40.00	0.00	40.00	S
MH 729	40.00	30.00	70.00	HS
ML 1299	30.00	35.00	65.00	HS
ML 131	26.67	16.67	43.34	S
ML 1354	65.00	10.00	75.00	HS
ML 1472	55.00	15.00	70.00	HS
ML 5	33.33	13.33	46.66	S
ML 818	40.00	16.67	56.67	HS
NDM 7-33	40.00	5.00	45.00	S
NDM 9-18	45.00	25.00	70.00	HS
NDU 9-15	55.00	0.00	55.00	HS
OGG 56	30.00	3.33	33.33	S
Pant M 4	63.33	13.33	76.66	HS
Pant M 5	40.00	13.33	53.33	HS
PDM 11	60.00	0.00	60.00	HS
PDM 54	13.33	6.67	20.00	MR
PS 16	30.00	5.00	35.00	S
PU 31	45.00	0.00	45.00	S
Pant U 30	15.00	40.00	55.00	HS
Pusa 2072	26.67	3.33	30.00	S
Pusa 9531	56.67	10.00	66.67	HS
Pusa 971	70.00	0.00	70.00	HS
Pusa 972	33.33	33.33	66.66	HS
Pusa Baisakhi	65.00	15.00	80.00	HS
Pusa Vishal	65.00	0.00	65.00	HS
Ratna	43.33	20.00	63.33	HS
RMG 977	15.00	50.00	65.00	HS
RMG 987	0.00	70.00	70.00	HS
RMG 989	25.00	15.00	40.00	S
RUG 1	30.00	10.00	40.00	S
RVSM 11	0.00	45.00	45.00	S
Samrat	20.00	25.00	45.00	S
Satya	60.00	0.00	60.00	HS
SB 25-19	40.00	30.00	70.00	HS
SG 33-5	70.00	3.33	73.33	HS
SG 63-14	85.00	0.00	85.00	HS
SGC 16	45.00	10.00	55.00	HS
TARM 1	73.33	3.33	76.66	HS
TARM 18	26.67	13.33	40.00	S
TJM 15	55.00	10.00	65.00	HS
TMB 26	30.00	55.00	85.00	HS
UH 4-4	75.00	0.00	75.00	HS
VBG 4-31	15.00	50.00	65.00	HS
VBG 4-8	55.00	0.00	55.00	HS
Cowpea				
BM 30	40.00	0.00	40.00	S
DCP 13	13.33	0.00	13.33	MR
DCP 7	6.67	3.33	10.00	R
Pusa Sukomal	33.33	0.00	33.33	S
V 130	13.33	26.67	40.00	S
V 240	0.00	0.00	0.00	R
V 578	6.67	13.33	20.00	MR
V 585	6.67	0.00	6.67	R

Note: R (resistant) = 0-10 % mortality, MR (moderate resistant) = >10-20 %, S (susceptible) = >20-50 % and HS (highly susceptible) = >50% mortality.

3.3 Virulence Analysis of AG Groups and Their Combinations

There was no significant difference was observed in the disease incidence recorded (30-35%) in the pots inoculated with different AGs, combinations of AGs and their hybrid.

3.4 Virulence Analysis

The results (Table 4) indicated that out of 90 isolates, 77 isolates caused moderately susceptible to susceptible reactions on a set of 10 differential cultivars. Only 13 isolates caused resistant reaction on the cultivars evaluated (Table 4). Based on the virulence on a set of the cultivars, the isolates were grouped into 5 pathotypes. The urdbean cultivar KU323 showed resistant reaction against two isolates, namely, RMHG24 (AG1) and RUPP93 (AG5) and considered as differential for the first group. The cultivar Uttara considered differential for the fourth group showing resistant reaction against four isolates, namely, RAPS3 (AG1), RMHM6 (AG5), RUPG103 (AG5) and RS9 (AG3). The urdbean cultivar KUG 216 considered differential for the third group consisting of 6 isolates, namely, RGJC18 (AG2-2), RKLC1 (AG2-3), RKLC 4 (UD), RMHM3 (AG2-3), RPBU5 (AG4) and RRJG3 (UD) showing resistant reaction. The fourth group had only one isolate RGJG 4 (UD) differentiated by cowpea cultivar V 578 showing resistant reaction. The fifth group had most of the isolates (77) showing susceptible to highly susceptible reactions against 10 cultivars used for virulence analysis (Table 5). The pathotypes were not corresponding to the AG type of the isolates.

Table 4. Reaction of mungbean, urdbean and cowpea cultivars against different isolates of *R. solani* during 2009-10 and 2010-11

Isolates	AG type	Disease incidence (%)									
		Mungbean			Urdbean			Cowpea			
		Hum 1	PDM 54	Pusa Vishal	NDU 34	KU 323	Uttara	KUG 216	V 240	V 578	Pusa Sukomal
RAPG 12	AG5	S	S	S	S	S	S	S	S	S	S
RAPG 14	AG2-3	S	S	S	S	S	S	S	S	S	S
RAPS3	AG1	S	S	S	S	S	R	S	S	S	S
RASC5	AG2-2	S	S	S	S	S	S	S	S	S	S
RASC8	AG2-2	S	S	S	S	S	S	S	S	S	S
RASC 26	AG4	S	S	S	S	S	S	S	S	S	S
RASC 27	AG2-3	S	S	S	S	S	S	S	S	S	S
RBRC1	AG3	S	S	S	S	S	S	S	S	S	S
RCGM1	AG3	S	S	S	S	S	S	S	S	S	S
RDLM1	AG3	S	S	S	S	S	S	S	S	S	S
RDLM6	AG3	S	S	S	S	S	S	S	S	S	S
RDLG3	AG3	S	S	S	S	S	S	S	S	S	S
RGJC 18	AG2-2	S	S	S	S	S	S	R	S	S	S
RGJM 24	AG2-3	S	S	S	S	S	S	S	S	S	S
RGJU 11	AG3	S	S	S	S	S	S	S	S	S	S
RGJG2	AG5	S	S	S	S	S	S	S	S	S	S
RGJG4	UD	S	S	S	S	S	S	S	S	R	S
RGJW 15	AG5	S	S	S	S	S	S	S	S	S	S
RHPF2	UD	S	S	S	S	S	S	S	S	S	S
RHRC 20	AG2-3	S	S	S	S	S	S	S	S	S	S
RHRC 21	AG4	S	S	S	S	S	S	S	S	S	S
RHRC 22	AG2-3	S	S	S	S	S	S	S	S	S	S
RHRC 28	AG3	S	S	S	S	S	S	S	S	S	S
RHRM3	UD	S	S	S	S	S	S	S	S	S	S
RHRM4	AG2-2LP	S	S	S	S	S	S	S	S	S	S
RHRG5	AG2-3	S	S	S	S	S	S	S	S	S	S
RHRW16	AG1	S	S	S	S	S	S	S	S	S	S
RHRW27	UD	S	S	S	S	S	S	S	S	S	S
RHRW32	AG2-3	S	S	S	S	S	S	S	S	S	S
RJKM2	AG2-3	S	S	S	S	S	S	S	S	S	S
RJKM8	AG1	S	S	S	S	S	S	S	S	S	S
RJKM 15	AG2-2LP	S	S	S	S	S	S	S	S	S	S
RJKU 13	AG5	S	S	S	S	S	S	S	S	S	S

RJHM1	AG5	S	S	S	S	S	S	S	S	S	S
RJHU1	AG1	S	S	S	S	S	S	S	S	S	S
RKLC1	AG2-3	S	S	S	S	S	S	R	S	S	S
RKLC4	UD	S	S	S	S	S	S	R	S	S	S
RKNM8	AG-3	S	S	S	S	S	S	S	S	S	S
RKNG9	AG1	S	S	S	S	S	S	S	S	S	S
RMPM9	AG3	S	S	S	S	S	S	S	S	S	S
RMPM10	AG3	S	S	S	S	S	S	S	S	S	S
RMPM13	AG2-3	S	S	S	S	S	S	S	S	S	S
RMPM23	AG4	S	S	S	S	S	S	S	S	S	S
RMPG28	AG2-3	S	S	S	S	S	S	S	S	S	S
RMPG29	AG1	S	S	S	S	S	S	S	S	S	S
RMPP 30	AG4	S	S	S	S	S	S	S	S	S	S
RMHM3	AG2-3	S	S	S	S	S	S	R	S	S	S
RMHM6	AG5	S	S	S	S	S	R	S	S	S	S
RMHG24	AG1	S	S	S	S	R	S	S	S	S	S
RMHP21	AG2-2	S	S	S	S	S	S	S	S	S	S
RORC9	AG3	S	S	S	S	S	S	S	S	S	S
RPBC1	AG3	S	S	S	S	S	S	S	S	S	S
RPBM 17	AG4	S	S	S	S	S	S	S	S	S	S
RPBU5	AG4	S	S	S	S	S	S	R	S	S	S
RPBU7	AG3	S	S	S	S	S	S	S	S	S	S
RPBR 18	AG5	S	S	S	S	S	S	S	S	S	S
RRJM7	AG3	S	S	S	S	S	S	S	S	S	S
RRJG1	AG5	S	S	S	S	S	S	S	S	S	S
RRJG3	UD	S	S	S	S	S	S	R	S	S	S
RTNU1	AG1	S	S	S	S	S	S	S	S	S	S
RTNG5	UD	S	S	S	S	S	S	S	S	S	S
RUKM10	AG2-2	S	S	S	S	S	S	S	S	S	S
RUKM8	UD	S	S	S	S	S	S	S	S	S	S
RUKU4	AG3	S	S	S	S	S	S	S	S	S	S
RUPC 95	UD	S	S	S	S	S	S	S	S	S	S
RUPM42	AG2-3	S	S	S	S	S	S	S	S	S	S
RUPM83	AG1	S	S	S	S	S	S	S	S	S	S
RUPU 58	AG2-2	S	S	S	S	S	S	S	S	S	S
RUPU 82	AG1	S	S	S	S	S	S	S	S	S	S
RUPU 23	AG3	S	S	S	S	S	S	S	S	S	S
RUPU 84	AG2-2	S	S	S	S	S	S	S	S	S	S
RUPU 20	AG2-3	S	S	S	S	S	S	S	S	S	S
RUPU 18	AG2-3	S	S	S	S	S	S	S	S	S	S
RUPU 50	AG2-3	S	S	S	S	S	S	S	S	S	S
RUPK8	UD	S	S	S	S	S	S	S	S	S	S
RUPG 103	AG5	S	S	S	S	S	R	S	S	S	S
RUPG 106	AG3	S	S	S	S	S	S	S	S	S	S
RUPP 93	AG5	S	S	S	S	R	S	S	S	S	S
RUPL 104	UD	S	S	S	S	S	S	S	S	S	S
RUPM 80	UD	S	S	S	S	S	S	S	S	S	S
RS6	AG1	S	S	S	S	S	S	S	S	S	S
RS7	AG5	S	S	S	S	S	S	S	S	S	S
RS8	AG4	S	S	S	S	S	S	S	S	S	S
RS9	AG3	S	S	S	S	S	R	S	S	S	S
RS11	AG2-2	S	S	S	S	S	S	S	S	S	S
RS15	AG2-3	S	S	S	S	S	S	S	S	S	S
RS14	AG2-2LP	S	S	S	S	S	S	S	S	S	S
RJHC1	AG1	S	S	S	S	S	S	S	S	S	S
RWBC1	AG3	S	S	S	S	S	S	S	S	S	S
RWBC4	AG5	S	S	S	S	S	S	S	S	S	S

R = Resistant (0-20% disease incidence) and S = Susceptible (>20-100% disease incidence).

Table 5. Pathogenic groups of *R. solani* and their differential cultivars

Pathotype/group	Cultivar (Resistant)	Isolate (No.)	Isolate (AG)
I	KU 323 (urdbean)	2	RMHG24 (AG1) and RUPP93 (AG5)
II	Uttara (urdbean)	4	RAPS3 (AG1), RMHM6 (AG5), RUPG103 (AG5) and RS9 (AG3)
III	KUG 216 (urdbean)	6	RGJC18 (AG2-2), RKLC1 (AG2-3), RKLC 4 (UD), RMHM3 (AG2-3), RPBU5 (AG4) and RRJG3 (UD)
IV	V 578 (cowpea)	1	RGJG 4 (UD)
V	All 10 cultivars	77	Moderately susceptible to susceptible

4. Discussion

Rhizoctonia solani produced typical web blight /wet root rot symptoms on different pulse crops under diverse environmental conditions. The development of disease was favoured by wide range of atmospheric and soil temperature and relative humidity. Wide range of soil properties as pH, EC and texture along with nutritional conditions as organic carbon, nitrogen and phosphorus also favoured disease development in the areas surveyed. Most of the areas surveyed showed low to medium level of soil organic carbon. Tewoldemedhin et al. (2006) reported variation in temperature requirement for the growth of *R. solani* and observed that the isolates of *R. solani* belonging to AG 2-2 and AG 4 HG-II had significantly higher optimum growth temperatures than those from other AGs. In the present study, the type of AGs were not correlated with either temperature or relative humidity requirement in the field conditions.

The present findings clearly indicated that the disease is favoured by wide range of soil ranging from silt, loam, sandy and clay. In general all type of soils was found suitable for the development of the disease in various crops. The pathogenicity of the combined as well as hybrid culture of different AGs showed that the first generation of hybrid culture of two AGs was more or less similar in the aggressiveness on susceptible cultivars of mungbean of their parental AGs.

First time through the present study, an attempt was made to standardize the differential cultivars for virulence analysis of the populations of *R. solani* originating from different pulse crops. Availability of resistant cultivars against the pathogen in pulse crops is major limitation for differentials. Therefore, a large number of cultivars of mungbean, urdbean and cowpea were evaluated against the pathogen with an aim to find out resistant cultivars to constitute an effective set of differentials. Out of 109 cultivars evaluated, ten cultivars having different degree of resistance and susceptibility against the pathogen (3 of mungbean, 4 of urdbean and 3 of cowpea) were selected to constitute a set of differentials for virulence analysis. The results confirmed that there were differences in virulence among the isolates tested. The results of virulence analysis of 90 isolates including 7 international isolates of AGs tester of *R. solani* indicated that most of the isolates caused susceptible reaction on the set of cultivars evaluated. The isolates were grouped into the five pathotypes and differential cultivars for each pathotype were determined. Attempts have not been made earlier to determine the pathotypes of *R. solani*. Scanty information is available on the pathogenic grouping of the limited number of the isolates on a few cultivars and the isolates were found variable in respect of pathogenicity. Similar to the present study Engelkes and Windels (1996) reported that the isolates of *R. solani* AG2-IIIB and AG2-2 IV were pathogenic to sugarbeet and bean crops and the severity of the isolates on these crops differed. Bohlooli et al. (2006) observed that 81 isolates of *R. solani* isolated from roots and hypocotyls of bean showed variability in respect of virulence on the cultivars of beans. Tewoldemedhin et al. (2006) also observed differences among the virulence of *R. solani* isolates representing different AGs on different crops. The isolates of AG 2-2 and AG 4 HG-II were the most virulent on all crops evaluated. AG 2-1 was highly virulent on canola, moderately virulent on medic and lupin, weakly virulent on lucerne and barley, and nonpathogenic on wheat. AG-11 isolates were moderate to

weakly virulent on all crops, with the exception of barley and wheat. AG-3 was weakly virulent on canola, lupin, and medic. In the present study, the isolates representing 7 AGs were highly variable on mungbean, urdbean and cowpea cultivars included in the present study, but there was no definite correlation in between AGs and cultivar or crops. Godoy-Lutz et al. (2008) observed at least six different subgroups of *R. solani* causing web blight symptoms in common bean. Khandaker et al. (2008) tested pathogenicity of two potato isolates of *R. solani* on 33 hosts including pulse crops and observed differences in the degree of pathogenicity of both the isolates in respect of hosts. Seventy eight isolates of *R. solani* were isolates from diseased lupin plants and various other crops in Alberta, Canada. Isolates belonging to AG-4 produced typical symptoms of stem rot and root rot on lupin seedlings and showed greater virulence compared with AG-2-1 and AG-2-2 isolates (Zhou et al., 2009). Caesar et al. (2010) observed significant differences among the isolates in respect of their virulence. Pathogenic behaviour of 368 isolates of *R. solani* representing 7 AGs collected from different leguminous crops from 16 agro-ecological regions of India were highly variable in pathogenicity and caused 10% to 100% wet root rot incidence in mungbean, urdbean and cowpea and 11% to 100% in chickpea (Dubey et al., 2011). The pathogenicity tests on *Beta vulgaris* revealed that *R. solani* AG2-2 IIIB and AG2-2 IV isolates were more virulent than *R. cerealis* (Taheri & Tarighi, 2012).

5. Conclusion

Wet root rot/web blight caused by *R. solani* is an important disease of pulse crops. Pathotypes based on virulence on a set of differential cultivars is not known for the populations of *R. solani*. No attempt has been made in the past to develop a set of differential cultivars for pathotyping of the pathogen. Considering the wide host range of pulses, a set of differential cultivars consisting of mungbean, urdbean and cowpea was developed in the present study. Based on the virulence on the a set of differential cultivars, the populations of *R. solani* representing 7 AGs associated with pulse crops were grouped into 5 pathotypes and differential cultivar for each pathotype was identified. The weather and soil parameters like temperature, humidity, pH, electric conductivity, soil texture, organic carbon, nitrogen and phosphorus influenced the disease development ranging from 2-48% in the areas surveyed for collection of the isolates. The pathotype groups generated in the present study were not corresponding to AGs/crop of origin/area of origin of the isolates. The information generated on pathotypes can be used for resistant breeding against the pathogen.

Acknowledgement

Authors are thankful to the Indian Council of Agricultural Research, New Delhi for providing financial support. Divisional publication accession No. 6/12.

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