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Incidence of wilt disease in pigeon pea with soil physicochemical properties and weather variability: A comparative study

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Abstract
Vascular wilt caused by *Fusarium udum* is a prominent disease in pigeon pea *Cajanus cajan* (L.) growing areas showing variable disease incidence. The severity of disease thus varies from place to place due to environmental factors, edaphic conditions as well as geographical areas. This study showed the correlation between disease incidence and edaphic and environmental conditions of various sites in Jhansi, Jalaun and Mahoba district. Soil samples collected from multiple pigeon pea fields exhibiting varying degrees of wilt were analysed for pH, electrical conductivity, organic carbon, moisture content, macro and micronutrient levels. The result revealed a strong positive correlation was found between disease incidence and nitrogen and potassium availability while soil moisture also influences pathogen proliferation.

Keywords: Fusarium udum, pigeon pea, vascular wilt, soil nutrients, disease incidence

Introduction

Pigeon pea [*Cajanus cajan* (L.) Millspaugh] is an important legume crop asymmetrically grown in both the New and Old World. It is grown in different regions of the world, covering about 24 countries [FAOSTAT, 2019] [7]. In India, pigeon pea is the second most important pulse crop after chickpea, whereas globally it holds the fifth prominent position [Patel et. al., 2012] [22]. In Tropical and Subtropical regions, pigeon pea is considered a lifeline of agriculture. In India, pigeon pea is widely cultivated in 315 districts of more than eighteen states and about 50% of the area is covered by twenty-six districts [Bhatia et. al., 2006] [4]. Pigeon pea cultivation is favoured by a wide range of soil types, ranging from sandy to heavy clay soil. Although saline-alkaline and waterlogged soil are unfavourable for the growth of the plant. It flourishes well more in well-drained deep loam soils free from excessive soluble salts with neutral pH ranging from pH 5.0-8.0 [Pathak 1970, Faroda and Johri, 1981] [23, 8].

Pigeon pea is affected by several phytopathological disorders and diseases. Among these, vascular wilt or *Fusarium* wilt of pigeon pea caused by *Fusarium udum* Butler is the most common disease of pigeon pea in all growing areas. Wilt disease in pigeon pea has been globally reported from more than fifteen countries [Nene *et al*. 1989] [21]. Although the disease is more prevalent in the African continent, especially in Eastern Africa or the Indian subcontinent [Kiprop *et al*., 2002] [17].

Important environmental factors may affect the development of plant disease and determine whether they will become epiphytotic or not. These factors include temperature, relative humidity, soil moisture, soil pH, soil type and soil fertility. Each pathogen has an optimum temperature for its growth. Different growth stages of fungus, such as the production of spores, their germination and the growth of the mycelium, may have slightly different optimum temperatures.

Environmental factors have traditionally been considered to have a major impact on disease development. Pathogen was most susceptible in regions with temperatures ranging between 21-24°C, although persistence of this pathogen is influenced by soil type and nutrient status [Nene and Reddy, 1981] [20]. Even if a susceptible host and a virulent pathogen are present in a certain locality, a common situation when the farmer has no choice but to plant the particular host, serious disease will not occur unless the environment favours its development.

This includes both the aerial and soil (edaphic) environment. The present study involves the impact of soil and weather conditions on the development of wilt disease in the villages of Jhansi, Jalaun and Mahoba districts. In this study we attempt to explore various factors affecting the disease incidence and their correlation with edaphic factors and soil composition.

Methodology

Disease incidence

These villages were further visited at different growth stages of the desired crop. Approximately five fields in each village were visited and the number of diseased fields along with the number of infected plants was recorded for further study and estimation of the disease incidence percent of that village. Disease incidence was calculated by the below given formula-

$$\text{Disease Incidence} = \frac{\text{No of infected plants}}{\text{Total no of plant observed}} \text{x}100$$

The data were analyzed by the standard statistical methods. The graphs and other statistical analysis were done using the software Microsoft Excel office 2019 (Window 10 Home). Correlation of disease incidence with different soil characteristics was calculated by Bivariate Pearson's correlation (One tailed test of significance) using IBM SPSS Statistics 20.

Collection of soil samples

Five soil samples were collected from the selected pigeon pea field by removing the top soil around the plant and then digging the rhizosphere area with the help of a sterilized spatula up to 12-15 cm depth. Approximately 300 soil samples were collected (5 samples per field × 5 fields per village × 12 villages), and 1 kg of soil sample was collected from all the fields and kept in the sterilized polythene bags and brought to the laboratory carefully.

Physico-chemical analysis of soil:

Air dried soil was ground to pass through 2 mm sieve. Electrical conductivity of saturated soil pastes extract (EC) and pH of saturated soil paste (pHs) were determined by digital conductivity and pH meters, respectively. For nitrogen determination, a known weight of soil was acid-digested followed by distillation on Kjeldahl apparatus. Olsen method was used to determine NaHCO3-extractable phosphorus. Ammonium acetate-extractable potassium was determined on flame photometer by comparing with a standard curve of known potassium concentrations [Arain *et al*., 2000] [1]. The quantity of microelements like zinc, boron, iron, manganese and copper was determined on Atomic Absorption Spectrophotometer (AS) following the method recommended by Issac and Kerber [1971]. The following formula calculated the soil moisture percentage-

$$\text{Moisture percentage} = \frac{\text{Amount of moisture in Soil}}{\text{weight of dry soil}} \times 100$$

Result and Discussion

Physical analysis of soil: The observations recorded in Table 1 and Graph 1. Morphologically the soil is distinguished in rankar, mar and kabar. The soil colour and texture were gray to black and loam to clay loam. Analysis revealed that the soil of selected villages was slightly alkaline in nature with a narrow range of pH 7.2-7.8 in 2017-2018 and neutral to slightly alkaline 7.0-7.9 in 2018-2019. Qudesia *et al*. [2017] found similar properties of the soil. In a similar work, it was noticed that 92% studied fields had soil with pH 8.3 or above [Bhatti, 1999; Arain, 2000] [5, 1]. Fertilizers, organic matter, rain and soil microorganisms are the factors affected by soil pH [Guleri *et al*., 2016] [10]. There was a change in the observation of electrical conductivity and soil moisture percent in both years.

Chemical analysis of soil

The chemical characters of the rhizospheric soil sample showed a wide range. The results of both the year are given in table 2 and graph 2A and 2B. The soil nutrient was divided into two categories macro and micronutrient.

Macronutrient

In the crop year 2017-18 fifty percent of villages possessed a low amount of organic carbon and in 2018-19 fifty percent of selected villages have a medium amount of organic carbon present in soil except village Saidnagar. Azam *et al*. [2001] [2] reported approximately 0.52-1.38% organic matter in different soils samples and most of the samples showed less than 1% organic matter [Kanwal *et al*., 2017] [15]. It is very clear that among all twelve villages, none was having high nitrogen content, and all were lying in the poor nitrogen content category except Bara and Bagi which were of medium nitrogen content Maximum nitrogen was recorded. Potassium was present in the adequate amount in the soil samples analysed. Rashid [2001] [25] and Qudsia *et al*. [2017] [24] found medium to fertile range of nitrogen content in different soil samples and also find similar result in the phosphorus and potassium estimation. Significant variation was observed in both the years. During 2017-2018 the range of sulphur was medium in about 83% of selected villages and rest have adequate amount of sulphur. In the next year probably 33% villages contained enough sulphur and remaining were having medium amount of sulphur.

Micronutrients

During the estimation of micronutrient there was deficiency of zinc in eleven out of twelve villages. Boron showed a resembling availability in all the soil samples undertaken it ranged between 0.19 ppm in Aata to 1.97 ppm in Kulpahad. Only few villages that is Kulpahad, Ratauli and Chirgaon possessed Boron in adequate quality. Quantity of iron increased in the subsequent year 2018-19. Only two villages were having iron deficiency while soil samples of ten villages had medium amount of iron present. The configuration varied in each soil sample and there was no uniform trend in both crop year.

Sarojini [1950] [26], observed that the addition of micro-nutrient elements like boron, manganese and zinc to wilt-sick soils reduced the loss considerably due to pre-emergence attack as well as wilt incidence in pigeon pea. Manganese obtained most beneficial results while zinc was not as satisfactory as manganese. Boron shows toxic result beyond a certain concentration.

Effect of soil type and weather condition on wilt disease

Data given in table 3 revealed that in above findings village Aata with maximum disease incidence 36% and Etora with

13% disease incidence in 2017 both were lying in the same district. Jalaun where probably the weather condition is same. It shows that the pathogen may flourish or subside below or above these weather conditions. Kannaiyan *et al.* [1984] [14], surveyed eleven major pigeon pea producing states in India and reported the wilt disease incidence percent of these states as Maharashtra (23%), Bihar (18%) and Uttar Pradesh (15%). Similar variation in incidence percent was observed in our study. Several workers Kannaiyan and Nene [1981] [13], Hukma Ram and Pandey [2011] [12] have reported 30-60% disease incidence at flowering and crop maturity stages. Bhargava and Singh [1978] [3], Upadhyay and Rai [1979] [27] reported that temperature range of 20-29°C and moisture range of 6-16% was favourable for disease development. It was also confirmed that water retentive nature of the soil and slightly acidic or alkaline soils with sand content more than 50% directly influence the growth of wilt disease [Hillocks *et al.*, 2000; Biswas and Ghosh, 2016] [24, 6]. According to Sarojini [1950] [26], pigeon pea wilt is more prevalent in clay soils favoured by high soil moisture [McRae and Shaw, 1933] [18] and low temperature conditions [Mitra, 1934] [19].

Correlation study of disease incidence with physicochemical characteristic with soil during 2017-19 is given in table 4 and graph 3. Soil moisture favours the growth of soil borne pathogen and increases the intensity of disease. The correlation of soil moisture with disease incidence is positive and significant at $P \leq 0.05$ level and $P \leq 0.01$ level in 2017-18 and 2018-19 respectively. Nitrogen also showed positive correlation with disease incidence and significant at $P \leq 0.05$ level. The enough nitrogen favours the execution of the disease. The disease incidence increases with increase of nitrogen. Groenewald [2006] [9] documented that the population enhancement of *Fusarium* wilt with disease development is proportionally related to high traces of nitrogen fertilization in agricultural soils. Studies have also shown that the form of nitrogen in the soil is important in the development of *Fusarium* wilt disease [Woltz and Jones, 1973; Groenewald, 2006] [29, 9]. Along with nitrogen, potassium is negatively correlated with disease incidence and significant at $P \leq 0.05$ level and $P \leq 0.01$ level in 2017-18 and 2018-19 respectively. Increasing the amount of potassium, the intensity of the disease is decreased. Walker [1971] [28] who reported that high nitrogen and low potassium favoured the disease, while low nitrogen and high potassium slowed disease development [Biswas and Ghosh, 2016; Karimi, 2012] [6, 16].

The correlation of disease incidence with pH, EC, organic carbon, phosphorus, sulphur and boron is positive and insignificant. Zinc, iron, manganese and copper also show negative and insignificant correlation with disease incidence.

Table 1: Physical characterization of rhizospheric soil samples (A). 2017-2018

S. No.	Villages	Local Name of Soil	Soil Colour	Soil Texture	Soil P^{H}*	Soil EC* Millimho/cm	Soil Moisture (%) *
1	Chirgaon	Rankar	Gray	Loam	7.2	0.47	8.32
2	Aata	Kabar	Black	Clay Loam	7.3	0.11	21.79
3	Okaruaa	Kabar	Gray-Black	Clay Loam	7.6	0.34	17.78
4	Lamsar	Mar	Dark Black	Clay Loam	7.8	0.19	16.00
5	Bara	Kabar	Black	Clay Loam	7.6	0.71	16.82
6	Bagi	Kabar	Black	Clay Loam	7.3	0.78	25.94
7	Babina	Mar	Dark Black	Clay Loam	7.3	0.44	14.15
8	Jolhopur	Mar	Dark Black	Clay Loam	7.3	0.24	8.73
9	Etora	Kabar	Gray-Black	Clay Loam	7.7	0.44	21.65
10	Saidnagar	Kabar	Gray-Black	Clay Loam	7.5	0.24	11.73
11	Kulpahad	Rankar	Gray	Loam	7.4	0.77	30.54
12	Ratauli	Rankar	Gray	Loam	7.7	0.42	10.64

(B). 2018-2019

S. No.	Villages	Local Name of Soil	Soil Colour	Soil Texture	Soil P^{H}*	Soil EC* Millimho/cm	Soil Moisture (%) *
1	Chirgaon	Rankar	Gray	Loam	7.4	0.52	12.62
2	Aata	Kabar	Black	Clay Loam	7.6	0.46	31.46
3	Okaruaa	Kabar	Gray-Black	Clay Loam	7.0	0.26	26.32
4	Lamsar	Mar	Dark Black	Clay Loam	7.9	0.72	16.80
5	Bara	Kabar	Black	Clay Loam	7.7	0.52	26.57
6	Bagi	Kabar	Black	Clay Loam	7.6	0.49	34.69
7	Babina	Mar	Dark Black	Clay Loam	7.5	0.35	18.96
8	Jolhopur	Mar	Dark Black	Clay Loam	7.3	0.42	14.23
9	Etora	Kabar	Gray-Black	Clay Loam	7.2	0.70	12.54
10	Saidnagar	Kabar	Gray-Black	Clay Loam	7.6	0.32	18.12
11	Kulpahad	Rankar	Gray	Loam	7.6	0.52	40.23
12	Ratauli	Rankar	Gray	Loam	7.7	0.24	16.82

* Values are the mean of five replications

Table 2: Chemical characterization of rhizospheric soil samples (A) 2017-2018

S. No.	Villages	Macronutrients					Micronutrients					Disease Incidence
		C (%)	N (Kg/h)	P (Kg/h)	K (Kg/h)	S (ppm)	Zn (ppm)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	
1	Chirgaon	0.57	218	27.0	448	12.71	2.14	1.74	5.18	5.94	2.15	Low
2	Aata	0.49	198	18.0	193	14.87	0.25	0.19	3.62	3.57	0.37	High
3	Okaruaa	0.72	226	13.5	345	15.21	0.24	0.92	4.77	2.36	0.70	Low
4	Lamsar	0.37	169	18.0	399	15.06	0.27	0.26	3.12	2.47	1.13	Low
5	Bara	0.70	262	22.5	300	13.73	0.14	1.54	4.30	1.74	0.81	Low
6	Bagi	0.85	297	13.5	237	14.55	0.20	1.24	4.70	2.97	0.91	High
7	Babina	0.28	133	22.5	242	13.88	0.16	0.98	3.88	2.78	1.44	Low
8	Jolhopur	0.45	101	4.5	161	13.93	0.31	0.22	3.52	1.60	1.12	Low
9	Etora	0.27	61	31.5	448	14.77	0.35	0.19	3.47	2.21	0.90	Low
10	Saidnagar	0.90	202	27	358	14.02	0.29	0.22	5.73	1.54	1.15	Low
11	Kulpahad	0.48	197	22.5	166	12.60	0.32	1.97	6.90	20.76	1.60	High
12	Ratauli	0.34	158	13.5	220	14.06	0.38	1.93	7.62	20.47	1.80	Low

(B) 2018-2019

S. No.	Villages	Macronutrients					Micronutrients					Disease Incidence
		C (%)	N (Kg/h)	P (Kg/h)	K (Kg/h)	S (ppm)	Zn (ppm)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	
1	Chirgaon	0.45	214	22.0	440	11.79	1.98	0.98	5.02	5.42	2.48	Low
2	Aata	0.62	196	24.3	190	15.92	0.62	0.24	4.91	2.37	0.42	High
3	Okaruaa	0.80	232	32.2	353	14.86	0.46	1.02	6.12	4.17	0.91	Low
4	Lamsar	0.32	182	16.8	410	15.26	0.28	0.32	4.48	2.47	1.12	Low
5	Bara	0.72	257	18.6	296	12.31	0.32	1.74	4.23	1.78	1.42	Low
6	Bagi	0.80	288	27.0	209	11.46	0.38	1.56	3.64	3.28	0.70	High
7	Babina	0.42	148	13.2	262	14.32	0.26	0.98	6.08	2.42	1.13	Low
8	Jolhopur	0.62	118	16.0	187	15.02	0.24	0.19	4.42	1.98	0.98	Low
9	Etora	0.27	68	31.5	452	13.47	0.36	0.21	3.88	3.46	0.90	Low
10	Saidnagar	0.96	216	27	374	12.40	0.16	0.28	7.01	1.28	1.28	Low
11	Kulpahad	0.64	186	24.0	146	15.21	0.29	2.00	5.68	20.42	1.44	High
12	Ratauli	0.49	162	17.1	239	14.96	0.49	1.86	6.47	18.87	1.86	Low

* Values are mean of five replications

Table 3: Compilation of disease incidence and meteorological data from 2017-2019

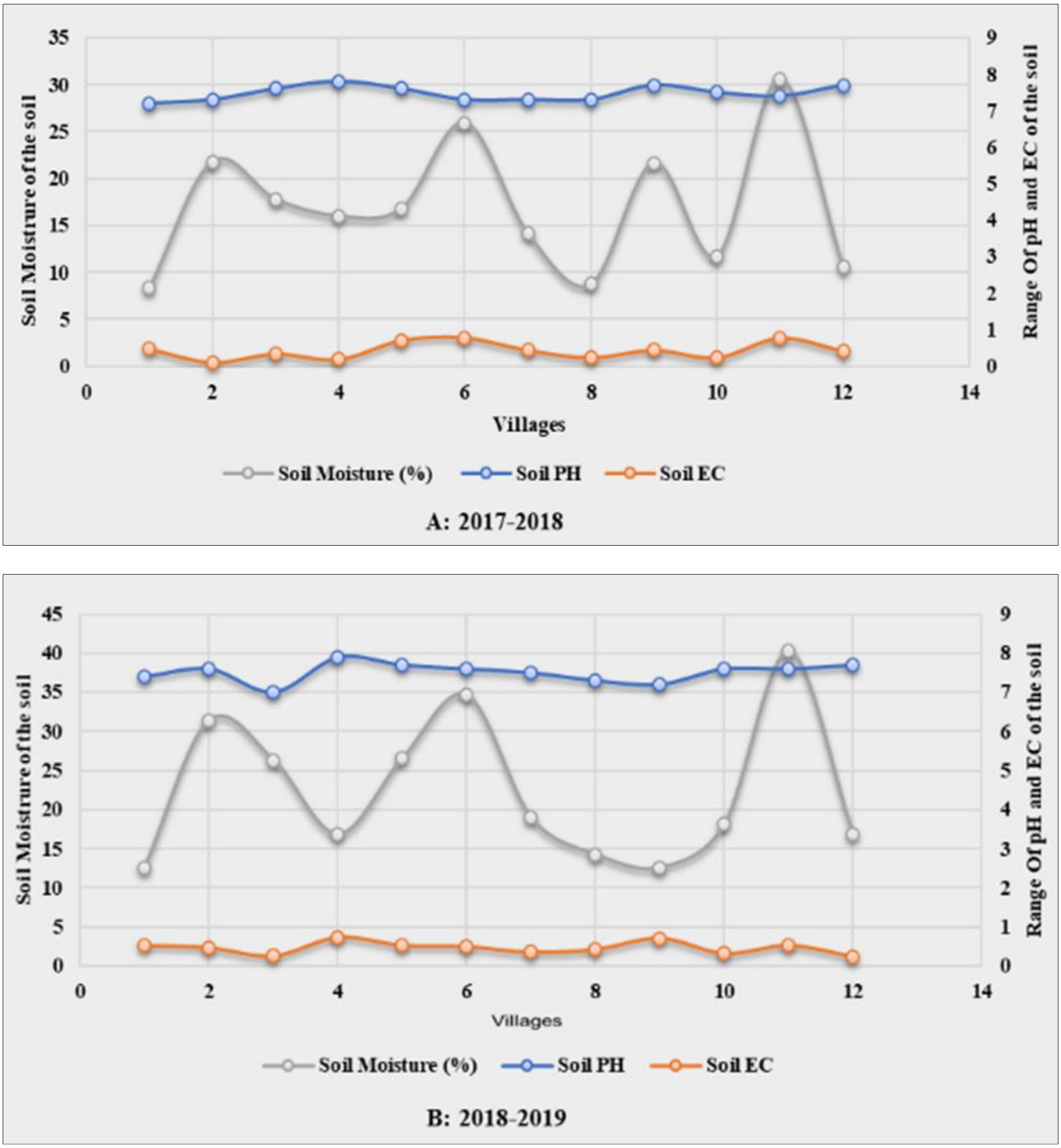
S. No.	Villages	District	Disease Incidence (%)		Average Disease incidence (2017-2019)	Humidity (%)		Average Temperature (ºC)	
			2017-2018	2018-2019		2017-2018	2018-2019	2017-2018	2018-2019
1	Chirgaon	Jhansi	18	13	15.5	62.66	68.9	20.66	24.2
2	Aata	Jalaun	36	28	32	62.66	68.9	20.66	24.2
3	Okaruaa		22	18	20				
4	Lamsar		16	18	17				
5	Bara		21	18	19.5				
6	Bagi		34	27	30.5				
7	Babina		20	16	18				
8	Jolhopur		15	18	16.5				
9	Etora		13	15	14				
10	Saidnagar		19	14	16.5				
11	Kulpahad	Mahoba	28	22	25	52.83	62.4	22	24.4
12	Ratauli		17	14	15.5				

Table 4: Correlation between disease incidences of pigeon pea fields with soil characteristic

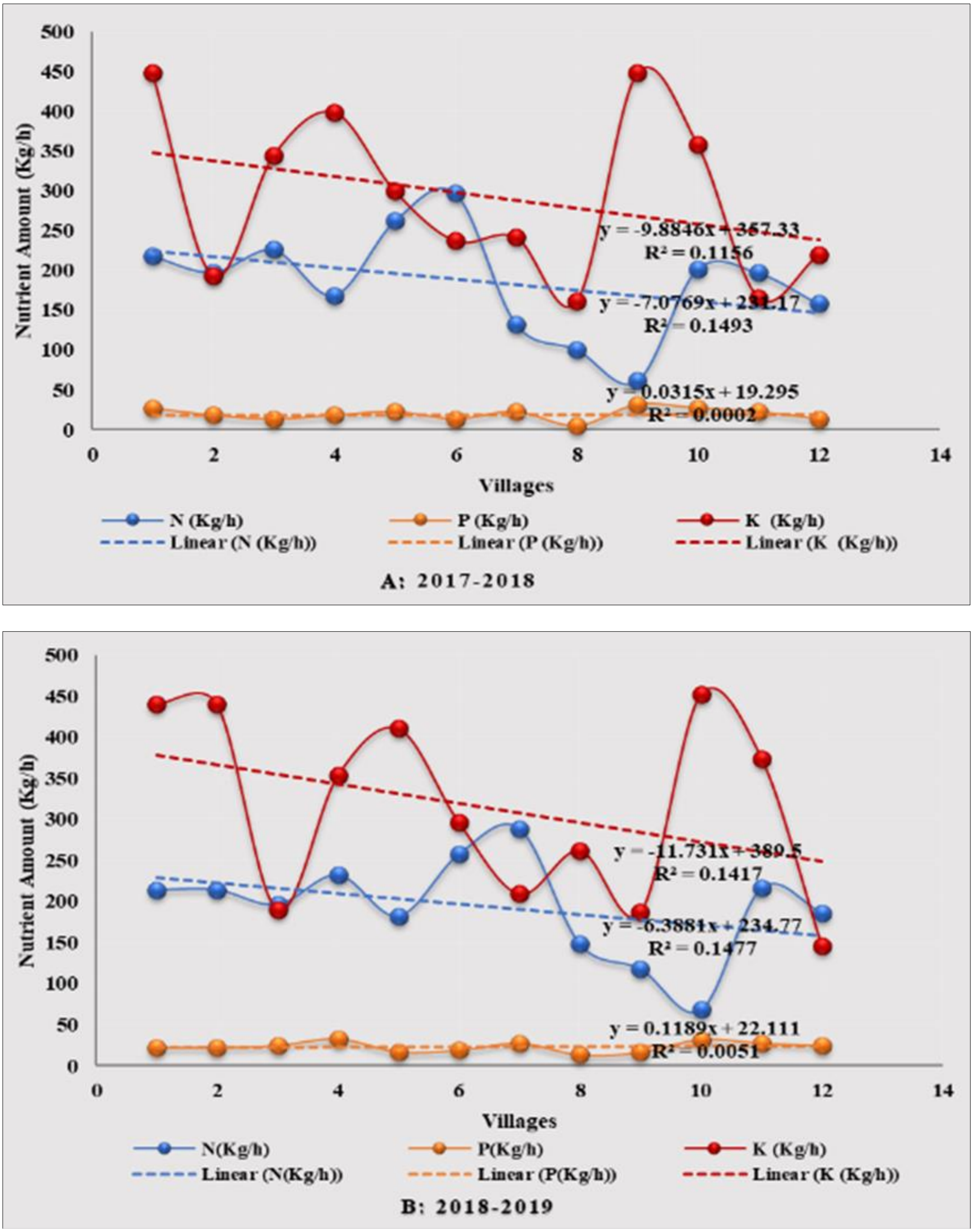
S. No.	Soil Parameters	Correlation Study with Disease incidence	
		2017-2018	2018-2019
1	pH	-0.470	0.185
2	EC	0.252	0.139
3	Soil Moisture (%)	0.652**	0.797*
4	C	0.396	0.292
5	N	0.632**	0.391
6	P	-0.165	0.185
7	K	-0.507**	-0.634*
8	S	0.051	0.193
9	Zn	-0.199	-0.219

10	B	0.146	0.096
11	Fe	0.083	-0.457
12	Mn	0.096	-0.121
13	Cu	-0.393	-0.412

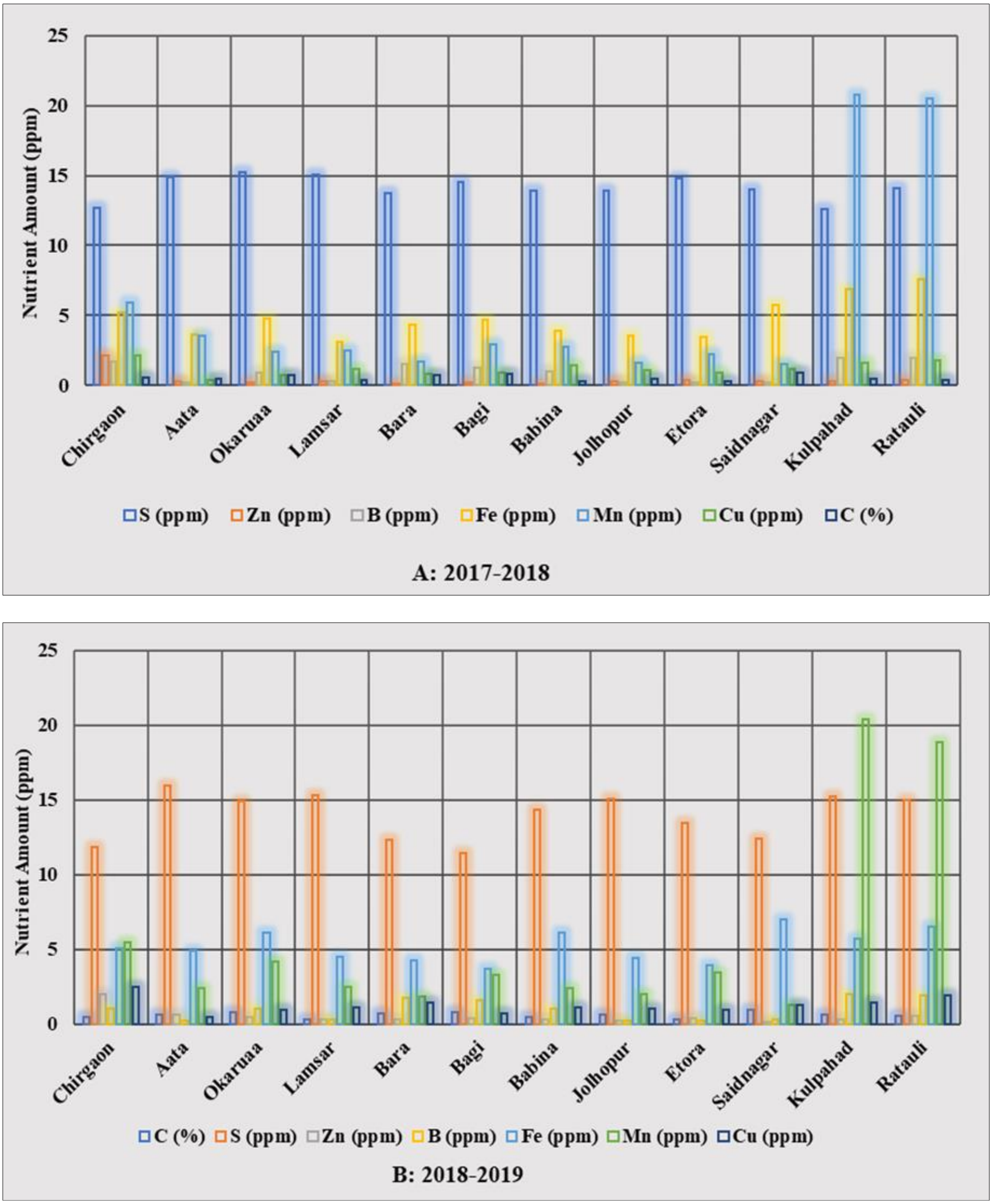
*Correlation is significant at the 0.01 level.
**Correlation is significant at the 0.05 level



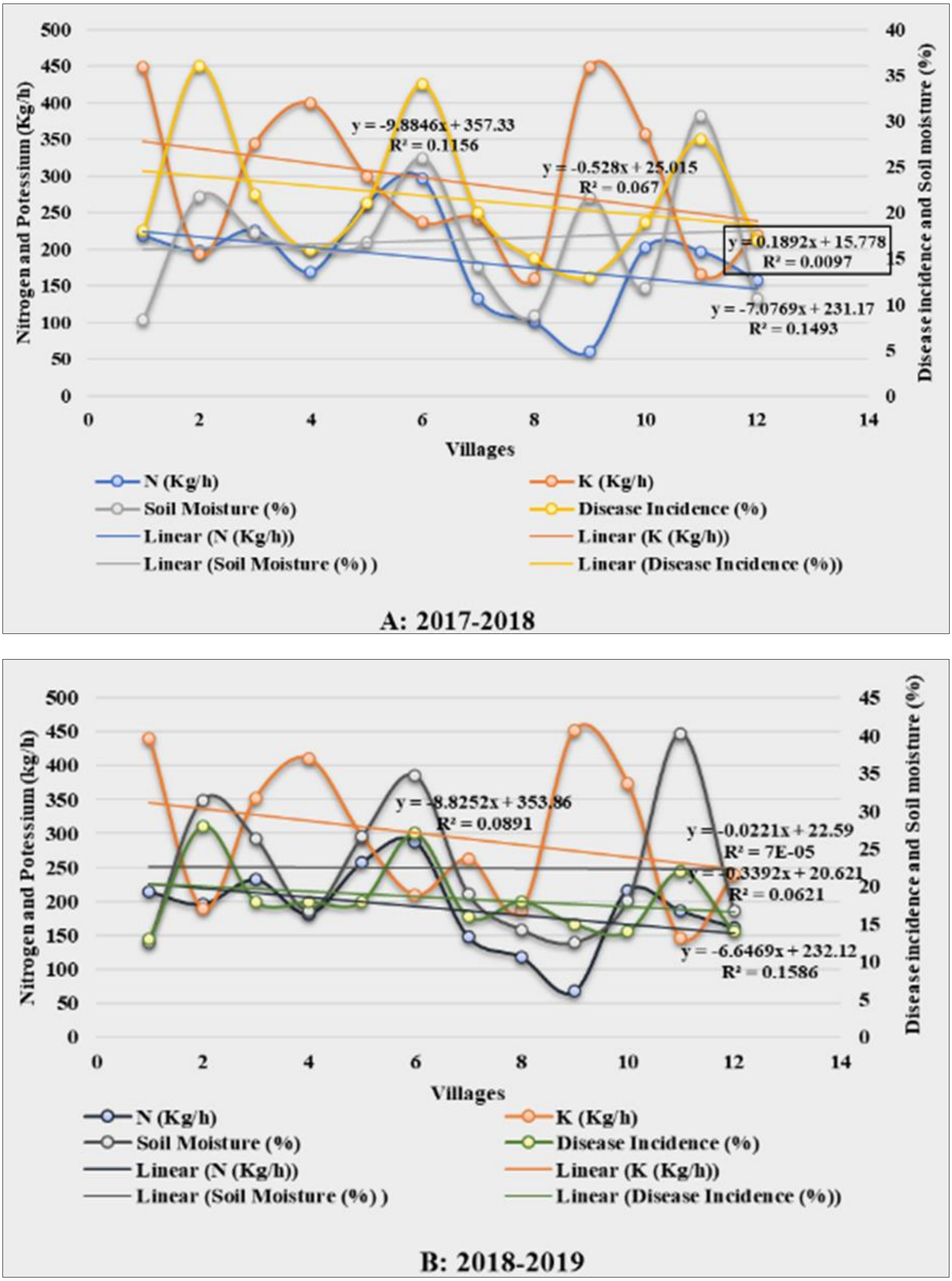
Graph 1: Physical characterisation of rhizospheric soil samples



Graph 2A: Chemical characterisation of rhizospheric soil samples (NPK)



Graph 2B: Chemical characterisations of rhizospheric soil samples



Graph 3: Relationship between disease incidence and nitrogen, potassium and moisture of soil

Conclusion

Progression and spread of any disease are dependent on the susceptibility and virulence of host and pathogen in general and edaphic factors in practical. The environmental factor is an important component of disease triangle. They play an important role in the regulation and development of certain diseases. The analysis revealed that the availability of macro and micronutrient in the soil samples had no uniform trend. Regarding this phenomenon the soil composition and nutrient were vigorously analysed. Organic carbon, sulphur, boron, iron and manganese had no significant impact on disease incidence whereas soil moisture and nitrogen favoured the disease development and imparted positive and significant impact on disease development. Potassium had negative and significant impact on disease incidence. Correlation of disease incidence with meteorological study in any area, locality, district represent an important outset for precision agriculture.

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