J.Mycopathol.Res. 63(2) : 273-285, 2025, ISSN : 0971-3719 (Print), 2583-6315 (Online)
10.57023/JMycR.63.2.2025.273

Roving surveillance and assessment of fungal diseases of pea (*Pisum sativum L.)* cultivated organically in the hills of Manipur

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Received : 22.02.2025 Accepted : 08.05.2025 Published : 30.06.2025

Odyssey survey was conducted for the quantification of fungal diseases in terms of disease incidence(DI) and disease severity(DS) associated with pea plants grown in the organic farming systems in the hill districts of Manipur (Kangpokpi, Senapati, Churachandpur, Ukhrul, Chandel and Tamenglong) during 2021-2024 growing season. Assessment of fungal diseases was made at three phenological stages of the crop (vegetative, flowering and fruiting/harvesting) following a simple random sampling methods. Locally cultivated five varieties of pea, namely Arkel, Makhyatmubi (Local variety),Rachna, RE-10, and Makuchabi (local variety) were assessed. Variation of disease occurrence were recorded over the district surveyed. Pooled DI of powdery mildew, rust, and wilt in all districts ranged from 9.33% to 52.7%, 9.97% to 66%, and 7.17% to 33.3%, respectively. Similarly, pooled DS of powdery mildew, rust, and wilt ranges from 5% to 27.9%, 5.37% to 34%, and 4.4% to 18.2%, respectively.Positive correlation exist between the severity of powdery mildew and both minimum and maximum temperatures, as well as morning and average relative humidity (RH).Rust also showed a positive correlation with maximum and minimum temperatures, rainfall, and wind velocity, while displaying a negative correlation with morning and evening RH. Fusarium Wilt exhibited a negative correlation with morning RH, minimum RH, and average RH, but displayed a positive correlation with both maximum and minimum temperatures.

Keywords : Flowering, fruiting, Powdery mildew, Rust, vegetative,wilt

INTRODUCTION

Pea (*Pisum sativum* L.) is a significant annual pulse crop in temperate regions worldwide and was initially farmed in the Mediterranean basin (Sardana *et al*. 2007). Its diverse use and large production area make it an important crop (Boros and Wawer, 2009). The global cultivated area for dry pea is approximately 6.2 million hectares with an average yield of 1.68 tons per hectare. Young leaves and green pods are used as vegetables. The nutritional composition of dry pea seeds is comparable to other grain legumes and consists of 18-30% proteins, 35-50% starch, and 4-7% fiber. The global cultivated area for dry pea is approximately 6.2 million hectares with an average yield of 1.68 tons per hectare, producing an estimated 105 million tons.

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Garden pea is best grown in cool temperatures with an optimal mean temperature of 10-18°C (Thumburaj and Singh, 2003), and hot, dry weather reduces pod quality as they convert to starch and cellulose.

In India, peas are cultivated over an area of 0.77 million hectares with a production of 0.71 million tons and a productivity of 1032 kg/ha (Anonymous, 2009). India's average yield is 9.15 q/ha (Singh, 2008) as compared to major pea-growing countries like France (15.5 q/ha) (Anonymous, 2002). Despite their enormous potential, peas still encounter challenges due to weed competition, (*Pisum sativum L*.) insect infestation, disease prevalence, production instability, and unsuccessful nodulation (Date, 2000; Lemerle *et al*. 2006; Martin Sanz *et al.* 2011). Pea is susceptible to various foliar and soil-borne fungal diseases, such as Powdery mildew (*Erysiphe pisi*), Rust (*Uromyces fabae*), Downy mildew (*Peronospora viciae)*, Fusarium wilt (*Fusarium*

oxysporum sp *pisi)*, and root rot, which may be caused by one or a combination of several soil-borne fungi (Kraft and Pfleger,2001; Marcinkowska, 2002; Koike et al. 2007; Melzer et al. 2016; Kamala and Indira, 2001). Among the various pea diseases, Powdery mildew, *Fusarium* wilt, and Rust are the major contributors to significant yield loss (Glawe, 2008; Singh and Tripathi, 2004; EPPO, 2012; Janila *et al*. 2001). Powdery mildew is identified by the presence of white powdery patches initially on the leaves, spreading to tendrils, pods, stems, and aerial parts, leading to reduced yield. Rust typically appears in mid-spring and can cause substantial yield losses, particularly in warm weather conditions, ranging from 56.8 to 100% (Kushwaha *et al*. 2010). *Fusarium oxysporum* sp. pisi has the potential to cause significant yield losses in pea production globally (Dubey *et al.* 2007). Winter crops are primarily affected by *Fusarium wilt,* causing significant losses, prevalent in many varieties with yield losses of up to 100% (Khan et al. 2002).

Field pea is the primary pulse crop cultivated in a 26,000ha area, constituting approximately 85% of the total pulses area in Manipur, a northeastern hill state of India (Anonymous, 2015). Manipur is situated in a tropical wet evergreen forest and moist deciduous region, leading to the acidic nature of the soil. The residual moisture plays a significant role due to the limited availability of rainfall. Reports on fungal diseases affecting peas, such as powdery mildew, Fusarium wilt, and rust, are limited (Nongmaithem *et al.* 2017).However, it is known that fungal diseases occur in the hills, so this study aimed to assess the occurrence and severity of various fungal diseases affecting pea (*Pisum sativum* L.) in six hill districts of Manipur namely Kangpokpi, Senapati, Churachandpur, Tamenglong, Chandel, and Ukhrul. The findings from this investigation may help in managing the spread and controlling the disease.

MATERIALS AND METHODS

A roving survey on the prevalence of fungal diseases was carried out in the six hill districts of Manipur between 2021-2022 to 2023-2024 covering Kangpokpi,Senapati,Churachandpur, Tamenglong, Chandel and Ukhrul during crop growing season (Rabi). Questionnaires were used to gather information on farming practices, land preparation, use of organic fertilizers, pea varieties planted, planting times, traditional disease control methods.Simple random sampling were followed for the collection of samples and assessment of the disease covering three stages of plant growth viz. vegetative, flowering and fruiting in all three selected sites in each of the six district surveyed during Rabi season- October to February.Five leaves from each of the randomly selected ten plants were assessed for the incidence and severity of the diseases using 0-9 scales of measurement (Mayee and Datar,1986). Prominent environmental data such as temperature, humidity, rainfall and wind speed from the sampling site that supposed to influence the occurrence of diseases were collected for statistical interpretation of the occurrence of diseases with respect to environmental factors. Further, extensive analysis of variance technique were used to test the significance of the occurrence of disease with respect to varieties ,site location, growth stages of crops etc. for testing their significance with respect to different parameters. and their correlation was studied by using Karl Pearson's correlation coefficient (r) as given below :

$$r = \frac{1}{n-1}\sum \frac{(x_i - X)(y_i - \underline{Y})}{S_x S_y}$$

Where, r = coefficient of correlation, $X = (x_i - X) Y = (y_i - \underline{Y}), S_X$ standard deviation of *x* series, S_y = standard deviation of y series, n = number of series.

RESULTS AND DISCUSSION

In the survey, three significant fungal infections including Powdery mildew, Rust, and *Fusarium wilt*, which are caused by *Erysiphe pisi, Uromyces fabae*, and *Fusarium oxysporum* sp.*pisi*, were identified. However, the prevalence of fungal diseases varied across different districts in the hills, but all districts reported the presence of these three major fungal diseases

Table 1(a):DI ,DS,and environmental data* pertaining to the occurrence of powdery mildew in Kangpokpi district.

Variety	Arkel		Makhyatmubi		Rachna		Makuchabi		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	MorRH	Avg RH	WS
Veg	28.8	16.83	25	14.2	28.5	15.65	22.8	12.8	20.43	11	89.4	70.35	2
Flo	36	19.9	32.2	17.7	33.62	19.21	26.6	15	20.67	10	87.1	68.2	1.63
Fru	51.6	26.9	41.1	21.7	50.3	25.37	32.7	17.8	22.1	12.5	91.4	72.4	2.5

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Avg RH	WS
Arkel	0.985	0.757	0.648	0.667	0.738
Makhyatmubi	0.938	0.626	0.498	0.521	0.603
Rachna	0.972	0.711	0.594	0.615	0.691
Makuchabi	0.948	0.650	0.524	0.547	0.627

Table 1 (b): DI ,DS, and environmental data* pertaining to the occurrence of Rust in Kangpokpi district

Variety	Arkel		Makhyatmubi		Rachna		Makuchabi		Weather parameters					
Stages	DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	MorRH	Eve RH	WS	RF
Veg	43.3	22.5	33.8	17.8	22.7	12.9	20	11.8	22.3	10.4	92.2	2.33	2	15
Flo	53.2	27.4	42.7	22.9	29.9	16.1	27.7	14.98	21.1	9.2	86.8	2.23	1.63	10.27
Fru	66	34	53.8	27.8	36	19.1	37.7	20.1	23.5	11.2	89.3	2.8	2.5	19.17

Correlation coefficient(r)of disease severity with weather parameters

Variety	Max T	Min T	Mor RH	Eve RH	WS	RF
Arkel	0.571	0.473	-0.462	-0.910	0.823	0.541
Makhyatmubi	0.489	0.386	-0.546	-0.946	0.764	0.457
Rachna	0.483	0.380	-0.552	-0.948	0.760	0.451
Makuchabi	0.611	0.516	-0.418	-0.889	0.850	0.582

Table 1(c): DI ,DS,and environmental data* pertaining to the occurrence of Fusarium wilt in Kangpokpi district.

Variety	Arkel		Makhyatmubi		Rachna		Makuchabi		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Min RH	Avg RH
Veg	19.4	11.5	16.6	10.31	14.9	9.23	12.7	8.3	21.2	10.6	89.7	53.8	71.75
Flo	26	14.7	22.2	12.53	20.5	11.72	18.3	10.9	19.8	9.7	86.1	49.4	67.75
Fru	32.2	17.6	28.8	15.7	26	13.9	23.8	13.67	22.2	11.6	88.1	50.9	69.5

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Min RH	Avg
Arkel	0.388	0.501	-0.468	-0.669	-0.584
Makhyatmubi	0.504	0.609	-0.350	-0.567	-0.474
Rachna	0.804	0.872	0.0472	-0.197	-0.088
Makuchabi	0.431	0.541	-0.427	-0.634	-0.545

*Pooled data for three years(2021-2024),r=correlation coefficient.

Table 2(a): DI ,DS,and environmental data* pertaining to the occurrence of powdery mildew in Churachandpur district.

Variety	Arkel		Rachna		Makhyatmubi		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	MorRH	AvgRH	WS
Veg	19.4	10.3	16.8	9.31	14.4	8.2	20.5	10.6	89.3	71	2.4
Flo	27.7	14	24	12.3	22.2	11	20.7	10.4	88.4	69.4	2.2
Fru	41.6	20.6	37	18	33.3	17.7	23	12.1	92.7	74	2.8

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	AvgRH	WS
Arkel	0.959	0.893	0.847	0.764	0.678
Rachna	0.962	0.899	0.855	0.773	0.688
Makhyatmubi	0.976	0.922	0.882	0.807	0.728

Table 2(b):DI ,DS,and environmental data* pertaining to the occurrence of Rust in Churachandpur district

Variety	Arkel		Makhyatmubi		Rachna		Weather parameters					
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Eve RH	WS	RF
Veg	30.5	15.3	25	13	16.1	8.6	23.1	11.4	91.4	44.2	2.22	19.7
Flo	42.2	20.9	33.5	17.2	25.5	12.8	21.9	10.1	88.7	43.3	1.73	13.2
Fru	53	26.6	44.5	22	34	17	24.2	12.3	90.2	39.6	2.65	25.1

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Eve RH	WS
Arkel	0.484	0.413	-0.437	-0.949	0.473
Makhyatmubi	0.511	0.441	-0.408	-0.959	0.500
Rachna	0.483	0.412	-0.437	-0.949	0.472

Table 2(c):Table showing DI ,DS,and environmental data* pertaining to the occurrence of Fusarium wilt in Churachandpur district

Variety	Arkel		Makhyatmubi		Rachna		Weather parameters					
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Eve RH	WS	RF
Veg	12.2	6.9	11.6	6.9	16.	8.6	23.1	11.4	91.4	44.7	2.22	19.7
Flo	19.4	11.5	17.7	10	25.5	12.	21.9	10.1	88.7	43.3	1.73	13.2
Fru	25.1	13.4	23.2	12	34	17	24.2	12.3	90.2	39.6	2.65	25.13

Correlation coefficient(r)of disease severity with weather parameters

Variety	Max T	Min T	Mor RH	Min RH	Avg RH
Arkel	0.297	0.486	-0.690	-0.788	-0.750
Makhyatmubi	0.389	0.570	-0.616	-0.724	-0.681
Rachna	0.775	0.888	-0.176	-0.317	-0.260

*Pooled data for three years(2021-2024),r=correlation coefficient

Table 3(a):DI ,DS,and environmental data* pertaining to the occurrence of Powdery mildew in Senapati district

Variety	Arkel		Rachna		Makhyatmubi		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Avg RH	WS
Veg	26.1	14.5	22.17	12.15	20	11.3	20.8	10.4	87	67.6	2.43
Flo	35.5	19.2	31.27	16.79	27.7	15.5	20.3	9.17	85	66	2.33
Fru	52.7	27.9	46.65	25	41.6	22.91	23	11.8	89.17	70	3

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	MorRH	Avg RH	WS
Arkel	0.863	0.668	0.657	0.723	0.881
Rachna	0.857	0.659	0.648	0.715	0.875
Makhyatmubi	0.857	0.658	0.648	0.715	0.875

Table 3(b):DI ,DS,and environmental data* pertaining to the occurrence of Rust in Senapati district

Variety	Arkel		Makhyatmubi		Rachna		Weather parameters					
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Eve RH	WS	RF
Veg	38.9	20.7	32.2	17.5	20	11.64	21	10.9	89.7	44.17	2.47	21.6
Flo	49.9	26.52	39.4	20.7	28.3	15.4	18.9	9.4	85.7	38.3	2.43	15.8
Fru	61.1	31.81	52.21	27.3	35	18.2	22.7	12.1	87.1	40.4	2.77	27.1

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	MorRH	Eve RH	WS	RF
Arkel	0.421	0.418	-0.661	-0.654	0.790	0.462
Makhyatmubi	0.613	0.610	-0.477	-0.469	0.907	0.648
Rachna	0.369	0.366	-0.702	-0.696	0.754	0.411

Table 3(c): DI ,DS,and environmental data* pertaining to the occurrence of Fusarium wilt in Senapati district

Variety	Arkel		Makhyatmubi		Rachna		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Min RH	Avg RH
Veg	20	11.2	16.6	9.74	14.9	9	21.9	10.4	90.1	50.8	70.45
Flo	26	14.67	22.2	12.92	20	11.64	20.2	9.2	84.6	46.3	65.45
Fru	33.3	18.21	30.5	18	25.18	14.9	22.8	11.9	87.2	48.5	67.85

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Min RH	Avg RH
Arkel	0.346	0.559	-0.522	-0.506	-0.514
Makhyatmubi	0.461	0.659	-0.410	-0.393	-0.402
Rachna	0.397	0.603	-0.474	-0.458	-0.467

*Pooled data for three years(2021-2024),r=correlation coefficient.

Table 4(a): DI ,DS, and environmental data* pertaining to the occurrence of Powdery mildew in Tamenglong district

Variety	Arkel		Makhyatmubi		Rachna		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	MorRH	Avg RH	WS
Veg	21.6	11.8	17.2	10	13.1	8.24	18.7	10	86	67.1	2.33
Flo	31.1	16.4	24.4	13.8	24.43	12.92	20.2	9.63	84.1	65.9	1.9
Fru	48.7	25.2	36.6	19	31.65	20.55	21.5	11.9	88.2	69.5	2.63

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Avg RH	WS
Arkel	0.975	0.878	0.677	0.778	0.564
Makhyatmubi	0.991	0.832	0.609	0.719	0.488
Rachna	0.984	0.858	0.646	0.752	0.530

Table 4(b): DI ,DS,and environmental data* pertaining to the occurrence of Rust in Tamenglong district

Variety	Arkel		Makhyatmubi		Rachna		Weather parameters					
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Eve RH	WS	RF
Veg	36.1	19	30	15.4	18.3	10.5	20	10.1	89.4	44.3	2.53	25.2
Flo	47.2	24.5	38.47	20.21	27.7	15	18.5	8.9	84.8	40	2.3	17.67
Fru	57.2	29.4	48.8	25.3	35.5	19.1	21.2	11.3	86.7	41.86	3.03	32.57

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Eve RH	WS	RF
Arkel	0.413	0.470	-0.610	-0.592	0.644	0.465
Makhyatmubi	0.458	0.514	-0.570	-0.552	0.681	0.508
Rachna	0.419	0.476	-0.605	-0.587	0.649	0.471

Table 4(c): DI ,DS,and environmental data* pertaining to the occurrence of Fusarium wilt in Tamenglong district

Variety	Arkel		Makhyatmubi		Rachna		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Min RH	Avg RH
Veg	16.1	9.3	12.7	8	10.5	7.17	19.7	9.8	87.2	48.2	67.7
Flo	23.3	13	18.3	11.1	17.2	10	17.9	8.43	83.3	43.7	63.5
Fru	29.4	16.4	26.1	14.2	22.2	12.2	20.9	10.8	83.9	45.7	45.7

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Min RH	Avg RH
Arkel	0.374	0.397	-0.800	-0.574	-0.933
Makhyatmubi	0.397	0.420	-0.785	-0.554	-0.941
Rachna	0.330	0.353	-0.828	-0.613	-0.915

*Pooled data for three years(2021-2024),r=correlation coefficient

Table 5(a): DI ,DS, and environmental data* pertaining to the occurrence of Powdery mildew in Ukhrul district

Variety	Arkel		Rachna		Makhyatmubi		RE-10		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	AvgRH	WS
Veg	18.3	10	14.61	8.17	12.2	7	10.5	6.4	19.4	9.93	85.6	64.6	2.5
Flo	25	13.12	20.5	11.27	19	10.1	16.67	9.1	20.8	8.97	84	63.5	2.1
Fru	37.2	19	32.57	17.21	30.32	15.4	25	13.5	22.16	11.37	88	66.9	2.87

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Avg RH	WS
Arkel	0.983	0.726	0.726	0.783	0.625
Rachna	0.982	0.729	0.729	0.785	0.629
Makhyatmubi	0.987	0.709	0.709	0.767	0.60
RE-10	0.989	0.700	0.700	0.759	0.595

Table 5(b): DI, DS, and environmental data* pertaining to the occurrence of Rust in Ukhrul district

Arkel		Makhyatmubi		RE-10		Rachna		Weather parameters					
DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	MorRH	Eve RH	WS	RF
24.4	12.6	18.8	9.6	14.4	7.81	11.1	6.5	20	10	88.7	45.1	2.71	18.4
35.5	18.1	28.3	14.31	24.4	12.75	19.4	10.3	18.3	8.6	84	40.27	2.35	13.1
46.67	23.6	38.12	19.4	33.3	17	29.4	15.1	21.3	11	86	42.4	3.18	26.53

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Eve RH	WS	RF
Arkel	0.432	0.414	-0.572	-0.557	0.564	0.600
Makhyatmubi	0.452	0.435	-0.553	-0.539	0.582	0.618
RE-10	0.392	0.374	-0.607	-0.593	0.528	0.565
Rachna	0.491	0.474	-0.516	-0.500	0.618	0.653

Table 5(c): DI ,DS,and environmental data* pertaining to the occurrence of Fusarium wilt in Ukhrul district

Arkel		Makhyatmubi		RE-10		Rachna		Weather parameters				
DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	MorRH	Min RH	Avg RH
10.55	6.58	9.44	6.22	7.7	5.43	7.7	5.41	20.4	10.7	88	48.8	68.4
17.2	9.72	15.5	8.89	14.4	8.5	12.7	7.82	18.2	9.4	84.4	43.9	64.1
22.2	11.81	21.67	11.56	21	10.9	20.17	11	22.2	11.6	86.1	45.7	66.1

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Min RH	Avg RH
Arkel	0.343	0.298	-0.621	-0.711	-0.628
Makhyatmubi	0.449	0.406	-0.527	-0.625	-0.534
RE-10	0.385	0.341	-0.586	-0.678	-0.592
Rachna	0.518	0.477	-0.458	-0.561	-0.465

*Pooled data for three years(2021-2024),,r=correlation coefficient.

Table 6(a):DI ,DS,and environmental data* pertaining to the occurrence of Powdery mildew in Chandel district

Variety	Arkel		Rachna		Makhyatmubi		Makuchabi		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	Mor RH	Avg RH	WS
Veg	14.6	7.41	11.82	6.68	10.5	5.58	9.43	5	20.1	10.8	87.4	67.65	2.37
Flo	22.2	10.31	18	9.54	17.2	8.1	17.7	8.1	20.8	10	84.9	65.75	2.07
Fru	30.5	15.7	26.65	14.51	25	12.5	23.3	11.1	22.5	12.6	89.1	70.4	2.9

Correlation coefficient(r)of disease severity with weather parameters

Variety	Max T	Min T	Mor RH	Avg RH	WS
Arkel	0.997	0.791	0.552	0.717	0.715
Rachna	0.996	0.781	0.538	0.705	0.703
Makhyatmubi	0.996	0.781	0.539	0.706	0.704
Makuchabi	0.970	0.668	0.393	0.580	0.578

Table 6(b): Table showing DI ,DS,and environmental data* pertaining to the occurrence of Rust in Chandel district

Variety	Arkel		Makhyatmubi		Makuchabi		Rachna		Weather parameters					
Stages	DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	MorRH	Eve RH	WS	RF
Veg	20.5	10	16.67	8.14	12.7	6.6	10	5.47	20.7	10.9	89.4	44.83	2.83	22.03
Flo	31.67	14.92	26.1	12.25	22.2	10.6	18.3	8.53	18.7	9.6	83.8	39.76	2.93	15.73
Fru	40.5	20	33.8	16.2	30.5	14.3	26.1	13	21.8	11.8	86.5	41.17	3.6	27.83

Correlation coefficient(r)of disease severity with weather parameters.

Variety	Max T	Min T	Mor RH	Eve RH	WS	RF
Arkel	0.358	0.415	-0.509	-0.692	0.923	0.487
Makhyatmubi	0.339	0.396	-0.527	-0.707	0.914	0.469
Makuchabi	0.328	0.386	-0.536	-0.715	0.910	0.459
Rachna	0.448	0.502	-0.422	-0.618	0.956	0.570

Table 6(c): DI ,DS,and environmental data* pertaining to the occurrence of Fusarium wilt in Chandel district.

Variety	Arkel		Makhyatmubi		Makuchabi		Rachna		Weather parameters				
Stages	DI	DS	DI	DS	DI	DS	DI	DS	Max T	Min T	MorRH	Min RH	Avg RH
Veg	8.3	4.67	10	5.4	8.3	4.7	7.21	4.4	19.5	11	85.7	48.1	66.9
Flo	15	7.1	16.6	8	15	7.13	12	6.19	17.5	7.3	81.3	44.2	62.95
Fru	21	10.15	21.6	10.5	20	9.7	18.3	8.74	20.9	11.8	83.2	45.5	64.6

Correlation coefficient(r)of disease severity with weather parameters

Variety	Max T	Min T	Mor RH	Min RH	Avg RH
Arkel	0.468	0.230	-0.511	-0.603	-0.525
Makhyatmubi	0.340	0.155	-0.575	-0.663	-0.588
Makuchabi	0.424	0.182	-0.553	-0.642	-0.566
Rachna	0.450	0.264	-0.480	-0.575	-0.494

*Pooled data for three years(2021-2024),,r=correlation coefficient

In Kangpokpi district, DI of Powdery mildew for Arkel variety ranges from 28.3% in Vegetative stage to 51.6% while DS for powdery mildew ranges from 16.1% to 26.9%,25% to 41% and 14.1% to 21.7% for Makhyatmubi variety, DI and DS for Makuchabi variety ranges from 22.2% to 32.7% and 12.8% to 17.8%,DI of rust for Arkel variety ranges from 42.2% to 66% and DS ranges from 22.5% to 34%,33.8% to 53.8% and 18% to 27.9% for Makhyatmubi variety,22.7% to 36% and 12.9% to 19.2% for Rachna,19.9% to 37.7% and 11.8% to 20.1% for Makuchabi variety. DI of *Fusarium wilt* for Arkel variety ranges from 19.4% to 32.2% and DS ranges from 11.4% to 17.3%, 16.6% to 28.8% and 10.2% to 15.7% for Makhyatmubi variety,14.9% to 26% and 9.45% to 14.4% for Rachna,12.7% to 23.8% and 8.3% to 13.4% for Makuchabi variety.

In Churachandpur district, DI of Powdery mildew for Arkel variety ranges from 26% in Vegetative stage to 52.7% while DS for powdery mildew ranges from 14.5% to 27.9%,19.9% to 41.6% and 11.3% to 22.8% for Makhyatmubi variety. DI of rust for Arkel variety ranges from 38% to 61.1% and DS ranges from 20.6% to 31.7%,32.2% to 52.1% and 17.4% to 27.3% for Makhyatmub ivariety,19.9% to 34.9% and 10.5% to 18.2% for Rachna. DI of *Fusarium wilt* for Arkel variety ranges from 19.9% to 33.3% and DS ranges from 11.2% to 18.1%, 16.6% to 30.5% and 9.76% to 18.2% for Makhyatmubi variety,14.9% to 25.5% and 8.7% to 14.8% for Rachna.

In Senapati district, DI of Powdery mildew for Arkel variety ranges from 19.9% in Vegetative stage to 41.6% while DS for powdery mildew ranges from 10.4% to 20.6%,14.4% to 33.3% and

Fig. 1: Major diseases of Pea. A. Survey site; B Wilted pea plant. ; C. Rust disease on pea leaf; D. Powdery mildew infected leaf.

8.35% to 17.7% for Makhyatmubi variety. DI of rust for Arkel variety ranges from 30.5% to 52.7% and DS ranges from 15.3% to 26.5%,24.9% to 44.4%and 13% to 22% for Makhyatmubi variety,16% to 33.8% and 8.86% to 16.9% for Rachna. DI of *Fusarium wilt* for Arkel variety ranges from 12.2% to 24.9% and DS ranges from 9.06% to 12.8%, 11.6% to 16.6% and 6.67% to 12% for Makhyatmubi variety,8.31% to 20.5% and 5.53% to 10.5% for Rachna

In Tamenglong district, DI of Powdery mildew for Arkel variety ranges from 21.5% in Vegetative stage to 48.3% while DS for powdery mildew ranges from 11.8% to 25.2%,17.2% to 36.6% and 10% to 18.8% for Makhyatmubi variety. DI of rust for Arkel variety ranges from 36.1% to 57.2% and DS ranges from 19% to 29.4%,29.9% to 48.8%and 17.4% to 25.3% for Makhyatmubi variety,18.2% to 35.5% and 10.4% to 18.97% for Rachna. DI of *Fusarium wilt* for Arkel variety ranges from 16.1% to 29.4% and DS ranges from 9.3% to 16.4%, 12.7% to 26% and 8% to 14.1% for Makhyatmubi variety,10.5% to 22.1% and 7.17% to 12.2% for Rachna.

In Ukhrul district, DI of Powdery mildew for Arkel variety ranges from 18.3% in Vegetative stage to 37.2% while DS for powdery mildew ranges from 9.9% to 18.9%,12.2% to 29.4% and 6.9% to 15.4% for Makhyatmubi variety, ,DI and DS for Makuchabi variety ranges from 10.5% to 24.9% and 7% to 13.6%.DI of rust for Arkel variety ranges from 24.4% to 46.67% and DS ranges from 12.6% to 23.6%,18.8% to 37.7% and 9.6% to 19.4% for Makhyatmubi variety,14.4% to 33.3% and 7.73% to 16.9% for Rachna, DI and DS for RE-10 variety ranges from 11.1% to 29.4% and 6.5% to 15.1%.DI of Fusarium wilt for Arkel variety ranges from 10.53% to 22.2% and DS ranges from 6.6% to 11.7%, 9.43% to 21.63% and 6.17% to 11.8% for Makhyatmubi variety,7.7% to 21% and 5.3% to 10.9% for Rachna, DI and DS for RE-10 variety ranges from 7.7% to 19.9% and 5.5% to 11.2%.

In Chandel district, DI of Powdery mildew for Arkel variety ranges from 14.9% in Vegetative stage to 30.5% while DS for powdery mildew ranges from 7.2% to 15.6%,10.5% to 25% and 5.46% to 12.4% for Makhyatmubi variety, 9.33% to 23.3% and 5% to 11.1% for Makuchabi variety. DI of rust for Arkel variety ranges from 20.5% to 40.5% and DS ranges from 10% to 19.9%,16.67% to 33.8% and 8% to 16% for Makhyatmubi variety, 12.7% to 30.5% and 6.53% to 14.3% for Makuchabi ,9.97% to 26.1% and 5.37% to 12.9% for Rachna. DI of Fusarium wilt for Arkel variety ranges from 8.3% to 21% and DS ranges from 5.2% to 10%, 10% to 21.6% and 5.4% to 10.5% for Makhyatmubi variety,8.3% to 19.9% and 4.87% to 9.7% for Rachna, 7.17% to 18.3% and 4.4% to 8.6% for Makuchabi variety.

Results of Disease index and Disease severity of the 3 diseases studied, as well as environmental data in six districts have been presented in Tables 1-6, along with the correlation of disease parameters with environmental data.

Correlation study

The result of correlation study examining the severity of powdery mildew disease in relation to meteorological parameters found that disease severity is positively correlated with maximum temperature, minimum temperature, relative humidity, and wind velocity. A positive correlation between powdery mildew severity and both temperature and wind velocity was reported earlier. Additionally, Kumar and Gupta (2006) reported a highly significant positive correlation between temperature and disease severity. However, it is important to note that disease

severity exhibits a strong negative correlation with relative humidity.

The results of the current investigation revealed a positive relationship between rust severity and factors such as temperature, rainfall, and wind velocity. In contrast, rust severity showed a negative correlation with relative humidity. Similar findings were reported by Bal and Kumar (2012), who noted a highly significant positive correlation between disease severity and both maximum and minimum temperatures. Singh *et al*. (2012) also found a significant positive correlation between rust severity and temperature. Kushwaha *et al.* (2006) also indicated that the germination of aeciospores of pea rust is favored by temperatures ranging from 10 to 25°C. Furthermore, Joshi and Tripathi (2012) observed that a temperature of 20°C is optimal for the germination of aeciospores, uredospores, and teliospores of lentil rust disease. These findings align with those of Bal and Kumar (2012), who reported a highly significant positive correlation between disease severity and both maximum and minimum temperatures. Singh *et al*. (2012) confirmed significant positive correlations between rust severity and temperature, while also noting a negative correlation with relative humidity.The findings highlight the significant impact of weather factors on the development of rust diseases. Long-term research is essential to investigate the influence of these weather conditions, which will help in creating accurate forecasting models. Furthermore, numerous researchers have noted similar correlations between weather parameters and the severity or incidence of rust (Upadhyay *et al.* 2017). *Fusarium* wilt also shows positive correlation between Disease severity and factors like Maximum and Minimum temperature which correlates with the findings of Chhetry and Ranjana Devi (2014) showing temperature as the factor for wilt disease development.

The investigation identified three fungal diseases affecting pea plants (*Pisum sativum* L.) namely powdery mildew, rust, and Fusarium wilt. These diseases were found in all stages of growth - vegetative, flowering, and fruiting/harvesting, in the six hills district of Manipur during the 2021-2022 to 2023-2024 growing season. The disease incidence of powdery mildew, rust, and wilt in all districts ranged from 9.33% to 52.7%, 9.97% to 66%, and 7.17% to 33.3% respectively. Similarly, the disease severity for these diseases in all districts ranged from 5% to 27.9%, 5.37% to 34%, and 4.4% to 18.2% respectively. This report aligns with findings from previous researchers (Rao, 2014; Rajalakshmi *et al*. 2016; Mishra *et al*. 2017; Upadhyay *et al*. 2016; Wani *et al*. 2003; Kripalini, 2019; Soylu *et al*. 2011), who reported these fungal diseases at different levels of severity. The variation in disease incidence and severity at different locations may be attributed to diverse location-specific climatic conditions such as traditional cultivation practices, rainfall, humidity, and temperature. Sandhu and Dhaliwal (2017) reported that maximum and minimum temperature, relative humidity, rainfall and sunshine hours were positively correlated and enhance rust diseases on field pea and wheat in India

It is important to note that the reported diseases occurred in a natural setting without external inputs. While these diseases were minor in previous years, they are now becoming more significant, possibly due to changing climatic conditions

CONCLUSION

The findings confirm that the hilly regions of Manipur are vulnerable to different fungal diseases, and the differences in disease occurrence and severity can be linked to varying weather conditions. To prevent the spread of disease, it is advised to implement suitable practices such as planting at the right time, providing timely irrigation, using disease-free seeds, and proper tilling.

ACKNOWLEDGEMENT

As a recipient of the CSIR-JRF Scholarship, I appreciate receiving the fellowship from CSIR-GOI. I am grateful to MU for granting me the opportunity to conduct my research. I am also appreciative of the cooperation and assistance provided by the residents of six districts during my survey.

DECLARATION

Conflict of Interest. Authors declare no conflict of interest.

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