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Kumar M
Department of Plant Pathology
Bihar Agricultural University,
Sabour, Bhagalpur, Bihar, India

Kudada N
Department of Plant Pathology
Birsa Agricultural University,
Ranchi, Jharkhand, India

Correspondence
Kumar M
Department of Plant Pathology
Bihar Agricultural University,
Sabour, Bhagalpur, Bihar, India

Effect of sowing dates and weather conditions on *Rhizoctonia* root rot disease incidence and green pod yield of French bean

Kumar M and Kudada N

Abstract
Maximum seed germination (88.91%), lowest pre-emergence (11.02%) root rot were recorded when the French bean crop was sown on 19th September. But lower post emergence (14.59%) and maximum yield (65.7q/ha) were recorded when the crop was sown on 29th September. The crop sown on 19th October and 29th October recorded average maximum pre- and post-emergence root rot disease incidence to the extent of 21.84 percent and 23.25 percent, respectively. Average temperature, relative humidity, soil temperature, rainfall and sunshine favoured pre- and post-emergence root rot disease development. Pre-emergence and post-emergence root rot disease incidence was highly significantly positively correlated with minimum soil temperature but pre-emergence and post-emergence root rot disease incidence was non-significantly negatively correlated with maximum, minimum temperature and maximum soil temperature during 2014-15. Highly and positive significant correlation was observed between the average maximum and minimum temperature, seed germination and green pod yield with sowing dates during 2014-15 and 2015-16 cropping seasons. However, there was a negative and significant correlation between the pre and post-emergence and sowing dates during 2014-15 and 2015-16 cropping seasons. Average humidity, rainfall and sunshine showed non-significant correlation with disease incidence and green pod yield in both 2014-15 and 2015-16 cropping seasons.

Keywords: French bean, *Rhizoctonia* root rot, sowing dates, weather factors, yield

Introduction
French bean (*Phaseolus vulgaris* L) is a leguminous and vegetable crop grown in India. In India the fresh pod used as vegetables are called French bean and the dried pod for pulse is called Rajama. French bean is an annual and herbaceous plant grown worldwide for its edible beans. The more fleshy tender pods of round podded types with less string are preferred for vegetable as compared to flat pods. They are rich source of protein and closely compared with meat. French bean is cultivated in a variety of environmental condition ranging from sea level to high-land in the temperature range of 20-25^0 C. This vegetable is largely grown in Andhra Pradesh, Jharkhand, Maharashtra, Karnataka, Odisha, Uttarakhand, Tamil Nadu etc. (Anusuya *et al*., 2016) [4]. French bean is affected by a number of diseases such as, root rot (*Rhizoctonia solani*), leaf spot (*Alternaria alternata*), collar rot (*Sclerotium rolfsii*), anthracnose (*Colletotrichum lindemuthianum*), powdery mildew (*Erysiphe polygoni*), rust (*Uromyces phaseoli*), Fusarium root rot (*Fusarium solani* f. sp. *phaseoli*), root knot nematode (*Meloidogyne sp.*), bacterial brown spot (*Pseudomonas syringae* pv. *syringae*), common blight (*Xanthomonas campestris* pv. *phaseoli*), halo blight (*Pseudomonas syringae* pv. *phaseolicola)*, bean yellow mosaic, etc. Several reviews on the subjects have been published (Back *et al*., 2002; Bhagwati *et al*, 2007) [5, 6]. Amongst these *Rhizoctonia* root rot is the prevalent disease in Jharkhand. *Rhizoctonia* root rot generally affects seedlings, but fungus can also infect mature plants and induce root rot leading to plant wilt and finally death of infected plants. The yield losses from this disease have been reported 8.5 to 64.7 % from Bangalore (Sharma and Sohi, 1980). Considering the importance of the disease and crop, the present investigation was undertaken to know the effect of different sowing dates on root rot disease incidence and green pod yield of French bean and its correlation with weather parameters in Jharkhand.

Materials and Methods
Effect of different sowing dates on disease development
To determine the effect of different dates of sowing on disease development, the experiments were conducted in glass house compound of Department of Plant Pathology, Faculty of Agriculture, Birsa Agricultural University, Ranchi,

Jharkhand during Rabi 2014-15 and 2015-16 cropping seasons. The field trial was carried out in Randomized Block Design. Seeds of French bean variety, "Pant Anumpa" were sown on ten different dates at an interval of ten days. Each starting from 19th September- 18th December during date the cropping seasons. Three replications were made for each date of sowing. The plot size was 1.5 m X 3.0 m. Seventy five seeds were sown in each plot at 30 cm X 20 cm spacing. The crop was raised as per recommended agronomic practices. The plots were irrigated time to time to maintain proper moisture. Observations regarding seed germination, pre- and post- emergence toot rot disease incidence were recorded periodically. Total green pods yield were recorded on the basis of four harvesting of the crop. After harvest, the yield of French bean was also calculated in q/ha. The temperature, humidity, soil temperature, sunshine and rainfall were also recorded during the experiment.

Effect of weather factors on disease development

Development of the disease in terms of incidence was recorded at ten days interval starting from its first appearance i.e., 29th September (2014 -15 and 2015-16) and mean per cent of disease incidence were calculated at ninety days after sowing. Disease incidence was recorded on the basis of twenty five selected plants randomly from each replication using seed germination, pre- and post- emergence mortality was recorded. Weather parameters like temperature (maximum and minimum), relative humidity (maximum and minimum), soil temperature (morning and evening), sunshine/hrs. and total rainfall up to ninety days corresponding to the disease, observations were obtained from the Department of Agricultural Physics and Meteorology and co-related with disease incidence. Simple and multiple regression analysis were calculated to determine the effect of individual as well as combined weather factors for disease development.

Results and Discussion

Effect of different sowing dates on disease development

Observations were recorded to find out the effect of weather factors viz., temperature, relative humidity, soil temperature, rainfall and sunshine on the disease development. To find out most suitable date (s) for sowing of French bean crop to get maximum yield and minimum disease, a field experiment was conducted as per methods described under "Materials and Methods". In pooled analysis Table-1, Fig.-1 revealed that maximum seed germination (88.96 percent) was recorded in the crop sown on 29th September. Seed germination percentage was gradually declined from 9th October sown crops up to 18th December. Minimum seed germination (57.55 %) was recorded in the crop sown on 18th December. Minimum pre- and post-emergence root rot disease incidence was recorded on 18th December sown crop to the extent of 10.90 and 14.15 percent, respectively followed by 19th September which recorded to the extent of 11.03 percent in case of pre-emergence and 29th September which recorded to the extent of 14.59 per cent in case of post emergence disease incidence. These sowing dates i.e., 29th September and 18th December are statistically at par with each other. Maximum green pod yield (65.70 q/ha) was recorded in the crop sown on 29th September followed by 19th September which recorded the yield of 63.75 q/ha. Least green pod yield (41.66 q/ha and 40.00 q/ha) was recorded on 18th December sown crop. These findings were also supported by Dubey and Dwivedi (1989) who reported that maximum disease incidence and intensity of root rot and web blight of groundnut was observed in second fortnight of October. Upmanyu (2002) reported that certain cultural practices viz., alteration of sowing date, spacing and use of soil amendments proved quite effective to manage the web blight disease of French bean caused by *Rhizoctonia solani* Kuhn. Anonymous (2007) [3] had also suggested that timely sowing preferably first fortnight of July for urdbean and mungbean for NEPZ (Eastern UP, Bihar including Jharkhand, West Bengal, Odisha and Assam) was found to be the most effective against *R. solani* causing root rot and web blight and other disease pest to obtain higher yield.

The average temperature (24.86°C and 26.40°C), relative humidity (76.8% and 79.0%), soil temperature (22.47ºC and 25.08ºC), total rainfall (0 and 37.1 mm) and sunshine (9.2 hrs. and 8.2 hrs.) favoured the maximum seed germination during 2014-15 and 2015-16 cropping seasons. Average temperature (20.79 and 22.95°C), relative humidity (75.30 and 76.0 %), soil temperature (22.15 - 24.91ºC), rainfall (3.1 and 0 mm) & less sunshine (7.3 hrs.) occurred on 19th October during both the years were found to favour pre-emergence root rot disease development but average temperature (19.64 - 23.40ºC), relative humidity (70.90 – 76.0 %), soil temperature (21.54 – 24.08ºC), rainfall (0 – 65.5 mm) sunshine (7.2 hrs.) occurred on 29th October played a significant role in post-emergence root rot disease development during both years. In general high rainfall occurred during 19th October was favourable for maximum pre- emergence root rot disease development and 29th October was favourable for maximum post- emergence root rot. Low temperature prevailed during 18th December was not favored the disease development (Table-2, Fig.- 2A, 2B) Similar findings were observed by several workers in other crops. Mathew (1995) studied on root rot and web blight *(R. solani)* of French bean & found that high rainfall, soil moisture, relative humidity coupled with soil temperature(23 - 25ºC) were found to favour the development of disease. Maximum disease intensity of web blight of groundnut was observed in second fortnight of October followed by first fortnight of October. 26-28° C temperature and 90 % relative humidity favoured heavy infection and rapid disease development. Rains for several days provided micro-climate highly congenial for rapid proliferation of the pathogen under warm humid condition with persistant over cast sky when the dew formation was maximum on the leaves. The disease buildup in patches and sprayed rapidly to cover large plant population. 90% RH and 28±2ºC temperature favoured the production of perfect state in nature (Dubey and Dwivedi, 1989). Dubey and Toppo (1997) reported that sheath blight of rice (*R. solani*) favoured by 21.7 – 30^{O} C temperature, 66.3 – 93.7% relative humidity and 6.1 – 23.3 mm rainfall. Sharma and Tripathi (2001) reported that higher aerial temperature (28 –30^{O} C), relative humidity (>80%) and soil temperature (30-33^{O} C) favoured high disease severity. Rainfall (91-97 mm) had a significant role in severe development of web blight during the early stage of the crop. Kumar and Dubey (2002) reported that web blight of winged bean caused by *R. solani* appeared during second week of September in 1999 and 2000 and increased gradually till maturity. Apparent infection rate was maximum during September 10 to 17, 1999 and 2000. Upmanyu (2002) reported that high soil moisture, relative humidity (>80%) and moderate temperature (25 ± 1^{O} C) favoured root rot and web blight disease development of French bean.

Table 1: Effect of different sowing dates on root rot disease incidence and green pod yield of French bean

Treatments	Seed germination (%)			Root Rot Incidence Percent**						Green pod yield (q/ha)		
				Pre- emergence			Post - emergence					
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
19th Sept.	88.49 (70.22)	89.34 (70.99)	88.91 (70.65)	11.51 (18.88)	10.52 (18.88)	11.00 (26.08)	15.00 (22.76)	17.14 (24.44)	16.07 (23.59)	62.50	65.00	63.75
29th Sept.	88.56 (70.99)	89.38 (71.14)	88.96 (70.72)	11.44 (18.88)	10.62 (18.88)	11.03 (19.33)	13.63 (21.62)	15.54 (23.19)	14.59 (22.40)	64.72	66.67	65.7
09th Oct.	87.52 (68.49)	86.51 (68.49)	87.02 (68.91)	12.48 (21.52)	13.49 (21.52)	12.99 (21.08)	21.00 (27.26)	20.00 (26.55)	20.5 (26.90)	57.00	58.33	57.67
19th Oct.	86.55 (68.90)	87.00 (68.90)	86.78 (68.73)	23.43 (26.74)	20.25 (26.74)	21.84 (27.84)	14.66 (22.50)	16.84 (24.45)	15.75 (23.47)	56.38	57.00	56.69
29th Oct.	86.31 (67.88)	85.80 (67.88)	86.06 (68.10)	13.69 (22.12)	14.20 (22.12)	13.95 (21.91)	25.16 (30.10)	21.34 (27.51)	23.25 28.80	54.66	56.00	55.33
08th Nov.	85.48 (67.24)	85.00 (67.24)	85.24 (67.43)	14.52 (22.75)	15.00 (22.75)	14.76 (22.54)	16.54 (23.98)	17.55 (24.72)	17.05 (24.35)	51.66	50.00	50.83
18th Nov.	84.00 (65.67)	83.00 (65.67)	83.5 (66.06)	16.00 (24.33)	17.00 (24.33)	16.5 (23.93)	18.21 (25.25)	19.11 (25.90)	18.66 (25.57)	48.44	46.67	47.56
28th Nov.	81.09 (66.04)	83.47 (66.04)	82.28 (65.13)	18.91 (23.97)	16.53 (23.97)	17.72 (24.87)	20.55 (26.94)	19.48 (26.18)	20.02 (26.56)	45.50	44.67	45.09
08th Dec.	59.26 (59.33)	62.00 (52.50)	60.63 (51.14)	13.45 (21.14)	13.00 (21.14)	13.23 (21.31)	14.19 (22.11)	16.11 (23.64)	15.15 (22.86)	43.66	42.83	43.25
18th Dec.	56.57 (48.75)	58.54 (49.90)	57.55 (49.34)	11.24 (19.03)	10.56 (19.03)	10.90 (19.29)	13.19 (21.19)	15.11 (22.90)	14.15 (22.04)	41.66	40.00	40.83
SEM ±	0.915	0.961	0.903	0.939	0.900	0.901	0.460	0.591	0.533	0.207	0.248	0.211
CD at 5%	2.71	2.85	2.57	2.79	2.67	2.56	1.39	1.75	1.52	0.62	0.74	0.603
C.V.	2.36	2.47	2.41	7.05	6.91	6.98	3.33	4.10	3.74	11.37	13.78	12.62

*Figures in parentheses are arcsine-transformed values.
**Average on three Replications.

Table 2: Weather parameters during experimental period against root rot disease of French bean Rabi 2014-15 Cropping season

Dates	Temperature ºC			Relative humidity %			Soil Temperature ^{O}C			Total Rainfall mm)	Sunshine (hr.)
	Max.	Min.	Av	Max	Min.	Av	Min.	Max.	Av		
19th Sept.	29.54	20.23	24.88	83.1	71.6	77.35	9.37	32.43	20.9	36.5	9.2
29 th Sept.	30.11	19.61	24.86	81.8	71.9	76.85	11.7	33.25	22.47	0	9.2
09th Oct.	28.59	18.81	23.70	81.3	71.2	76.25	12.6	29.91	21.25	36.3	9.1
19th Oct.	27.24	14.35	20.79	81.1	69.5	75.30	13.2	31.11	22.15	3.1	7.3
29th Oct.	26.98	12.30	19.64	81.8	60.0	70.90	11.5	31.58	21.54	0	7.2
08thNov.	26.64	12.01	19.32	81.2	71.1	76.15	12.3	31.47	21.88	0	9.3
18th Nov.	23.93	04.76	14.34	82.9	65.1	74.00	13.0	27.21	20.10	0	8.3
28th Nov.	25.9	06.10	16.0	81.0	67.9	74.45	13.5	27.40	20.45	0	9.3
08th Dec.	24.14	05.70	14.92	83.6	69.0	76.3	14.0	27.23	20.61	0	8.2
18th Dec.	17.75	02.40	10.07	81.9	69.5	75.7	14.3	26.83	20.56	0	9.4

Rabi 2015-16 Cropping season

Dates	Temperature ºC			Relative humidity%			Soil Temperature ^{O}C			Total Rainfall (mm)	Sunshine (hrs)
	Max	Min.	Av	Max.	Min.	Av	Min.	Max.	Av		
19th Sept.	33.3	23.6	28.45	80	77	78.5	19.62	31.5	25.56	26.9	8.2
29 th Sept.	31.3	21.5	26.40	80	78	79.0	19.18	30.98	25.08	37.1	8.2
09th Oct.	30.3	19.5	24.90	84	75	79.5	19.4	32.33	25.86	12.5	8.3
19th Oct.	29.6	16.3	22.95	82	70	76.0	17.78	32.04	24.91	0	10.1
29th Oct.	29.3	17.5	23.40	82	67	74.5	17.44	30.73	24.08	65.5	7.2
08thNov.	28.4	11.8	20.10	82	70	76.0	16.02	28.68	22.35	0	9.2
18th Nov.	29.4	15.4	22.40	81	70	75.5	14.01	30.88	22.44	0	8.3
28th Nov.	30.3	15.5	22.90	82	70	76.0	15.95	31.57	23.76	0	10.2
08th Dec.	26.9	10.3	18.60	83	72	77.5	11.95	26.32	19.13	0	6.2
18th Dec.	23.3	10.2	16.75	81	71	76.0	16.13	30.17	23.15	3.2	8.2

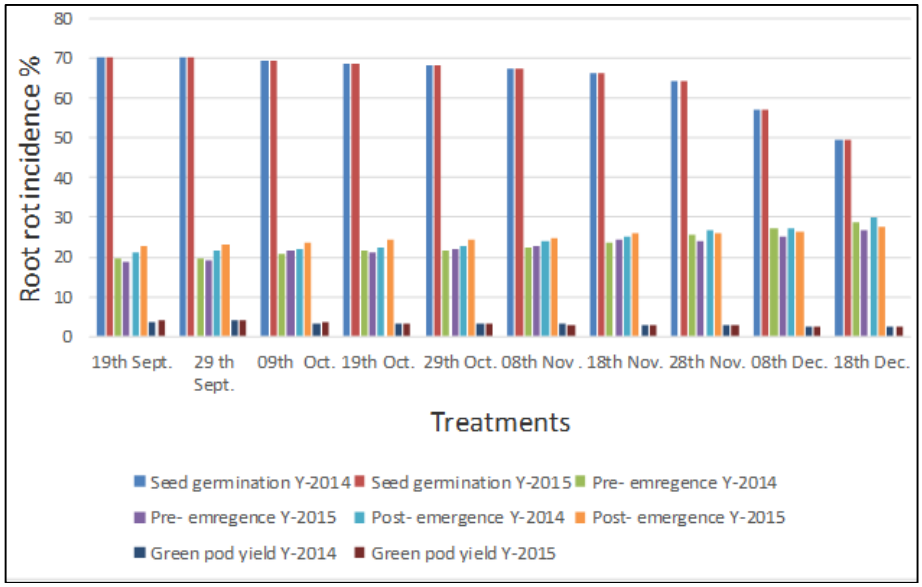

Fig 1: Effect of different dates of sowing on root rot disease incidence and green pod yield of French bean

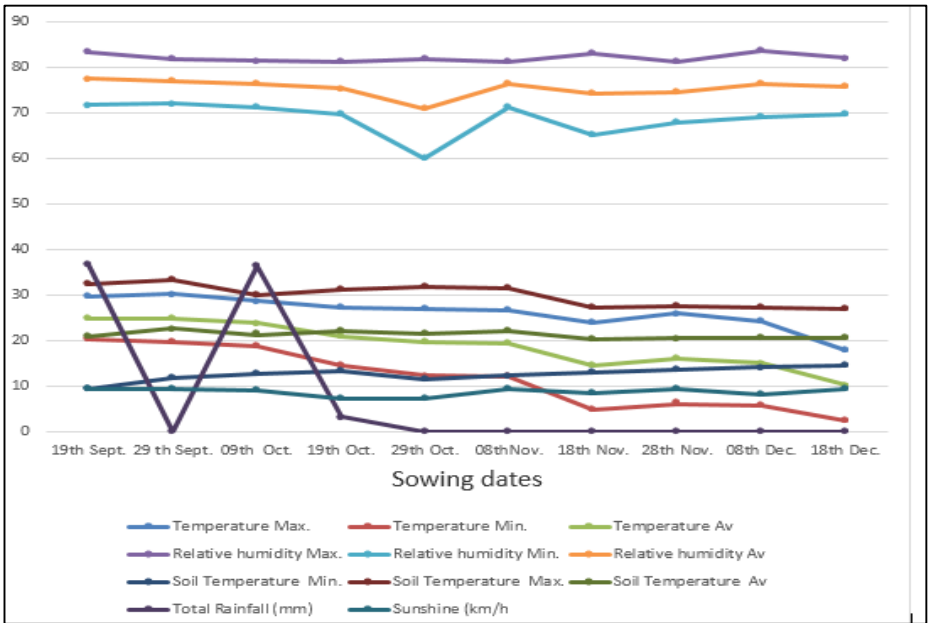

Fig 2A: Weather parameters against root rot disease incidence of French bean (2014)

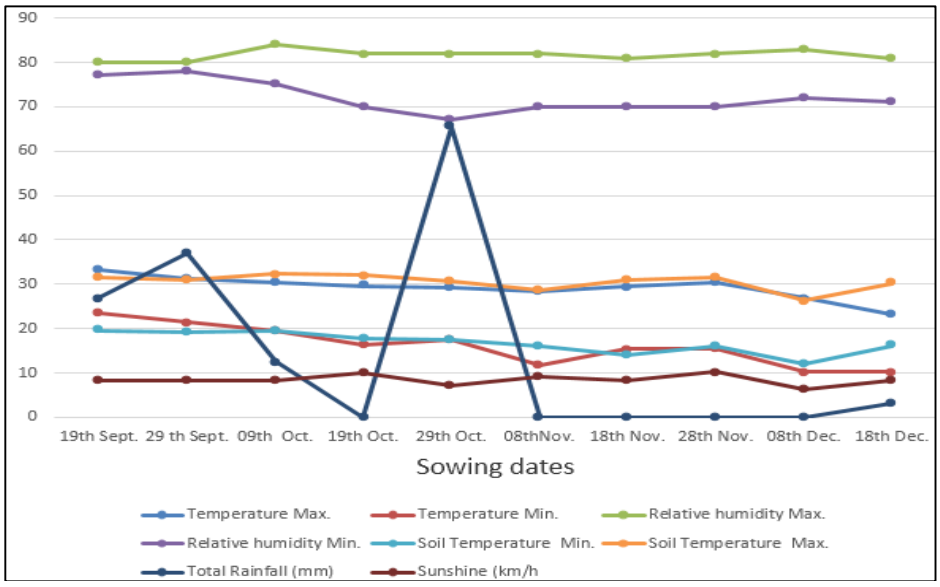

Fig 2B: Weather parameters against root rot disease incidence of French bean (2015)

Correlation and simple regression between Pre- and Post-emergence, seed germination and green pod yield in relation to weather parameters during Rabi 2014-15 and 2015-16 cropping seasons

Correlation coefficient among seed germination, pre- and post–emergence root rot disease incidence, green pod yield and various weather parameters were studied during 2014-15 and 2015-16 cropping seasons. The correlation studies presented in Table-3 revealed that pre- emergence root rot disease incidence showed positive highly significantly association with minimum soil temperature (r = 0.790) and highly non-significant negative association with maximum temperature (r = -0.908), minimum temperature (r = -0.920) and maximum soil temperature (r = -0.880) but post-emergence root rot disease incidence showed highly significant positive association with minimum soil temperature (r = 0.787) and highly non-significant negatively association with maximum temperature (r = - 0.925), minimum temperature (r = -0.926) and maximum soil temperature (r = -0.877) and. Seed germination showed highly significant positively correlation with maximum temperature (r =0.925), minimum temperature (r =0.785) and evening soil temperature (r = 0.750) and significant negatively correlation with morning soil temperature (r = -0.700). Rest factors showed non-significant with maximum and minimum relative humidity, total rainfall (mm) and sunshine (hr.).

During Rabi 2015-16 cropping season, the correlation and simple regression showed that pre- and post-emergence root rot disease incidence showed highly significant positive association with minimum temperature (r = 0.894 and 0.875) but highly non-significant negative association with maximum temperature (r = - 0.863 and - 0.835) and minimum soil temperature (r = -0.789 and -0.801) during cropping season 2015-16, respectively. Seed germination showed highly significant positive association with maximum and minimum temperature (r = 0.896 and 0.807) and minimum and maximum soil temperature (r = 0.684 and 0.633) and green pod yield highly significant positive association with maximum and minimum temperature (r = 0.795 and 0.908) and minimum soil temperature (r = 0.832) Rest factors correlated with maximum and minimum Relative humidity, total rainfall (mm) and sunshine (hr.) were found non-significant during 2015-16 cropping season.

Correlation and multiple regressions between Pre- and Post-emergence, seed germination and green pod yield with weather parameters Rabi 2014-15 and 2015-16 cropping seasons

During Rabi 2014-15 cropping season, the correlation and multiple regression among seed germination, pre- and post-emergence disease incidence, green pod yield and weather factors viz., maximum and minimum temperature, maximum and minimum relative humidity, morning and evening soil temperature, total rainfall were established and found that minimum soil temperature was significantly positive correlated with pre-and post-emergence root rot disease incidence but maximum and minimum temperature and maximum soil temperature were significantly negatively correlated with pre-emergence root rot disease incidence. Other factors viz., maximum relative humidity and sunshine were non-significantly positively correlated with pre-emergence and minimum relative humidity and total rainfall were non-significantly negatively correlated with pre-emergence in (Table-4).

During Rabi 2015-16 cropping season, the correlation and multiple regression among seed germination, pre- and post-emergence disease incidence, green pod yield and weather factors viz., maximum and minimum temperature, maximum and minimum relative humidity, minimum and maximum soil temperature, total rainfall were established and found that maximum and minimum temperature, minimum and maximum soil temperature was highly significantly positive correlated with pre-emergence root rot disease incidence but maximum and minimum temperature and minimum soil temperature were highly significantly negatively correlated with green pod yield and post-emergence root rot disease incidence. Other factors viz., maximum relative humidity and sunshine were non-significantly positively correlated with pre-emergence and minimum relative humidity and total rainfall were non-significantly negatively correlated with pre-emergence (Table-4). Brugen *et al.* (1986) [7] also reported a positive correlation between lesion size and soil moisture. They found that maximum lesion size occurred at 10 per cent soil moisture. Sharma and Tripathi (2001) observed significant and positive correlation between web blight severity and relative humidity, aerial temperature, rainfall and soil temperature.

Table 3: Correlation and simple regression between Pre- and Post-emergence, seed germination and green pod yield in relation to weather parameters Rabi 2014-15 cropping season

Description	Temperature (^{O}C)		Relative humidity (%)		Soil Temperature (cm)		Total rainfall (mm	Sunshine (hrs.)
	Max.	Min.	Max.	Min.	Min. (7.0 am)	Max. (2.0 pm)		
Root rot disease incidence								
Pre-emergence	-0.908**	-0.920**	0.176^{NS}	-0.151^{NS}	0.790**	-0.880**	-0.488^{NS}	0.124^{NS}
Post-emergence	-0.925**	-0.926**	0.133^{NS}	-0.122^{NS}	0.787**	-0.877**	-0.507^{NS}	0.209^{NS}
Seed germination	0.925**	0.785**	-0.238^{NS}	0.019^{NS}	-0.700*	0.750*	0.373^{NS}	-0.178^{NS}
Green pod yield	0.869**	0.957**	-0.116^{NS}	0.273^{NS}	-0.806**	0.917**	0.496^{NS}	-0.033^{NS}

**=Significant at 1% level of significance, NS= Non-significant

Rabi 2015-16 Cropping season

Description	Temperature (^{O}C)		Relative humidity (%)		Soil Temperature (cm)		Total rainfall (mm)	Sunshine (hrs.)
	Max.	Min.	Max.	Min.	Min.	Max.		
Root rot disease incidence								
Pre-emergence	-0.863**	-0.894**	0.310^{NS}	-0.601^{NS}	-0.789**	-0.476^{NS}	-0.506^{NS}	-0.152^{NS}
Post-emergence	-0.835**	-0.875**	0.179^{NS}	-0.569^{NS}	-0.801**	-0.468^{NS}	-0.528^{NS}	-0.086^{NS}
Seed germination	0.896**	0.807**	-0.189^{NS}	0.266^{NS}	0.684**	0.633**	0.397^{NS}	0.423^{NS}
Green pod yield	0.795**	0.908**	-0.310^{NS}	0.623^{NS}	0.832**	0.506^{NS}	0.589^{NS}	0.057^{NS}

**=Significant at 1% level of significance, NS= Non-significant

Table4: Correlation and multiple regressions between Pre- and Post-emergence, seedgermination and green pod yield with weather parameters Rabi 2014-15 cropping season

Weather Parameters	Root rot disease incidence		Seed germination	Green pod yield
	Pre-emergence	Post-emergence		
Temperature (^{O}C)				
Maximum (X_1)	-0.908**	-0.925**	0.925**	0.869**
Minimum (X_2)	-0.920**	-0.926**	0.785**	0.957**
Relative humidity (%)				
Maximum (X_3)	0.176NS	0.133NS	-0.238NS	-0.116NS
Minimum (X_4)	-0.151NS	-0.122NS	0.019NS	0.273NS
Soil Temperature (C^{O})				
Minimum (7.0 am) (X_5)	0.790**	0.787**	-0.700*	-0.806**
Maximum (2.0 pm) (X_6)	-0.880**	-0.877**	0.750*	0.917**
Total rainfall (mm) (X_7)	-0.488NS	-0.507NS	0.373NS	0.496NS
Sunshine (hr.) (X_8)	0.124NS	0.209NS	-0.178NS	-0.033NS

**=Significant at 1% level of significance, NS= Non-significant

Rabi 2015-16 cropping season

Weather Parameters	Root rot disease incidence (%)		Seed germination	Green pod yield
	Pre-emergence	Post-emergence		
Temperature (^{O}C)				
Maximum (X_1)	0.896**	-0.863**	0.135NS	-0.835**
Minimum (X_2)	0.807**	-0.894**	-0.580NS	-0.875**
Relative humidity (%)				
Maximum (X_3)	-0.189NS	0.310NS	-0.144NS	0.179NS
Minimum (X_4)	0.266NS	-0.601NS	0.182NS	-0.569NS
Soil Temperature (^{O}C)				
Minimum (7.0 am) (X_5)	0.684**	-0.789**	0.155NS	-0.801**
Maximum (2.0 pm) (X_6)	0.633**	-0.476NS	0.053NS	-0.468NS
Total rainfall (mm) (X_7)	0.397NS	-0.506NS	-0.041NS	-0.528NS
Sunshine (hrs.) (X_8)	0.423NS	-0.152NS	-0.559NS	-0.086NS

**=Significant at 1% level of significance, NS= Non-significant

Multiple linear regression equation between pre-and post-emergence, seed germination and green pod yield in relation to weather parameters during Rabi 2014-15 and 2015-16 cropping season

Multiple linear regression presented in (Table-5) among seed germination, pre-and post-emergence, green pod yield and factors exhibited strong relationship among different components of the epiphytotic during 2014-15 cropping season. The coefficient of multiple determinations (R^2) indicated that the combined effect of different factors, maximum relative humidity, minimum and maximum soil temperature, total rainfall and sunshine favoured the disease development. Weather factors viz., maximum relative humidity, minimum and maximum temperature, total rainfall and sunshine were positive significant. These factors showed significant positive effect on pre- and post-emergence and accounted for 93.1 per cent variation and 96.46 per cent variation, respectively. Weather factors, maximum and minimum temperature, minimum relative humidity showed significant positive effect on seed germination and accounted for 98.22 per cent variation. Weather factors viz., minimum temperature and minimum relative humidity showed significant positive on green pod yield and accounted for 99.09 per cent variation.

During Rabi 2015-16 cropping season, multiple regression equation showed that maximum temperature, minimum relative humidity, minimum and maximum soil temperature and total rainfall (mm) were found to be positive effect on pre-emergence and accounted for 93.69 percent variation. However, minimum temperature, minimum relative humidity and sunshine (hrs.) were found to be negative effect on pre-emergence root rot disease incidence. The weather factors viz., minimum temperature, maximum relative humidity, minimum soil temperature, sunshine were found to be negative effect and only four factors viz., maximum temperature, minimum relative humidity, maximum soil temperature and total rainfall showed positive effect on post-emergence and accounted for 96.42 percent variation. .In case of seed germination, all the weather parameters found to be negative effect except maximum temperature showed positive effect and accounted for 99.91 percent variation. Out of eight weather parameters, minimum relative humidity, maximum soil temperature, total rainfall were found to be positive effect and rest factors showed negative effect on green pod yield and accounted for 94.61 percent variation.

Similar results were found by several workers. Sharma *et al* (2001) reported that maximum and minimum temperature (22.1 – 5.4ºC), high relative humidity (71.84%) and rainfall ranging between 26.4 – 38.0 mm played a significant role in the development of the diseases. Correlation regression analysis showed 74-84 % variation in the disease progress during 1993-1994 and 1994-1995. *Rhizoctonia* disease of roots was reported to be most severe under moist soil condition (Rolfe, 1904; Small, 1927; Fahmy, 1931; Abdel Salam, 1933 [1]; Afanasiev and Morris, 1942). In the present study weather variables, maximum relative humidity, minimum relative humidity morning and evening soil temperature rainfall and sunshine together influenced the pre- and post-emergence disease incidence during 2014-15 while maximum temperature, minimum temperature, morning and evening soil temperature and rainfall influenced the pre- and post-emergence disease incidence during 2015-16. All the variables which showed a positive or negative trend in 2014-15 season exhibited exactly an opposite negative or positive trend in 2015-16 season. Therefore, data sets for several years may be needed to resolve and develop appropriate prediction systems for pre- and post-emergence *Rhizoctonia* root rot diseases in French bean.

Table 5: Multiple linear regression equation between pre-and post-emergence, seed germination and green pod yield in relation to weather parameters Rabi 2014-15 cropping season

Description	Multiple linear regression equation	R^2 Value
Root rot disease incidence (%)		
Pre-emergence	$Y=-56.757-0.088\ X_1-0.561\ X_2+0.545\ X_3-0.014\ X_4+1.215\ X_5+0.783\ X_6+0.079\ X_7+0.658\ X_8$	0.9310
Post-emergence	$Y=-6.482-0.234\ X_1-0.287X_2+0.245X_3-0.015\ X_4+0.600\ X_5+0.207\ X_6+0.016\ X_7+0.857\ X_8$	0.9646
Seed germination	$Y=311.797+1.452\ X_1+0.291X_2-2.293\ X_3+0.146\ X_4-3.099\ X_5-1.811\ X_6-0.118\ X_7-1.867\ X_8$	0.9822
Green pod yield	$Y=383.079-1.202\ X_1+3.162\ X_2-1.366\ X_3+0.355\ X_4-5.749\ X_5-5.156\ X_6-0.555\ X_7-2.091\ X_8$	0.9909

Where,

Y= Pre-emergence, Y=Post-emergence, Y=Seed germination, Y=Green pod yield,

X_1 = Maximum Temperature (^{O}C), X_2 = Minimum Temperature (^{O}C), X_3 = Maximum Relative humidity (%), X_4 = Minimum Relative humidity (%), X_5 = Soil Temperature (^{O}C) Minimum (7.0 am), X_6 = Soil Temperature (^{O}C) Maximum (2.0pm), X_7 = Total rainfall (mm), X_8 = Sunshine (hrs.)

Rabi 2015-16 cropping season

Description	Multiple linear regression equation	R^2 Value
Root rot disease incidence (%)		
Pre-emergence	$Y=-108.85+6.636\ X_1-4.810\ X_2-1.356\ X_3+0.445\ X_4+2.422\ X_5+3.988\ X_6+0.101\ X_7-3.255\ X_8$	0.9369
Post-emergence	$Y=-43.426+1.542\ X_1-2.356X_2-0.535X_3+0.507\ X_4-0.087X_5+2.787X_6+0.042\ X_7-2.134\ X_8$	0.9642
Seed germination	$Y=292.247+0.132X_1-1.195X_2-0.354\ X_3-1.316\ X_4-0.678\ X_5-1.414\ X_6-0.138\ X_7-1.098\ X_8$	0.9991
Green pod yield	$Y=21.827-0.309\ X_1-0.108\ X_2-0.022\ X_3+0.132\ X_4-0.623X_5+0.464\ X_6+0.019\ X_7+0.268\ X_8$	0.9461

Where,

Y= Pre-emergence, Y=Post-emergence, Y=Seed germination, Y=Green pod yield

X_1 = Maximum Temperature (^{O}C), X_2 = Minimum Temperature (^{O}C), X_3 = Maximum Relative humidity (%), X_4 = Minimum Relative humidity (%), X_5 = Soil Temperature (^{O}C) Minimum (7.0 am), X_6 = Soil Temperature (m) Maximum (2.0pm), X_7 = Total rainfall (mm), X_8 = Sunshine (hrs.)

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