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Original Research Paper

Unraveling the impact of soil nutrients on papaya black spot disease caused by *Asperisporium caricae* (Speg.) Maubl

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ABSTRACT

The study was conducted to correlate soil nutrient factors and papaya black spot disease severity on leaves and fruits of the papaya plant cv. Taiwan Red Lady. The results revealed that there was a positive correlation coefficient i.e. increase in black spot severity) for soil pH, available nitrogen, available phosphorus, exchangeable calcium and magnesium and hot water extractable boron with black spot of leaf severities, whereas, electrical conductivity, organic carbon, available potassium, available sulfur, DTPA extractable zinc, DTPA extractable manganese, iron and copper were negatively correlated with black spot severity on leaves. Further, black spot severity on fruits were positively correlated with soil pH, available N, available P, exchangeable Ca and Mg, DTPA extractable Cu, and negatively correlated with EC, OC, available K and S, DTPA extractable Zn, Mn and Fe, and hot water extractable B. Hence, the available nitrogen and exchangeable magnesium concentrations in soil significantly influence the papaya black spot disease severity but the difference in black spot severity due to changes in the concentration of nutrients other than these two analyzed in the experiment was non-significant.

Keywords: Available nitrogen, correlation, disease severity, exchangeable magnesium, soil

INTRODUCTION

Papaya (*Carica papaya* L.) is esteemed as a highly valuable fruit in tropical and sub-tropical regions, known for its taste, nutritional significance, and medicinal applications. This dicotyledonous, polygamous, diploid species, belonging to the *Caricaceae* family, possesses a modest genome size of 372 Mbp/1C (Bennett & Leitch, 2005) with 2n=18. Papaya originating in Mexico and Central America (Storey et al., 1986), cultivated in nearly sixty countries, with major producers including India, Brazil, Nigeria, Indonesia, Mexico, Dominican Republic, the Democratic Republic of Congo, the Philippines, Venezuela, and Thailand. In India, papaya cultivation spans approximately 144,000 ha, yielding an annual production of 5,951,000 MT, with significant contributions from states like Gujarat, Andhra Pradesh, Karnataka, Madhya Pradesh, and Tamil Nadu. Karnataka ranks third in papaya production (NHB, 2020-21), while globally, India leads in production, followed by Brazil and Indonesia.

Despite its widespread cultivation, papaya faces significant challenges due to various diseases such as foot rot, anthracnose, powdery mildew, papaya ring spot, leaf curl and mosaic, brown spot, and black spot disease (Rajukumar et al., 2018). *Asperisporium caricae*, identified as the causal agent for the crucial leaf and fruit spot disease of *Carica papaya*, commonly known as black spot (Patel et al., 2024), The Black spot disease also called as blight; or ‘rust’ of pawpaw (Ellis & Holliday, 1972), affects both leaves and fruits, diminishing their market value. The prevalence of papaya black spot disease has led to substantial economic losses, reducing both yield and fruit quality. This disease is particularly problematic in papaya-growing areas of Karnataka, contributing to a decline in the state’s papaya production. Approximately 30 per cent of losses in papaya fruit commercialization were reported due to black-spot disease (Santos & Barreto, 2003). Despite the substantial amount of losses caused by the disease in many parts of the world only a few works are available regarding the management of this disease.

Traditionally, chemical interventions have proven less effective in managing this disease, and the use of fungicides negatively impacts on consumers, the environment, and fruit commercialization due to pesticide residues. Therefore, addressing disease by creating favorable conditions for plant resistance is crucial. In some instances, soil conditions, including soil pH, electrical conductivity, organic carbon content, and macro and micro-nutrients, have been found to influence disease incidence and severity. In light of this, the current study aims to explore the correlation between soil nutrient factors and the severity of papaya black spot, with the goal of identifying sustainable approaches to mitigate its impact.

MATERIALS AND METHODS

Collection of soil samples

The soil samples collected from ten months-old papaya cv. Taiwan Red Lady orchards affected with papaya black spot disease in Gunnayakanahalli village, Mandya district, Karnataka, India, during the *kharif*, 2020. Fifty-two papaya plants, exhibiting varying degrees of leaf and fruit disease severity, were randomly selected from six distinct orchards in the same vicinity.

To collect soil samples, soil profiles were exposed using a spade, and collected around each plant at different horizons: 0-15 cm, 15-30 cm, 30-45 cm, and 45-60 cm segments. Composite soil samples were created from each depth by crushing them into smaller pieces, ensuring a representative one-kilogram sample was collected as a miniature representation of the original material. These soil samples were properly labeled for proper identification.

Additionally, for each soil sample, the disease severity percentage on both fruits and leaves of the corresponding plant was recorded using a disease rating scale ranging from 0 to 5, as per the scale developed by Mayee & Datar (1986) (Table 1). These numerical scales were then converted into a per cent disease index (PDI) using the formula described by Wheeler (1969).

$$PDI = \frac{\text{Sum of individul disease ratings} \times 100}{\text{No. of observations assessed} \times \text{maximum disease rating}}$$

Table 1 : Disease scoring scale for papaya black spot disease caused by *Asperisporium caricae*

Score	Description
0	No leaves or fruits showing any symptoms
1	1% or less leaves or fruits exhibiting symptoms
2	1-10% of leaves or fruits exhibiting symptoms
3	11-20% of leaves or fruits exhibiting symptoms
4	21-50% of leaves or fruits exhibiting symptoms

The samples were transported to the fungal pathology laboratory for analysis. Initially, the samples underwent a drying process under shade conditions and subsequently, the dried samples were finely powdered using a wooden pestle and mortar and then sieved through a 2 mm mesh to ensure homogeneity. The 2 mm sieved soil samples were carefully preserved in polythene bags for subsequent analysis.

For organic carbon analysis, the 2 mm sieved soil samples underwent further grinding and were passed

Table 2 : List of soil nutrient factors and the methods followed

Soil nutrient factors	Methods	References
Soil pH (1:2.5 soil water suspension)	Potentiometric method	Sparks (1996)
Soil organic matter	Walkely and Black's wet oxidation method	Sparks (1996)
Electrical conductivity (1:2.5 soil water suspension)	Conductometric method	Sparks (1996)
Available nitrogen	Alkaline potassium permanganate method	Subbaiah & Asija (1956)
Available phosphorus	Bray's or Olsen's method	Sparks (1996)
Available potassium	Ammonium acetate method	Piper (1966)
Exchangeable calcium and magnesium	Complexometric titration	Piper (1966)
Available sulphur	Turbidometric method	Sparks (1996)
DTPA extractable Zn, Fe, Mn and Cu	Atomic absorption spectrophotometer method	Lindsay & Novell (1978)
Hot water extractable boron	Hot water extraction method	-

through a finer 0.2 mm sieve, following the methodology outlined by Jackson (1973). This meticulous preparation ensured that the soil samples were appropriately processed and ready for comprehensive analysis in the subsequent stages of the study.

Soil analysis

Soil samples underwent analysis for various parameters including pH, electrical conductivity, organic carbon, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, iron, manganese, copper, and boron. Standard procedures outlined by various researchers (Table 2) were followed for analyses of different soil parameters.

Statistical analysis

Values obtained from soil analysis (Table 3) for different soil nutrient factors and disease severities were utilized for correlation and regression analysis. The correlation, regression coefficients, and p values derived from this analysis were then employed to interpret the relationship between soil factors and disease severity percentage using Statistical Package for the Social Sciences software.

RESULT AND DISCUSSION

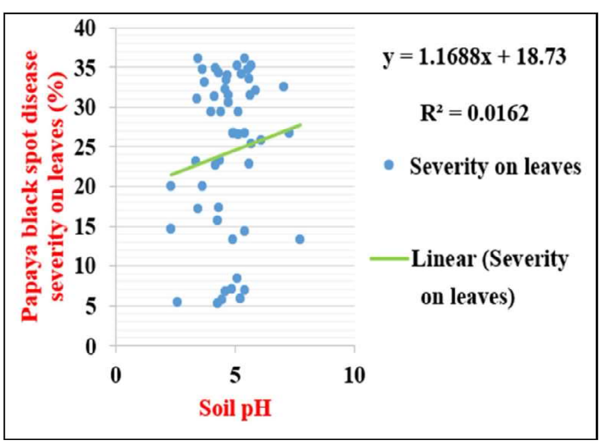
Correlation of soil pH with black spot disease severity on leaves and fruits

Soil pH exhibited a positive correlation with black spot severity on both leaves and fruits. The correlation coefficient for soil pH with leaf black spot severity was $r = 0.13$, and with fruit disease severity, it was $r = 0.06$. The black spot severity tended to be more pronounced in high pH soil, possibly due to higher micronutrient availability at lower pH, which is crucial for plant disease resistance. However, this difference was deemed non-significant based on the significance test of the correlation coefficient at the probability level $p=0.05$. The study's findings are illustrated in Fig. 1. These results align with the research of Workneh et al. (1993), who observed a positive association between soil pH and corky root severity in tomato ($r = 0.52$).

Correlation of soil electrical conductivity with black spot severity on leaves and fruits

Negative correlation was observed between soil electrical conductivity and papaya black spot severity on both leaves and fruits, suggesting that an increase in soil electrical conductivity leads to a decrease in papaya black spot severity. The black spot severity appeared more pronounced in soils with low electrical conductivity (Fig. 2). This relationship may be attributed to the general trend of decreasing pH as electrical conductivity increases, typically resulting in higher micronutrient availability in acidic soils. These micronutrients play a crucial role in conferring resistance to pathogens.

However, based on the significance test of the correlation coefficient at the probability level $p=0.05$, the difference in papaya black spot severity concerning soil electrical conductivity was deemed non-significant. These findings align with the research of Garibaldi et al. (2012), who observed a reduction in tomato powdery mildew due to changes in the electrical conductivity of the nutrient solution in a soilless system.



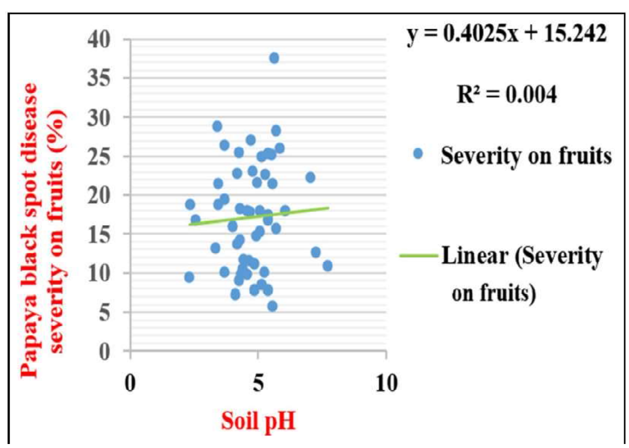


Fig.1 : Correlation between soil pH and papaya black spot disease severity on leaves and fruits

Table 3 : Papaya black spot severity on leaves and fruits of selected papaya plants and soil nutrient factor values of soil samples

Sample	Black spot severity on leaves	Black spot severity on fruits	pH	EC (dS m^{-1})	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (meq./ 100 g)	Mg (meq./ 100 g)	S (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)
P_1S_1	36.20	21.40	3.44	0.40	0.27	257.15	62.00	289.14	14.60	5.95	33.75	0.90	19.27	15.64	1.44	1.9
P1S2	15.71	25.50	4.25	0.51	0.21	112.90	43.09	134.62	16.15	8.20	13.75	0.78	6.99	5.45	0.98	2.2
P1S3	29.33	16.00	4.03	0.31	0.24	301.06	27.51	185.07	16.95	9.25	16.25	0.86	7.06	5.38	1.02	0.5
P1S4	30.66	23.00	4.77	0.44	0.27	313.60	69.51	231.08	8.20	14.80	22.50	0.96	7.42	7.38	1.26	0.6
P1S5	34.20	22.67	5.32	0.50	0.21	169.34	62.65	269.76	7.40	14.05	16.25	0.78	4.92	4.03	0.90	0.2
P1S6	26.70	17.50	5.40	0.27	0.24	163.07	57.45	122.17	12.80	10.10	52.50	0.78	6.01	5.91	1.24	0.1
P1S7	26.66	12.63	7.29	0.33	0.24	175.62	55.34	157.05	15.70	9.45	65.00	0.80	9.07	7.28	1.32	0.9
P1S8	33.31	11.42	4.64	0.40	0.24	464.13	56.94	238.72	12.70	9.20	58.75	0.80	14.90	12.98	1.34	1.0
P1S9	14.28	16.66	5.39	0.35	0.27	137.98	39.43	247.25	15.10	10.00	48.75	0.94	5.73	4.01	1.10	0.3
P1S10	22.81	05.70	5.61	0.31	0.27	175.62	59.31	166.34	12.65	8.25	50.00	0.92	7.75	4.93	1.18	0.2
P1S11	25.70	18.00	6.07	0.20	0.21	169.34	83.87	111.26	10.85	7.20	7.50	0.68	8.00	4.76	1.02	0.8
P1S12	35.20	15.23	5.08	0.23	0.27	526.85	116.38	307.13	10.70	10.40	7.50	0.86	7.31	4.23	1.04	0.5
P1S13	36.10	25.33	5.38	0.21	0.18	50.18	75.28	171.61	9.80	4.35	7.50	0.60	8.67	5.54	1.06	0.9
P1S24	25.33	15.65	5.71	0.38	0.06	200.70	56.23	229.98	11.35	5.75	25.00	0.26	5.01	6.04	1.10	0.6
P1S15	34.90	22.85	4.21	0.33	0.18	495.49	76.11	205.70	17.50	8.90	15.00	0.60	8.80	9.34	1.98	0.1
P1S26	31.40	27.05	4.74	0.27	0.18	156.80	26.87	69.24	18.00	11.75	12.50	0.68	8.33	11.13	1.94	0.4
P1S17	34.60	25.18	5.52	0.21	0.15	144.26	72.78	84.47	13.15	17.50	22.50	0.52	6.45	5.57	1.56	0.2
P1S28	35.20	28.10	5.71	0.22	0.30	163.07	25.65	123.22	14.65	8.25	10.00	1.00	7.45	7.23	1.86	0.9
P1S19	33.47	21.30	5.60	0.27	0.15	175.62	16.03	62.81	14.20	9.50	20.00	0.58	6.50	6.48	1.50	0.1
P1S20	32.60	22.23	7.06	0.23	0.21	144.26	21.03	154.27	12.60	11.55	20.00	0.70	11.34	9.47	2.10	0.6
P2S21	34.10	17.69	4.69	0.21	0.12	439.04	30.46	62.68	8.60	4.55	17.50	0.42	4.25	4.40	0.50	0.5
P2S22	34.30	18.18	4.32	0.27	0.15	169.34	31.29	107.74	7.50	6.65	7.50	0.54	3.01	3.863	0.54	1.2
P2S23	26.67	21.60	4.94	0.28	0.21	589.57	25.90	113.03	7.30	3.95	15.00	0.70	4.72	5.02	0.62	0.4
P2S24	17.14	18.75	3.45	0.28	0.24	156.80	53.80	145.44	7.50	4.05	12.50	0.82	6.48	6.82	0.70	0.4
P2S25	22.67	13.68	4.22	0.32	0.39	457.86	28.02	129.99	7.05	3.90	20.00	2.36	6.30	5.21	1.04	0.7
P2S26	31.30	07.10	4.14	0.40	0.21	119.17	21.48	177.34	9.05	6.25	20.00	0.70	5.88	4.85	0.62	1.9
P2S27	13.33	07.80	4.89	0.27	0.60	326.14	35.07	112.56	8.85	4.80	25.00	2.06	14.67	7.88	1.40	2.2
P2S28	32.30	09.69	4.60	0.30	0.24	577.02	34.82	127.84	7.50	5.50	20.00	0.82	15.21	13.26	1.62	0.7
P2S29	34.60	10.00	3.67	0.21	0.24	200.70	45.20	102.12	9.75	1.75	22.50	0.82	16.20	13.29	1.62	0.5

Sample	Black spot severity on leaves	Black spot severity on fruits	pH	EC (dS m^{-1})	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (meq./ 100 g)	Mg (meq./ 100 g)	S (ppm)	Zn (ppm)	Mn (ppm)	Fe (ppm)	Cu (ppm)	B (ppm)
P2S30	08.50	17.89	5.08	0.23	0.30	131.71	57.90	137.74	10.95	6.20	20.00	1.08	14.42	10.71	1.86	0.1
P3S31	20.00	09.33	2.32	0.31	0.18	144.26	27.25	154.76	10.40	7.00	25.00	0.64	15.89	11.61	2.20	0.6
P3S32	05.70	11.66	4.46	0.29	0.21	150.53	44.44	186.64	14.25	2.20	20.00	0.76	16.48	12.86	2.08	0.1
P3S33	05.20	08.89	4.27	0.21	0.21	62.72	48.47	196.74	9.75	6.10	20.00	0.74	17.54	14.66	1.92	0.5
P3S34	05.30	16.68	2.56	0.27	0.24	225.79	35.65	130.17	12.95	0.40	20.00	0.88	18.79	13.34	1.96	0.2
P3S35	06.67	18.00	4.59	0.19	0.27	213.25	24.11	138.01	9.20	3.85	17.50	0.90	18.75	12.13	1.88	0.2
P3S36	17.33	14.11	4.29	0.15	0.21	188.16	68.99	177.52	9.95	3.05	17.50	0.72	20.90	16.97	2.24	0.2
P3S37	13.33	10.76	7.73	0.30	0.27	175.62	30.52	167.78	8.60	6.00	22.50	0.94	17.55	11.49	2.12	1.1
P3S38	05.91	10.00	5.24	0.31	0.42	200.70	25.14	235.13	10.60	4.45	25.00	1.40	11.45	12.57	1.68	0.9
P3S39	06.93	11.11	4.86	0.30	0.45	181.89	41.61	179.27	9.95	7.45	15.00	1.58	12.18	11.37	1.44	0.8
P3S40	29.33	10.37	4.40	0.23	0.24	144.26	21.03	158.55	11.20	6.00	25.00	0.84	11.75	12.12	1.82	0.6
P4S41	06.82	07.69	5.38	0.30	0.30	175.62	32.38	156.58	10.20	4.70	17.50	1.06	12.68	12.05	1.46	0.5
P_4S_{42}	23.33	09.62	4.37	0.25	0.36	194.43	49.69	252.52	9.95	6.30	30.00	1.24	14.23	13.62	2.46	0.8
P_4S_{43}	23.12	13.17	3.38	0.18	0.33	194.43	31.55	254.80	8.85	4.95	25.00	1.10	15.33	10.80	2.26	1.0
P_4S_{44}	26.66	14.66	4.90	0.30	0.24	106.62	38.47	183.48	9.15	6.00	42.50	0.82	14.81	12.02	1.80	0.2
P_4S_{45}	33.00	19.39	3.69	0.25	0.42	188.16	36.55	174.74	9.65	5.55	27.50	1.40	20.03	13.19	2.48	0.6
P_5S_{46}	14.66	18.70	2.35	0.41	0.45	200.70	40.46	383.20	8.75	5.20	55.00	1.56	22.89	25.10	2.40	0.2
P_5S_{47}	20.00	26.45	3.68	0.40	0.45	200.70	50.98	383.87	7.80	3.75	47.50	1.52	23.02	20.21	2.44	0.9
P_5S_{48}	26.60	08.42	5.17	0.30	0.36	200.70	32.00	282.69	9.20	3.70	37.50	1.26	16.95	12.23	2.28	1.0
P_5S_{49}	31.40	37.50	5.64	0.20	0.21	225.79	19.88	143.40	9.65	4.45	25.00	0.78	17.14	11.68	2.32	0.3
P_5S_{50}	29.33	25.00	5.16	0.21	0.30	351.23	32.89	197.34	8.40	3.80	22.50	1.02	15.67	9.05	1.86	0.7
P_6S_{51}	31.00	28.80	3.40	0.20	0.36	413.95	60.53	230.14	9.75	5.70	22.50	1.26	15.78	13.08	2.56	1.0
P_6S_{52}	32.00	26.00	5.87	0.18	0.30	313.60	51.04	231.48	10.00	5.65	25.00	1.08	15.83	12.06	2.46	0.2

PS: plant sample

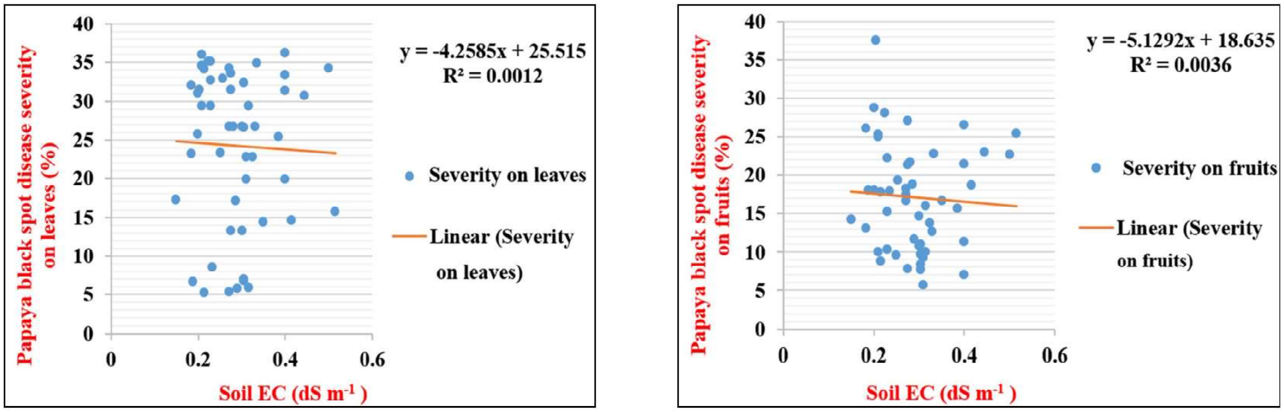


Fig. 2 : Correlation between soil EC and papaya black spot disease severity on leaves and fruits

Correlation of soil organic carbon with black spot disease severity on leaves and fruits

Negative correlation coefficients for soil organic carbon with black spot severity on leaves and fruits, indicating that disease tends to be more severe in soils with lower organic matter (Fig. 3). While, soil organic matter plays a crucial role in soil improvement and nutrient supply, this correlation was found to be non-significant at the p=0.05 level. Similar findings were reported by Workneh et al. (1993), associating soil organic carbon with corky root severity in tomatoes.

Correlation of available nitrogen with black spot disease severity on leaves and fruits

Significant positive correlation between available nitrogen in the soil and papaya black spot severity on leaves, while the correlation coefficient between fruit severity and fruit was observed (Fig. 4). The plant's susceptibility to papaya black spot with an increase in nitrogen can be attributed to the rise in amino acid concentration in the apoplasm and on the leaf surface induced by a high nitrogen supply, promoting the germination and growth of conidia. Moreover, a high nitrogen supply may reduce the activity of key enzymes in phenol metabolism, leading to a decrease in phenolic concentration and lignin deposition. Additionally, high nitrogen supply could decrease silicon concentrations in plants. These results aligned with the findings of Olesen et al. (2003), who observed increased severity of leaf spot pathogens of wheat with an increased nitrogen rate. Similarly, Bavaresco & Eibach (1987) also noted an increased powdery mildew and downy mildew severity in grapes with an elevated nitrogen rate.

Correlation of available phosphorus with black spot disease severity on leaves and fruits

The black spot severity on leaves and fruits positively correlated with the available phosphorus in the soil, which may be due to a potential decrease in essential elements (B, Cu, Zn) crucial for pathogen resistance with increasing soil phosphorus (Fig. 5). However, this correlation was not statistically significant (p=0.05).

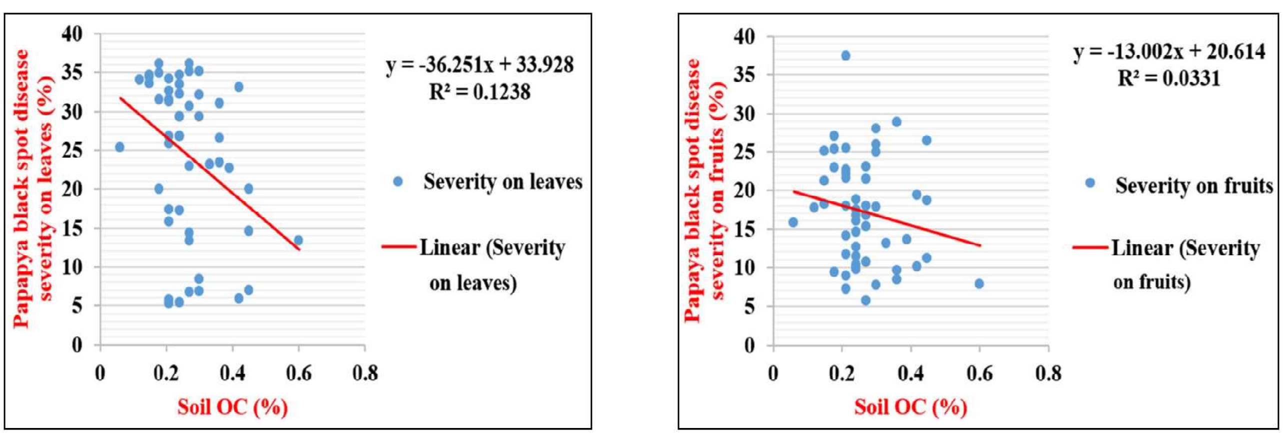
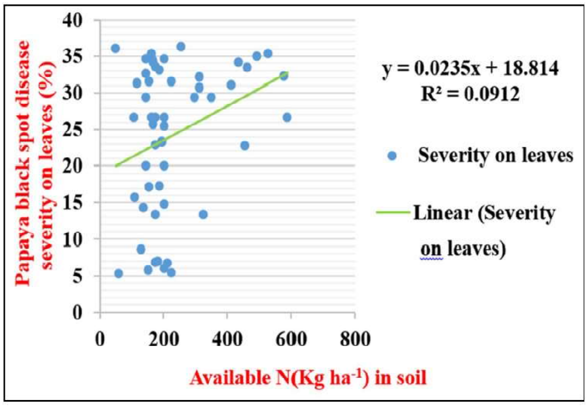


Fig. 3 : Correlation between soil OC and papaya black spot disease severity on leaves and fruits



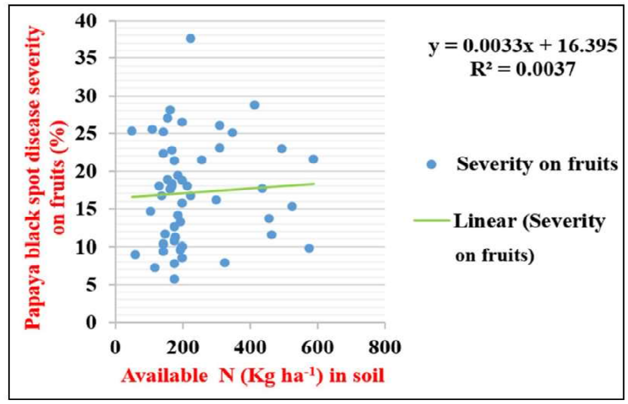


Fig. 4 : Correlation between available N in soil and papaya black spot disease severity on leaves and fruit

Huber's (1980) also reported that phosphorus application increased disease severity in various plants.

Correlation of available potassium with black spot disease severity on leaves and fruits

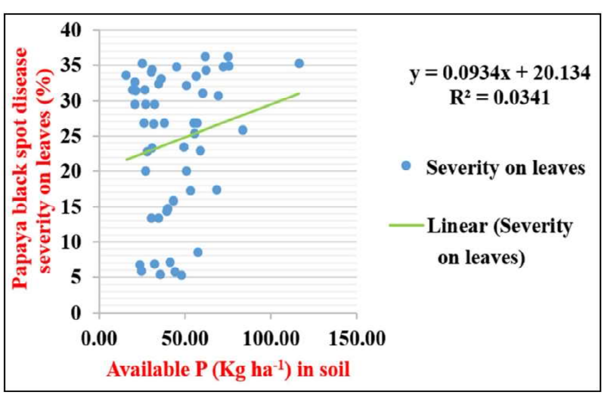
Negative correlation between available potassium in the soil and black spot severity on both leaves and fruits. The high susceptibility of potassium-deficient plants to disease is linked to K's metabolic functions. Potassium deficiency reduces the synthesis of high-molecular-weight compounds (proteins, starch, and cellulose), leading to the accumulation of low-molecular-weight organic compounds that serve as easily available nutrient sources for parasites (Fig. 6). However, the correlation obtained was not statistically significant (p=0.05). Sharma & Duveiller's (2004) indicated that potassium application can decrease *Helminthosporium* leaf blight severity in wheat.

Correlation of exchangeable calcium with black spot disease severity on leaves and fruits

A positive correlation (Fig. 7) was observed between exchangeable calcium in the soil and black spot severity on leaves and fruits. This correlation might results from a decrease in the availability of Zn, Fe, Mn, Cu, and B, which play a role in conferring resistance against pathogens, as the soil calcium content increases. However, the difference in papaya black spot severity for a unit change in exchangeable calcium level was not statistically significant at the p=0.05 level. Graham (1983) noted that calcium confered resistance against *Pythium*, *Sclerotinia*, *Botrytis*, and *Fusarium*. Similarly, Keane & Sackston (1970) reported that the highest disease indices were recorded for those from a low calcium solution on flax.

Correlation of exchangeable magnesium with black spot disease severity on leaves and fruits

A significant positive correlation (Fig. 8) was observed between exchangeable magnesium in the soil and black spot severity on leaves. A positive but no significant correlation was found between exchangeable magnesium in the soil and black spot severity on fruits. This positive correlation may be attributed to a decrease in the uptake of potassium as the magnesium concentration in the soil increases, as potassium is



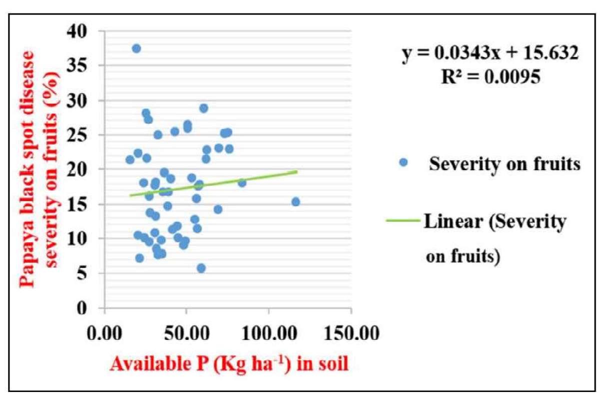


Fig. 5 : Correlation between available P in soil and papaya black spot disease severity on leaves and fruits

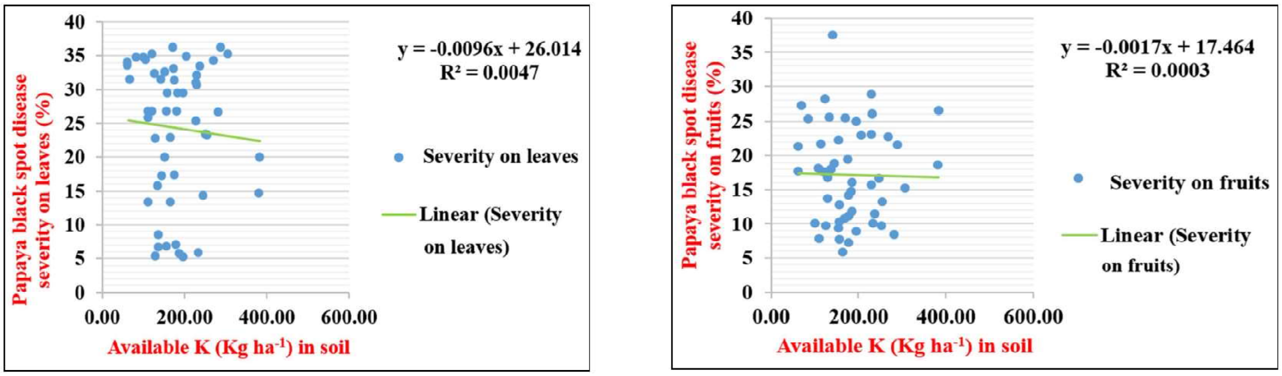


Fig. 6 : Correlation between available K in soil and papaya black spot disease severity on leaves and fruits

crucial for displaying resistance. These results also aligned with the findings of Filippi & Prabhu (2014), who reported a significant ($p<0.01$) and positive correlation between magnesium contents in tissue and panicle blast in rice.

Correlation of available sulphur with black spot disease severity on leaves and fruits

Negative correlation (Fig. 9) between the available sulfur content of the soil and black spot severity on leaves and fruits was observed which implies that as the sulfur concentration in the soil increases, the disease severity percentage decreases. This relationship may be due to sulfur possessing some antimicrobial properties. However, based on the significance test of the correlation coefficient at the p=0.05 level, the observed difference was deemed non-significant. Huber (1980) reported that available sulfur in soil could reduce the severity of potato scab disease.

Correlation of micronutrients (Zn, Fe, Cu, Mn and B) soil with black spot disease severity on leaves and fruits

The correlation between DTPA extractable Zn, Fe, Mn, Cu and black spot severity on leaves was negative, whereas, the hot water extractable boron in the soil recorded positive. Similarly, the correlation between DTPA extractable Zn, Fe, Mn, and hot water extractable boron and black spot severity on fruits was negative, whereas, that of DTPA extractable Cu ($r = 0.12$) was positive. The effect of micronutrients in reducing disease severity can be attributed to their vital role in plant metabolism by influencing phenolic and lignin content, as well as membrane stability. Micronutrients can indirectly affect resistance, as deficient plants become more susceptible. However, the observed differences were not significant according to the significance test of the correlation coefficient at the p=0.05 level. The correlation of DTPA extractable Zn, Fe, Mn, and Cu, as well as hot water extractable B (Fig. 10) and correlation and regression coefficient between papaya black spot disease severity on leaves, fruits and its soil nutrient factors are detailed in Table 4. These results were consistent with the findings of Filippi & Prabhu (2014), reported a negative correlation between tissue concentrations of Zn and panicle blast severity in rice. Dong et al. (2016), indicated that Fe and B play a multifunctional role in reducing the severity of diseases by affecting the growth of *F. oxysporum* and the interactions between plants and pathogens.

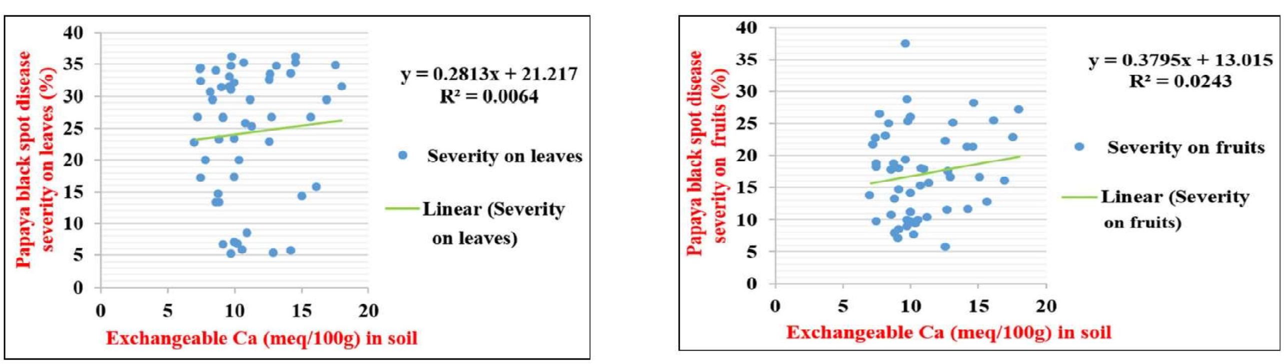


Fig. 7 : Correlation between exchangeable Ca in soil and papaya black spot disease severity on leaves and fruits

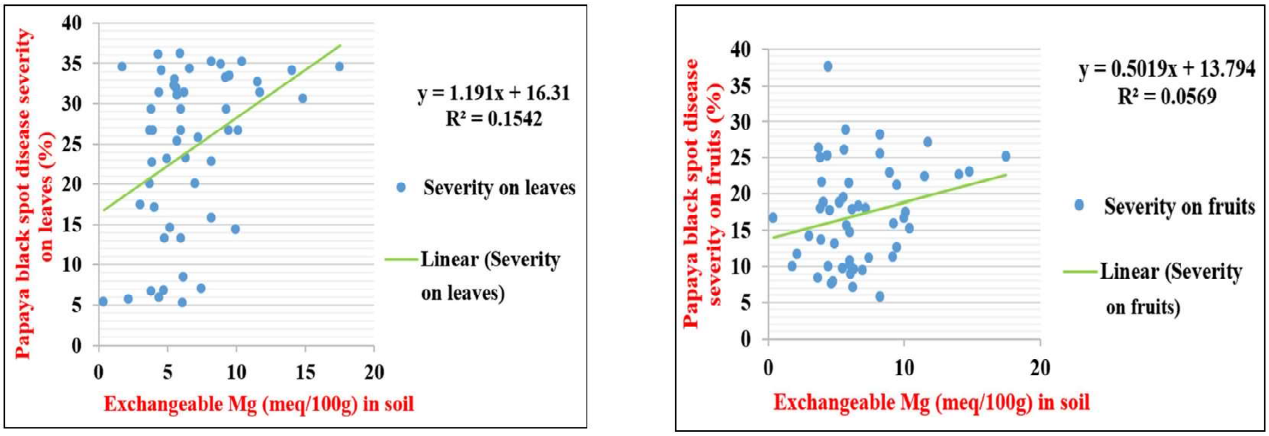


Fig. 8 : Correlation between exchangeable Mg in soil and papaya black spot disease severity on a) leaves b) fruits

Table 4 : Correlation and regression coefficient between papaya black spot disease severity on leaves, fruits and its soil nutrient factors

Soil nutrient factor	Disease severity on leaves		Disease severity on fruits	
	R	R^2	r	R^2
Soil pH	0.13	0.02	0.06	0.004
Electrical conductivity	-0.03	0.001	-0.06	0.004
Soil organic carbon	-0.35	0.12	-0.18	0.03
Available nitrogen	0.30**	0.09	0.06	0.004
Available phosphorus	0.18	0.03	0.09	0.009
Available potassium	-0.06	0.005	-0.02	0.0003
Exchangeable calcium	0.08	0.006	0.16	0.02
Exchangeable magnesium	0.39*	0.06	0.24	0.06
Available sulphur	-0.05	0.002	-0.21	0.04
DTPA extractable zinc	-0.33	0.11	-0.17	0.02
DTPA extractable manganese	-0.35	0.12	-0.08	0.006
DTPA extractable iron	-0.32	0.10	-0.06	0.004
DTPA extractable copper	-0.17	0.03	0.12	0.015
Available boron	0.06	0.003	-0.13	0.01

p value represent significance of correlation coefficient, * $p < 0.05$, ** $p < 0.01$

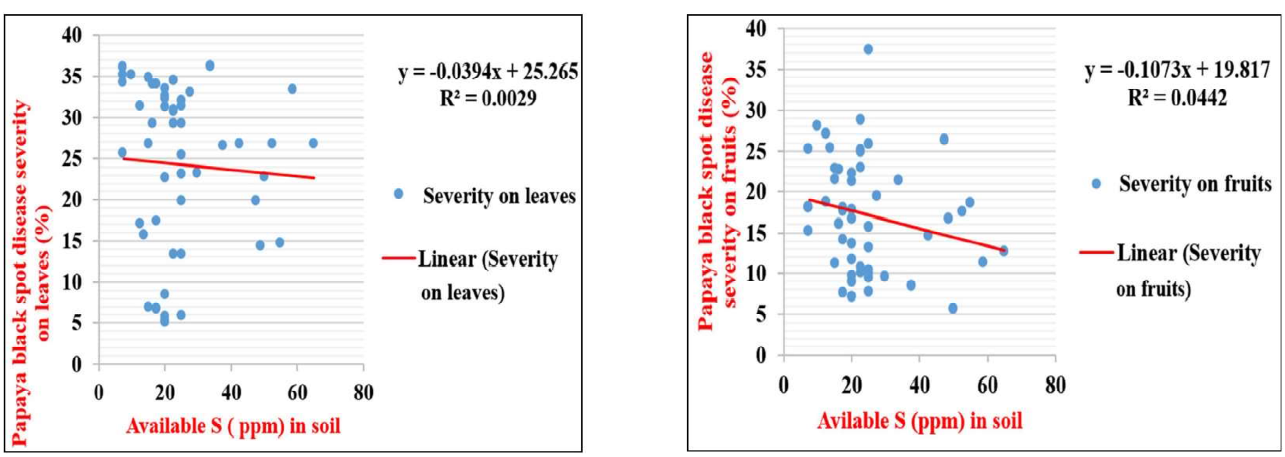


Fig. 9 : Correlation between available S in soil and papaya black spot disease severity on leaves and fruits

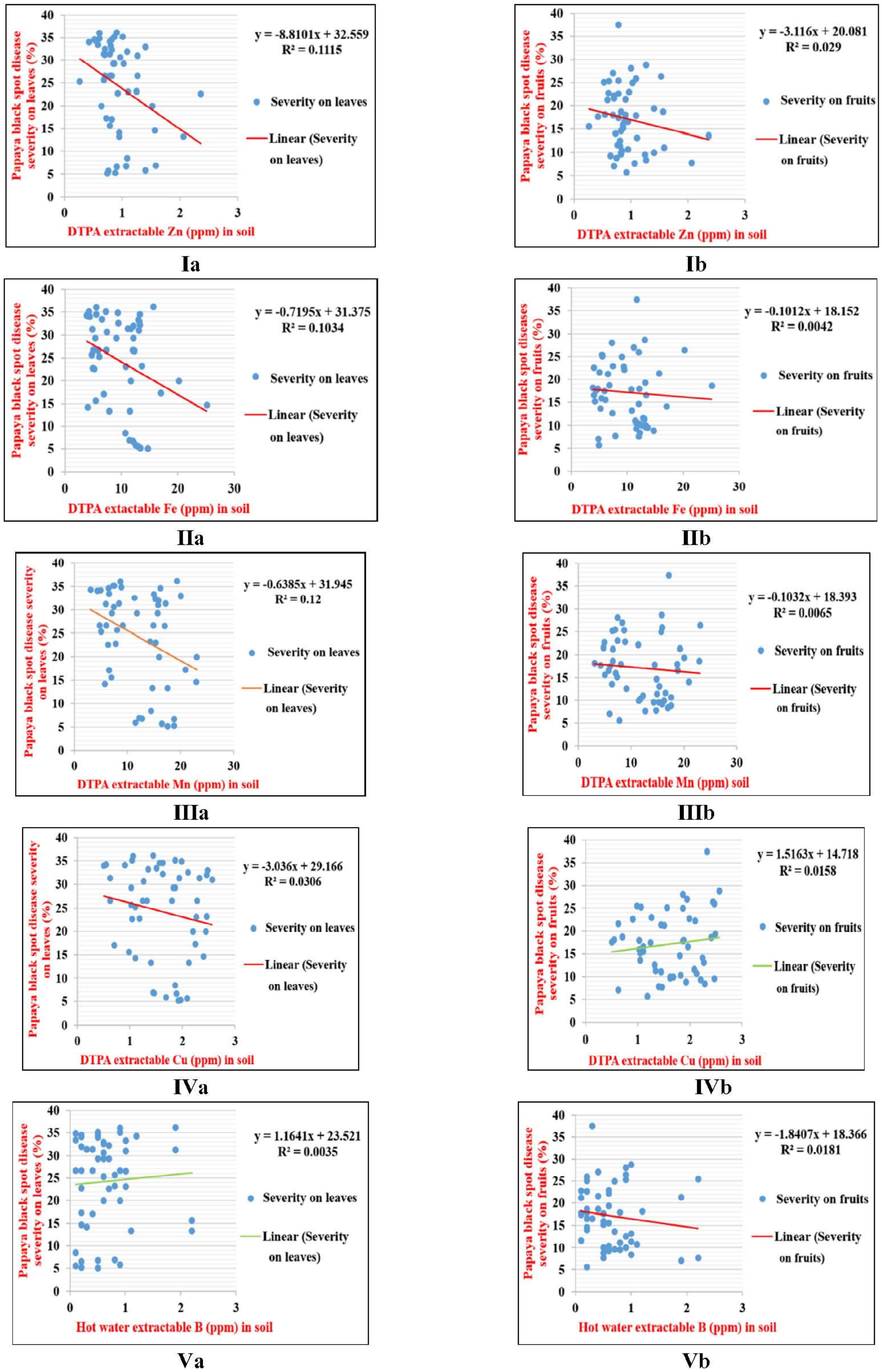


Fig. 10 : Correlation between, I. DTPA extractable Zn, II. DTPA extractable Fe, III. DTPA extractable Mn, IV. DTPA extractable Cu, V. Hot water extractable B, papaya black spot disease severity on a. leaves and b. fruits, respectively

CONCLUSION

The present study underscores the multifaceted relationships between soil nutrient availability and the severity of papaya black spot. A significant positive correlation was observed between available nitrogen and disease severity on leaves, suggesting that high nitrogen levels can enhance pathogen growth and reduce plant defenses. In contrast, potassium and sulfur exhibited negative correlations with disease severity, emphasizing their roles in disease resistance. The influence of micronutrients such as Zn, Fe, Mn, Cu, and B further highlights the importance of balanced nutrient management, as deficiencies in these elements can increase susceptibility to diseases.

Overall, these findings suggest that a nuanced approach to nutrient management is essential for mitigating papaya black spot severity and promoting plant health. Subsequent research efforts should focus on exploring the correlation between soil nutrient factors and nutrient concentrations in plant tissue. It is imperative to conduct investigations in controlled greenhouse conditions to elucidate the impact of soil nutrient factors on black spot of papaya. The findings of the studies have the potential to pave the way for sustainable strategies to manage and combat this disease.

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